Hyper-heuristic Bibliography

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- **Web Version**: `https://mustafamisir.github.io/hh.html`
- **Books**: [128, 298]
- **Surveys**: [186, 262, 427, 494, 650, 685, 959, 995]
- **Tutorials**: [206, 648, 909, 1044, 1056]
- **Generality**: [718]
- **Theory**: [224, 258, 377, 598, 712, 775]
- **Discussion**: [109, 310]

[1] Mohammed Ahmed and G Babu. Hyper-heuristic multi-objective online optimization for cyber security in big data. *International Journal of System Assurance Engineering and Management*, pages 1–10, 2022. The tremendous growth in data inside the Big data era has created data management challenges as well as data security concerns. These large data cyber security challenges can be successfully addressed with AI computations, with the SVM providing the best results on big data order issues. Master information in picking the kernel work and different boundaries is required to characterize the correct design of the SVM, and this can significantly advance its arrangement outcomes. The fake positive rate, bogus negative rate, and model unpredictability boundaries addressed using the SVM arrangement process is shown to be

a multi-objective optimization problem in this study. The hyper-heuristic online particle swarm optimization (HHOPSO) computation with the SVM multi-objective optimization problem, a hyper-heuristic online particle swarm optimization system is produced was presented. The hyper-heuristic system comprises a high-level technique for directing the search process for determining low-level heuristics, and the low-level heuristics build new SVM setup configurations using various PSO standards. The proposed HHOPSO was evaluated on two cyber security datasets i.e., NSL-KDD and ISCX-IDS. The results revealed that the suggested approach is more effective than other calculations in refining the order of big data cyber security issues. The designed HHOPSO can classify cyber-attacks like DoS, Probe, R2L, and U2R with an accuracy of 93.23%. `https://link.springer.com/article/10.1007/s13198-022-01727-w`.

[2] Canan Hazal Akarsu and Tarık Küçükdeniz. Job shop scheduling with genetic algorithm-based hyperheuristic approach. *International Advanced Researches and Engineering Journal*, 6(1):16–25, 2022. Job shop scheduling problems are NP-hard problems that have been studied extensively in the literature as well as in real-life. Many factories all over the world produce worth millions of dollars with job shop type production systems. It is crucial to use effective production scheduling methods to reduce costs and increase productivity. Hyperheuristics are fast-implementing, low-cost, and powerful enough to deal with different problems effectively since they need limited problem-specific information. In this paper, a genetic algorithm-based hyperheuristic (GAHH) approach is proposed for job shop scheduling problems. Twenty-six dispatching rules are used as low-level heuristics. We use a set of benchmark problems from OR-Library to test the proposed algorithm. The performance of the proposed approach is compared with genetic algorithm, simulating annealing, particle swarm optimization and some of dispatching rules. Computational experiments show that the proposed genetic algorithm-based hyperheuristic approach finds optimal results or produces better solutions than compared methods. `https://doi.org/10.35860/iarej.1018604`.

[3] Omar Abdullah Murshed Farhan Alnaggar, Basavaraj N Jagadale, Swaroopa H Narayan, and Mufeed Ahmed Naji Saif. Brain tumor detection from 3d mri using hyper-layer convolutional neural networks and hyper-heuristic extreme learning machine. *Concurrency and Computation: Practice and Experience*, page e7215, 2022. Automated techniques for brain tumor classification using deep learning approaches have gained significant research interest in recent years. Yet, the difficulties in extracting and classifying the tumor regions from the 3D Magnetic Resonance Imaging (MRI) do not have a definite solution. The major challenge in utilizing machine and deep learning algorithms for brain cancer classification from 3D images is the time complexity in analyzing the multiple frames of a brain MRI. This paper introduces Hyper-Layer Convolutional Neural Networks (HL-CNN) and Hyper-Heuristic Extreme Learning Machine (HH-ELM). The proposed method consists of three main phases are pre-processing, deep feature min-

ing and selection, and classification. The input MRI images are pre-processed through denoising and image enhancement methods in the first phase. In the second phase, the HL-CNN is introduced for feature extraction. The hyper-layer technique is a masking technique that also inherent the features of the specified layers instead of only considering the features at the last layer. The best features are selected using a simple correlation-based selection approach through HL-CNN validation to minimize the irrelevant features in the system. In the last phase, the HH-ELM is introduced to classify the tumor images to identify the different types of tumors. HH-ELM is an enhanced version of ELM through optimal tuning of ELM parameters using a hyper-heuristic optimization algorithm. Evaluations are performed over the BRATS 2020 database of MRI images and the proposed method of HL-CNN and HH-ELM achieved dice scores of 0.9020, 0.9393, and 0.9589 for ED, WT, and TC tumor classes with 95.89% accuracy, 98.46% precision, 96% recall, and 97.21% f-measure which are 2%-13% higher and processing time of 139.88 s which is 66%-78% lesser than the existing methods. `https://onlinelibrary.wiley.com/doi/abs/10.1002/cpe.7215`.

[4] Haya Alshareef and Mashael Maashi. Application of multi-objective hyper-heuristics to solve the multi-objective software module clustering problem. *Applied Sciences*, 12(11):5649, 2022. Software maintenance is an important step in the software lifecycle. Software module clustering is a HHMO_CF_GDA optimization problem involving several targets that require minimization of module coupling and maximization of software cohesion. Moreover, multi-objective software module clustering involves assembling a specific group of modules according to specific cluster criteria. Software module clustering classifies software modules into different clusters to enhance the software maintenance process. A structure with low coupling and high cohesion is considered an excellent software module structure. In this study, we apply a multi-objective hyper-heuristic method to solve the multi-objective module clustering problem with three objectives: (i) minimize coupling, (ii) maximize cohesion, and (iii) ensure high modularization quality. We conducted several experiments to obtain optimal and near-optimal solutions for the multi-objective module clustering optimization problem. The experimental results demonstrated that the HHMO_CF_GDA method outperformed the individual multi-objective evolutionary algorithms in solving the multi-objective software module clustering optimization problem. The resulting software, in which HHMO_CF_GDA was applied, was more optimized and achieved lower coupling with higher cohesion and better modularization quality. Moreover, the structure of the software was more robust and easier to maintain because of its software modularity. `https://doi.org/10.3390/app12115649`.

[5] Sarra Zohra Ahmed Bacha, Karima Benatchba, and Fatima Benbouzid-Si Tayeb. Adaptive search space to generate a per-instance genetic algorithm for the permutation flow shop problem. *Applied Soft Computing*, page 109079, 2022. This study introduces, , a new hyper-heuristic for permutation-based problems. It is

a high-level local search that generates tailored genetic algorithms for considered problem instances. The motivation of this work is to reduce the time needed to design a dedicated genetic algorithm for a new instance increasing the chance to explore undiscovered search spaces. It uses three search spaces to build genetic algorithms. In the first one, standard blind operators are used. In the second one, problem-oriented ones are used and finally, in the last one, knowledge extracted during the search process is taken into consideration through diversification and intensification strategies. 's solving process explores the three search spaces starting from the standard one and jumps to the next search spaces until it gets the best found solution so far, for the given instance, or all search spaces are covered. Extensive experiments have been conducted on the well-known PFSP. The performance comparison, on the Taillard instances, against state-of-the-art algorithms verified the reliability of the proposed organization of the search space on its performance. Besides, it allowed us to classify instances into easy, medium and difficult. `https://doi.org/10.1016/j.asoc.2022.109079`.

[6] Juliana Marino Balera and Valdivino Alexandre de Santiago Júnior. Multiperspective web testing supported by a generation hyper-heuristic. In *International Conference on Computational Science and Its Applications*, pages 447–462. Springer, 2022. Web interface testing is a sort of system testing level and it is laborious if accomplished manually, since it is necessary to map each of the elements that make up the interface with its respective code. Furthermore, this mapping makes test scripts very sensitive to any changes to the interface's source code. Approaches for automated web testing have been proposed but the use of hyper-heuristics, higher-level search techniques aiming to address the generalization issues of metaheuristics, for web testing are scarce in the literature. In this article we present a multi-objective web testing method, MWTest, which automates the generation of test cases based only on the URL of the web application and a new proposed generation hyper-heuristic, called GECOMBI. The GECOMBI hyper-heuristic takes into account combinatorial designs to generate low-level heuristics to support our goal. Moreover, the implementation of the MWTest method creates a Selenium test script quickly and without human interaction, exclusively based on the URL in order to support the automated execution of test cases too. In our evaluation, we compared GECOMBI to another generation hyper-heuristic, GEMOITO, and four metaheuristics (NSGA-II, IBEA, MOMBI, NSGA-III). Results show superior performance of GECOMBI compared to the other approaches. `https://link.springer.com/chapter/10.1007/978-3-031-10548-7_33`.

[7] Saptarshi Biswas, Subhrapratim Nath, Sumagna Dey, and Utsha Majumdar. Tangent-cut optimizer on gradient descent: an approach towards hybrid heuristics. *Artificial Intelligence Review*, 55(2):1121–1147, 2022. The world has witnessed a surfeit of usage of Artificial Intelligence systems for a long time. Nowadays, most of the problems are transforming from logical solutions into statistical domains. This requires the implementation of machine learning algorithms to

mine useful data from the statistical datasets which in turn demands high-end computing. Generally, machine learning algorithms utilize Gradient Descent as a tool to find the optimal solution of computationally expensive problems. This gave rise to the development of optimization algorithms like Momentum, RMSProp, Adam and the like, which could speed up the convergence to the global optimum besides increasing the learning accuracy. However, nowadays the supervised machine learning models got more data intensive which increased their computational cost, putting the efficiency of these algorithms into question. In this context, a new optimization algorithm namely, the Tangent-Cut Optimizer (TC-Opt) has been proposed which can converge faster than the traditional optimization algorithms for supervised machine learning models. Furthermore, the proposed work brings forward a phenomenon that intertwines the statistical and logical decision-making model into a single unit while shedding light on a new heuristic approach named Hybrid Heuristics. The proposed algorithm has been implemented on the standard dataset of Boston House Pricing Dataset for linear regression and MNIST image dataset of handwritten digits from 0 to 9 for logistic regression and its performance has been compared with the existing algorithms. Finally, the robustness and high accuracy of the proposed optimization algorithm have been proved and demonstrated in the presentation. `https://link.springer.com/article/10.1007/s10462-021-09984-0`.

[8] Vinicius Renan de Carvalho. *Using multi-agent systems and social choice theory to design hyper-heuristics for multi-objective optimization problems.* PhD thesis, Universidade de São Paulo, 2022. The majority of the most effective and efficient algorithms for multi-objective optimization are based on Evolutionary Computation. However, choosing the most appropriate algorithm to solve a certain problem is not trivial and often requires a time-consuming trial process. As an emerging area of research, hyper-heuristics investigates various techniques to detect the best low-level heuristic while the optimization problem is being solved. On the other hand, agents are autonomous component responsible for watching an environment and perform some actions according to their perceptions. In this context, agent-based techniques seem suitable for the design of hyper-heuristics. There are several hyper-heuristics proposed for controlling lowlevel heuristics, but only a few of them are focused on selecting multi-objective optimization algorithms (MOEA). This work presents an agent-based hyper-heuristic for choosing the best multi-objective evolutionary algorithm. Based on Social Choice Theory, the proposed framework performs a cooperative voting procedure, considering a set of quality indicator voters, to define which algorithm should generate more offspring along to the execution. Comparative performance analysis was performed across several benchmark functions and real-world problems. Results showed the proposed approach was very competitive both against the best MOEA for each given problem and against state-of-art hyper-heuristics. `https://doi.org/10.11606/T.3.2022.tde-16032022-105222`.

[9] Shelvin Chand, Kousik Rajesh, and Rohitash Chandra. Map-elites based hyper-heuristic for the resource constrained project scheduling problem. *arXiv preprint arXiv:2204.11162*, 2022. The resource constrained project scheduling problem (RCPSP) is an NP-Hard combinatorial optimization problem. The objective of RCPSP is to schedule a set of activities without violating any activity precedence or resource constraints. In recent years researchers have moved away from complex solution methodologies, such as meta heuristics and exact mathematical approaches, towards more simple intuitive solutions like priority rules. This often involves using a genetic programming based hyper-heuristic (GPHH) to discover new priority rules which can be applied to new unseen cases. A common problem affecting GPHH is diversity in evolution which often leads to poor quality output. In this paper, we present a MAP-Elites based hyper-heuristic (MEHH) for the automated discovery of efficient priority rules for RCPSP. MAP-Elites uses a quality diversity based approach which explicitly maintains an archive of diverse solutions characterised along multiple feature dimensions. In order to demonstrate the benefits of our proposed hyper-heuristic, we compare the overall performance against a traditional GPHH and priority rules proposed by human experts. Our results indicate strong improvements in both diversity and performance. In particular we see major improvements for larger instances which have been under-studied in the existing literature. `https://doi.org/10.48550/arXiv.2204.11162`.

[10] HaoJie Chen, Guofu Ding, Jian Zhang, Rong Li, Lei Jiang, and Shengfeng Qin. A filtering genetic programming framework for stochastic resource constrained multi-project scheduling problem under new project insertions. *Expert Systems with Applications*, 198:116911, 2022. Multi-project management and uncertain environment are very common factors, and they bring greater challenges to scheduling due to the increase of problem complexity and response efficiency requirements. In this paper, a novel hyper-heuristic based filtering genetic programming (HH-FGP) framework is proposed for evolving priority rules (PRs) to deal with a multi-project scheduling problem considering stochastic activity duration and new project insertion together, namely the Stochastic Resource Constrained Multi-Project Scheduling Problem under New Project Insertions (SRCMPSP-NPI), within heuristic computation time. HH-FGP is designed to divide traditional evolution into sampling and filtering evolution for simultaneously filtering two kinds of parameters constituting PRs, namely depth range and attribute, to obtain more effective PRs. Based on this, the existing genetic search and local search are improved to meet the depth constraints, and a multi-objective evaluation mechanism is designed to achieve effective filtering. Under the existing benchmark, HH-FGP is compared and analysed with the existing methods to verify its effectiveness. `https://doi.org/10.1016/j.eswa.2022.116911`.

[11] HaoJie Chen, Jian Zhang, Rong Li, Guofu Ding, and Shengfeng Qin. A two-stage genetic programming framework for stochastic resource constrained multi-project scheduling problem under new project insertions. *Applied Soft Computing*, page

109087, 2022. This study proposes a novel hyper-heuristic based two-stage genetic programming framework (HH-TGP) to solve the Stochastic Resource Constrained Multi-Project Scheduling Problem under New Project Insertions (SRCMPSP-NPI). It divides the evolution of genetic programming into generation and selection stages, and then establishes a multi-state combination scheduling mode with multiple priority rules (PRs) for the first time to realize resource constrained project scheduling under both stochastic activity duration and new project insertion. In the generation stage, based on a modified attribute set for multi-project scheduling, NSGA-II is hybridized to evolve a non-dominated PR set for forming a selectable PR set. While in the selection stage, the whole decision-making process is divided into multiple states based on the completion activity duration, and a weighted normalized evolution process with two crossovers, two mutations and four local search operators to match the optimal PR for each state from the PR set. Under the existing benchmark, HH-TGP is compared with the existing methods to verify its effectiveness. `https://doi.org/10.1016/j.asoc.2022.109087`.

[12] Lixin Cheng, Qiuhua Tang, Liping Zhang, and Zikai Zhang. Multi-objective q-learning-based hyper-heuristic with bi-criteria selection for energy-aware mixed shop scheduling. *Swarm and Evolutionary Computation*, 69:100985, 2022. Owning to diverse customer demands and enormous product varieties, mixed shop production systems are applied in practice to improve responsiveness and productivity along with energy-saving. This work addresses a mixture of job-shop and flow-shop production scheduling problem with a speed-scaling policy and no-idle time strategy. A mixed-integer linear programming model is formulated to determine the speed level of operations and the sequence of job-shop and flow-shop products, aiming at the simultaneous optimization of production efficiency and energy consumption. Then, a multi-objective Q-learning-based hyper-heuristic with Bi-criteria selection (QHH-BS) is developed to obtain a set of high-quality Pareto frontier solutions. In this algorithm, a new three-layer encoding is designed to represent the production sequence of job-shop and flow-shop products; the Pareto-based and indicator-based selection criteria are sequentially implemented to encourage diversity and convergence; Q-learning with a multi-objective metric-based reward mechanism is applied to select an optimizer from three prominent optimizers in each iteration for better exploration and exploitation. Three conclusions are drawn from extensive experiments: (1) Bi-criteria selection is superior to single-criterion selections; (2) Q-learning-based hyper-heuristic is more effective and robust than single optimizer-based algorithms and simple hyper-heuristics; (3) QHH-BS outperforms the existing state-of-the-art multi-objective algorithms in convergence and diversity. `https://doi.org/10.1016/j.swevo.2021.100985`.

[13] Matthew J Craven and John R Woodward. Evolution of group-theoretic cryptology attacks using hyper-heuristics. *Journal of Mathematical Cryptology*, 16(1):49–63, 2022. In previous work, we developed a single evolutionary algorithm (EA)

to solve random instances of the Anshel Anshel Goldfeld (AAG) key exchange protocol over polycyclic groups. The EA consisted of six simple heuristics which manipulated strings. The present work extends this by exploring the use of hyper-heuristics in group-theoretic cryptology for the first time. Hyper-heuristics are a way to generate new algorithms from existing algorithm components (in this case, simple heuristics), with EAs being one example of the type of algorithm which can be generated by our hyper-heuristic framework. We take as a starting point the above EA and allow hyper-heuristics to build on it by making small tweaks to it. This adaptation is through a process of taking the EA and injecting chains of heuristics built from the simple heuristics. We demonstrate we can create novel heuristic chains, which when placed in the EA create algorithms that out perform the existing EA. The new algorithms solve a greater number of random AAG instances than the EA. This suggests the approach may be applied to many of the same kinds of problems, providing a framework for the solution of cryptology problems over groups. The contribution of this article is thus a framework to automatically build algorithms to attack cryptology problems given an applicable group. `https://doi.org/10.1515/jmc-2021-0017`.

[14] Jorge M Cruz-Duarte, José C Ortiz-Bayliss, and Ivan Amaya. Mathh: A matlab-based hyper-heuristic framework. *SoftwareX*, 18:101047, 2022. Hyper-Heuristics (HHs) have proven to be a valuable tool for solving complex problems, such as Combinatorial Optimization Problems (COPs). These solvers have an assorted set of models arising through extensive research from the scientific community. Hence, it is customary that researchers develop their models from scratch, which increases development times. Drafting and testing new ideas become burdensome and time-consuming. In this work, we present MatHH, a Matlab-based framework to allow rapid prototyping of HHs. We summarize the architecture and some examples of their usage. We also discuss some research questions that upcoming research may explore through MatHH. `https://doi.org/10.1016/j.softx.2022.101047`.

[15] Kassem Danach, Ali Baydoun, Jomana Al-Haj Hassan, and Abbas Tarhini. Mobile clinics routing in response to covid-19 outbreak: an intelligent hyperheuristic approach. 6(9), 2022. In March 2020, the World Health Organization (WHO) announced the COIVD-19 as a global pandemic that caused thousands of deaths and brought the world to a standstill with a huge economic burden. Health is an essential factor for sustaining a better life in a better world. Today, for different reasons, several districts in our countries would be deprived from the needed health support and thus, in such cases, we need to deliver health care to those regions. Despite its considerable cost, the mobile clinic remains one of the good solutions to deliver health care to critical areas in our countries. A recognized problem in this domain is minimizing the cost of mobile clinics route in a way that the number of served patients is maximized. This problem is known as the mobile clinics routing problem (MCRP). The purpose of this paper is to present a novel approach that, within the given limited resources, it minimizes the cost and

the traveling distance of mobile clinics while maximizing the number of served patients as per priorities assigned according to the patients' medical status. This paper implements and tests an intelligent variable neighbourhood search algorithm for MCRP. https://www.ijeast.com/papers/1-9,Tesma609,IJEAST.pdf.

[16] Valdivino Alexandre de Santiago Júnior, Ender Özcan, and Juliana Marino Balera. Many-objective test case generation for graphical user interface applications via search-based and model-based testing. *Expert Systems with Applications*, page 118075, 2022. The majority of the studies that generate test cases for graphical user interface (GUI) applications are based on or address functional requirements only. In spite of the fact that interesting approaches have been proposed, they do not address functional and non-functional requirements of the GUI systems, and non-functional properties of the created test suites altogether to generate test cases. This is called a many-objective perspective where several desirable and different characteristics are considered together to generate the test cases. In this study, we show how to combine search-based (optimisation) with model-based testing to generate test cases for GUI applications taking into account the many-objective perspective. We rely on meta and hyper-heuristics and we address two particular issues (problems) considering code-driven and use case-driven GUI testing. As for the code-driven testing, we target desktop applications and automatically read the C++ source code of the system, translate it into an event flow graph (EFG), and use objective functions that are graph-based measures. As for the use case-driven testing, EFGs are created directly via use cases. A rigorous evaluation was performed using 32 problem instances where we considered three multi-objective evolutionary algorithms and six selection hyper-heuristics using those algorithms as low-level (meta)heuristics. The performance of the algorithms was compared based on five different indicators, and also a new Multi-Metric Indicator (MMI) utilising multiple indicators and providing a unique measure for all algorithms. Results show that the metaheuristics obtained better performances overall, particularly NSGA-II, while Choice Function was the most outstanding hyper-heuristic approach. https://doi.org/10.1016/j.eswa.2022.118075.

[17] Fakhrud Din and Kamal Z Zamli. Hyper-heuristic strategy for input-output-based interaction testing. In *Recent Trends in Mechatronics Towards Industry 4.0*, pages 967–977. Springer, 2022. Software testing aims at exploring faults within software in order to ensure it meets all necessary specifications. Test case design strategies play key role in software testing. Classical test case design strategies, however, do not sufficiently include support for exploration of faults due to interaction between parameter values. New strategies known as t-way strategies (where t expresses interaction strength) have been developed for finding interaction faults. However, existing t-way strategies for input-output-based relationship (IOR) interaction testing mostly adopt greedy algorithms which often generate poor quality test data. Therefore, this paper presents the design of a new IOR test suite generation strategy called IOR_HH based on the exponential Monte Carlo

with counter (EMCQ) hyper-heuristic. EMCQ is a parameter free hyper-heuristic which works as controller of the three implemented low-level meta-heuristic operators, namely crossover, peer learning and global pollination in the proposed IOR_HH strategy. Experimental results demonstrate the impact of the proposed strategy against existing computational strategies for IOR interaction testing. https://link.springer.com/chapter/10.1007/978-981-33-4597-3_88.

[18] Gabriel Duflo, Gregoire Danoy, El-Ghazali Talbi, and Pascal Bouvry. Learning to optimise a swarm of uavs. 2022. The usage of Unmanned Aerial Vehicles (UAVs) has shown a drastic increase of interest in the past few years. UAVs find applications where human action would be ineffective, slow, risky or even impossible. With a three-dimensional mobility and payload flexibility, they can indeed be used for missions like infrastructure inspection or search and rescue. Most applications have considered the usage of a single UAV so far, but using several autonomous UAVs as a swarm would overcome some drawbacks like mission duration (if one UAV of the swarm is out of battery, the latter can pause the mission while others keep flying) or payload capacity (the payload can be distributed among all UAVs). Designing an efficient swarm of UAVs however comes with some challenges, including the difficulty to define the necessary distributed algorithms to tackle specific tasks. The desired global behaviour, e.g. monitoring an area or transporting material, is indeed emergent from local interactions. Manually designing these local interactions can therefore be tedious and time-consuming. This work thus aims at automating that process in the context of area coverage. The first step has been to define a multi-objective optimisation problem to represent an area coverage mission. The second step has been to define an algorithm to generate distributed heuristic for the latter optimisation problem. The proposed method is based on Q-learning and experimental results demonstrate that it permits to generate heuristics that not only outperform the state-of-the-art, but also provide a high stability. https://assets.researchsquare.com/files/rs-1854988/v1_covered.pdf?c=1658259347.

[19] Gian Fritsche and Aurora Pozo. On the cooperation of meta-heuristics for solving many-objective problems: An empirical analysis including benchmark and real-world problems. *Expert Systems with Applications*, 192:116343, 2022. The performance of state-of-the-art evolutionary algorithms in solving many-objective problems varies according to different problem characteristics, which poses a challenge for many-objective optimization. In this study, we analyze the cooperative hyper-heuristic (HH-CO) for many-objective optimization. HH-CO tackles the challenge of dynamically finding the best MOEA (multi-objective evolutionary algorithm) for applying and, at the same time, exploiting the MOEAs cooperation for a given problem instance. This recently proposed hyper-heuristic (HH) showed results competitive to stand-alone MOEAs and a state-of-art hyper-heuristic. Our goal is to identify what leads HH-CO towards its competitive results and distinguishes it from other state-of-art hyper-heuristics. To answer those questions, we

observed the choices made by HH-CO and a state-of-art HH. In addition, we analyzed how those choices are related to the quality of MOEAs applied standalone. Furthermore, we evaluated scenarios where HH-CO presented better and worse results and identified the main reasons for these outcomes. Overall, HH-CO presented better results in 80% of instances. We concluded that the greedy selection heuristic employed by HH-CO could be improved. Still, the positive influence of the cooperative migration procedure surpasses HH-CO deficiencies for most problem instances. Finally, we evaluated the capabilities of both strategies on a real-world problem. They achieved very similar hypervolume results, without a significant difference to the best MOEA, but better than some state-of-the-art MOEAs. `https://www.sciencedirect.com/science/article/abs/pii/S0957417421016419`.

[20] Yu Gao, Ziyue Wang, Liang Gao, and Xinyu Li. A hyper-heuristic algorithm for the no-wait flowshop scheduling problem with makespan criterion. In *2022 IEEE 25th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, pages 1028–1033. IEEE, 2022. The no-wait flowshop scheduling problem (NWFSP) has received widespread attention because of its wide application in the steel industry, food industry, and so on. This paper proposes a hyper-heuristic algorithm to solve it with the objective to minimize the makespan. Firstly, three Modified Nawaz-Enscore-Ham (MNEH) algorithms are designed to keep the diversity of initial values. Secondly, in order to fully search for potential solution domains, the Low-Level Heuristics (LLH) are constructed to speed up the search process for each neighborhood and the search order are decided by proposed High-Level Strategies (HLS). Thirdly, one taboo mechanism and two backtracking mechanisms are designed to promote the exploitation performance. No parameters are used in all stages. Therefore, it is not necessary to adjust parameters when it is used to solve any NWFSP problems and the equivalent Asymmetric Traveling Salesman Problems (ATSP). The test results of the Tailard benchmarks confirm the stability and effectiveness of the proposed algorithm. `https://ieeexplore.ieee.org/abstract/document/9776169`.

[21] Abdul Ghaffar, Mian Usman Sattar, Mubbasher Munir, and Zarmeen Qureshi. Multi-objective fuzzy-based adaptive memetic algorithm with hyper-heuristics to solve university course timetabling problem. *EAI Endorsed Transactions on Scalable Information Systems*, pages e14–e14, 2022. The university course timetabling is an NP-hard (non-deterministic polynomial-time hard) optimization problem to create a course timetable without conflict. It must assign a set of subject classes to a fixed number of timeslots with physical resources, including rooms and teachers. Avoiding hard constraints creates an executable timetable, whereas the removal of different soft constraints creates a satisfactory timetable. The most common way to resolve this problem is through the use of a hybrid genetic algorithm. The multi-objective fuzzy-based adaptive memetic algorithm, a population-based hybrid genetic approach, is proposed by combining genetic algorithm with local

search with tabu search and various artificial intelligence techniques. It starts with generating a random population by using the hyper-heuristics and initial repairing method. By using the hill-climbing algorithm, it iteratively generates new offspring from the population by applying fuzzy- based adaptive crossover and mutation operations. If the solution still contains some conflicts, then the tabu search improves it by applying the most appropriate candidate repeatedly. While getting the workable solution, the algorithm tries to maximize multiple objective functions to get manageable solutions with different perspectives. It efficiently allocates all the required resources to subject classes and generates optimal solutions for the datasets provided by the University of Management & Technology, Lahore. It shows 96.29% accuracy in resolving conflicts compare with that of the simple and hybrid genetic algorithms. A web-based dynamic timetable manager visually represents a timetable and also provides options to adjust conflicts manually. `https://doi.org/10.4108/eai.16-12-2021.172435`.

[22] Francisco J Gil-Gala, Marko urasević, María R Sierra, and Ramiro Varela. Building heuristics and ensembles for the travel salesman problem. In *International Work-Conference on the Interplay Between Natural and Artificial Computation*, pages 130–139. Springer, 2022. The Travel Salesman Problem (TSP) is one of the most studied optimization problems due to its high difficulty and its practical interest. In some real-life applications of this problem the solution methods must be very efficient to deal with dynamic environments or large problem instances. For this reasons, low time consuming heuristics as priority rules are often used. Even though such a single heuristic may be good to solve many instances, it may not be robust enough to take the best decisions in all situations so, we hypothesise that an ensemble of heuristics could be much better than the best of those heuristic. We view an ensemble as a set of heuristics that collaboratively build a single solution by combining the decisions of each individual heuristic. In this paper, we study the application of single heuristics and ensembles to the TSP. The individual heuristics are evolved by Genetic Programming (GP) and then Genetic Algorithms (GA) are used to build ensembles from a pool of single heuristics. We conducted an experimental study on a set of instances taken from the TSPLIB. The results of this study provided interesting insights about the behaviour of rules and ensembles. `https://link.springer.com/chapter/10.1007/978-3-031-06527-9_13`.

[23] Francesco Guerriero and Francesco Paolo Saccomanno. A hierarchical hyper-heuristic for the bin packing problem. *Soft Computing*, pages 1–14, 2022. This paper addresses the two-dimensional irregular bin packing problem, whose main aim is to allocate a given set of irregular pieces to larger rectangular containers (bins), while minimizing the number of bins required to contain all pieces. To solve the problem under study a dynamic hierarchical hyper-heuristic approach is proposed. The main idea of the hyper-heuristics is to search the space of low-level heuristics for solving computationally difficult problems. The proposed approach

is dynamic since the low-level heuristic to be executed is chosen on the basis of the main characteristics of the instance to be solved. The term hierarchical is used to indicate the fact that the main hyper-heuristic can execute either simple heuristics or can run in a recursive fashion a hyper-heuristic. The developed solution strategy is evaluated empirically by performing extensive experiments on irregular packing benchmark instances. A comparison with the state-of-the-art approaches is also carried out. The computational results are very encouraging. `https://link.springer.com/article/10.1007/s00500-022-07118-4`.

[24] Ibrahim H Hamdy, Maxwell J St John, Sidney W Jennings, Tiago R Magalhaes, James H Roberts, Thomas L Polmateer, Mark C Manasco, Joi Y Williams, Daniel C Hendrickson, Timothy L Eddy, et al. Quantum computing and machine learning for efficiency of maritime container port operations. In *2022 Systems and Information Engineering Design Symposium (SIEDS)*, pages 369–374. IEEE, 2022. Maritime container ports are experiencing a variety of challenges, including the pandemic and other stressors, that are altering perspectives on efficiency, risk, and resilience. This study reviews new methods of operations optimization that serve major goals of logistics systems: Increasing energy and time efficiencies and reducing emissions and congestion. Several computational methods will be assessed, including quantum computing, neural networks, and operations heuristics. The methods are compared by potential for increased efficiencies, including the increase in container volumes, reduction of dwell times, reduction of container moves, utilization of demand forecasts, and decreases in emissions. The results suggest opportunities for reinforcement learning to improve the scheduling of container transactions across transportation modes, including maritime, truck, rail, crane, and barge. `https://ieeexplore.ieee.org/abstract/document/9799399`.

[25] Julia Heise. Adaptive crossover operators in evolutionary algorithms using online learning hyper-heuristics. 2022. In this work, we present Hyper-Heuristic Online Learners as Selectors for crossover operators in multi-objective evolutionary algorithms. We answer whether HyperHeuristics are suitable for this task, by designing different Hyper-Heuristics and evaluating them by different means. We first examine known implementations of crossover operators and Hyper-Heuristics. We gain information about the different components of Hyper-Heuristic Online Learner, namely the selection heuristic, the reward function and the selection pool. We chose two different selection heuristics, the roulette wheel selection and the generation distribution, and four different reward function. Therefore, we design eight different Hyper-Heuristics, which are afterwards experimental evaluated by benchmark tests. In our evaluation, we compare the quality of the results of the Hyper-Heuristics and single crossover operators and evaluate afterwards in-depth the learning and selection behaviour of the Hyper-Heuristics. Throughout those analyses, we note that crossover operators perform dependent on more circumstance, than only the problem's properties, but also the current

distribution of the population and the phase of the algorithm. Thus, crossover operators can achieve an enormously better result, when utilized in combination. After those benchmark tests and analyses, we conclude that Hyper-Heuristics are not only suitable as crossover operators selectors, but improve also the quality in nearly all cases and give a more general approach that can be used for a wider range of problems. https://www.is.ovgu.de/is_media/Master+und+Bachelor_Arbeiten/MasterThesis_JuliaHeise-p-7028.pdf.

[26] Aurelius Ian, Ahmad Muklason, and Faizal Mahanto. Cross domain optimization problem with hyperheuristic approach using size stochastic move acceptance. *Procedia Computer Science*, 197:428–436, 2022. Cross domain optimization problem is a complex optimization problem because in each of the problem contains a different characteristic which can be solved with hyperheuristic. Hyperheuristic has two kind of search space, low-level heuristic (LLH) and move acceptance that work into the domain barrier. In this paper, an effort is made to develop a strategy in the high-level heuristic (HLH) order to regulate the selection process for the LLH and will be followed by a solution acceptance mechanism. The method that will be used is size stochastic move acceptance (SM) approach as a solution acceptance mechanism in the HLH setting, combined with the self-adaptive (SAD) LLH selection method. https://doi.org/10.1016/j.procs.2021.12.158.

[27] Paveen Juntama, Daniel Delahaye, Supatcha Chaimatanan, and Sameer Alam. Hyperheuristic approach based on reinforcement learning for air traffic complexity mitigation. *Journal of Aerospace Information Systems*, pages 1–16, 2022. Airspace capacity has become a critical resource for air transportation. Complexity in traffic patterns is a structural problem, whereby airspace capacity is sometimes saturated before the number of aircraft has reached the capacity threshold. This paper addresses a strategic planning problem with an efficient optimization approach that minimizes traffic complexity based on linear dynamical systems in order to improve the traffic structure. Traffic structuring techniques comprise departure time adjustment, en route trajectory deviation, and flight-level allocation. The resolution approach relies on the hyperheuristic framework based on reinforcement learning to improve the searching strategy during the optimization process. The proposed methodology is implemented and tested with a full day of traffic in the French airspace. Numerical results show that the proposed approach can reduce air traffic complexity by 92.8%. The performance of the proposed algorithm is then compared with two different algorithms, including the random search and the standard simulated annealing. The proposed algorithm provides better results in terms of air traffic complexity and the number of modified trajectories. Further analysis of the proposed model was conducted by considering time uncertainties. This approach can be an innovative solution for capacity management in the future air traffic management system. https://arc.aiaa.org/doi/abs/10.2514/1.I011048.

[28] Lenin Kanagasabai. Real power loss reduction by q-learning and hyper-heuristic

method. *International Journal of System Assurance Engineering and Management*, pages 1–16, 2022. This paper proposes an algorithm endorsement design using Q-learning and hyper-heuristic method (QH) to support choice architects select the supreme appropriate bio-inspired algorithm for the power loss reduction problem. For this an artificial bee colony (ABC) algorithm, Mobulidae optimization algorithm (MOA), enhanced Salp swarm algorithm (ESS) and Orcinus orca optimization (OOO) algorithm are employed as small level optimizers consequently that the Q-learning and hyper-heuristic robotically pick the optimizer in every cycle of the optimization procedure. Q-learning is a prototypical unrestricted fortification learning procedure to discover the optimal solution. In Q-learning, representatives interrelate with the environs, and their segment is rationalized. At every segment, a representative does engagements and obtains an incentive or fine. Q-learning contains of five constituents, including representatives, environs, engagements, segment, and incentive. In this paper, Q-learning intends to pick the bio-inspired algorithm in every series of the run. Hyper-heuristic is demarcated as an elevated heuristic that exploits a set of small level heuristics to determine the preeminent solution. A hyper-heuristic is frequently used to select a local examine tool such as inset, passage, and exchange. In this paper ABC, MOA, ESS, and OOO are engaged as small level heuristics. As a response tool, extra fruitful algorithms are endorsed based on the grade of development. Proposed QH is corroborated in IEEE 30 bus system and loss lessening is amplified. `https://link.springer.com/article/10.1007/s13198-021-01516-x`.

[29] Emmanuel Kieffer, Gabriel Duflo, Grégoire Danoy, Sébastien Varrette, and Pascal Bouvry. A rnn-based hyper-heuristic for combinatorial problems. In *European Conference on Evolutionary Computation in Combinatorial Optimization (Part of EvoStar)*, pages 17–32. Springer, 2022. Designing efficient heuristics is a laborious and tedious task that generally requires a full understanding and knowledge of a given optimization problem. Hyper-heuristics have been mainly introduced to tackle this issue and are mostly relying on Genetic Programming and its variants. Many attempts in the literature have shown that an automatic training mechanism for heuristic learning is possible and can challenge human-based heuristics in terms of gap to optimality. In this work, we introduce a novel approach based on a recent work on Deep Symbolic Regression. We demonstrate that scoring functions can be trained using Recurrent Neural Networks to tackle a well-know combinatorial problem, i.e., the Multi-dimensional Knapsack. Experiments have been conducted on instances from the OR-Library and results show that the proposed modus operandi is an alternative and promising approach to human-based heuristics and classical heuristic generation approaches. `https://link.springer.com/chapter/10.1007/978-3-031-04148-8_2`.

[30] Lucas Kletzander and Nysret Musliu. Hyper-heuristics for personnel scheduling domains. In *Proceedings of the International Conference on Automated Planning and Scheduling*, volume 32, pages 462–470, 2022. In real-life applications problems

can frequently change or require small adaptations. Manually creating and tuning algorithms for different problem domains or different versions of a problem can be cumbersome and time-consuming. In this paper we consider several important problems with high practical relevance, which are Bus Driver Scheduling, Rotating Workforce Scheduling, and Minimum Shift Design. Instead of designing very specific solution methods, we propose to use the more general approach based on hyper-heuristics which take a set of simpler low-level heuristics and combine them to automatically create a fitting heuristic for the problem at hand. This paper presents a major study on applying hyper-heuristics to these domains, which contributes in three different ways: First, it defines new low-level heuristics for these scheduling domains, allowing to apply hyper-heuristics to them for the first time. Second, it provides a comparison of several state-of-the-art hyper-heuristics on those domains. Third, new best solutions for several instances of the different problem domains are found. These results show that hyper-heuristics are able to perform well even on very complex practical problem domains in the area of scheduling and, while being more general and requiring less problem-specific adaptation, can in several cases compete with specialized algorithms for the specific problems. These results help to improve industrial systems in use for solving different scheduling scenarios by allowing faster and easier adaptation to new problem variants. `https://ojs.aaai.org/index.php/ICAPS/article/view/19832`.

[31] Mourad Lassouaoui, Dalila Boughaci, and Belaid Benhamou. A synergy thompson sampling hyper-heuristic for the feature selection problem. *Computational Intelligence*, 38(3):1083–1105, 2022. To classify high-dimensional data, feature selection plays a key role to eliminate irrelevant attributes and enhance the classification accuracy and efficiency. Since feature selection is an NP-Hard problem, many heuristics and metaheuristics have been used to tackle in practice this problem. In this article, we propose a novel approach that consists in a probabilistic selection hyper-heuristic called the synergy Thompson sampling hyper-heuristic. The Thompson sampling selection strategy is a probabilistic reinforcement learning mechanism to assess the behavior of the low-level heuristics, and to predict which one will be more efficient at each point during the search process. The proposed hyper-heuristic is combined with a 1 nearest neighbor classifier from the Weka framework. It aims to find the best subset of features that maximizes the classification accuracy rate. Experimental results show a good performance in favor of the proposed method when comparing with other existing approaches. `https://doi.org/10.1111/coin.12325`.

[32] Jian Lin, Yang-Yuan Li, and Hong-Bo Song. Semiconductor final testing scheduling using q-learning based hyper-heuristic. *Expert Systems with Applications*, 187:115978, 2022. Semiconductor final testing scheduling problem (SFTSP) has extensively been studied in advanced manufacturing and intelligent scheduling fields. This paper presents a Q-learning based hyper-heuristic (QHH) algorithm to address the SFTSP with makespan criterion. The structure of QHH employs the

Q-learning algorithm as the high-level strategy to autonomously select a heuristic from a pre-designed low-level heuristic set. The selected heuristic in different stages of the optimization process is recognized as the executable action and performed on the solution space for better results. An efficient encoding and decoding pair is presented to generate feasible schedules, and a left-shift scheme is embedded into the decoding process for improving resources utilization. Additionally, the design-of-experiment method is implemented to investigate the effect of parameters setting. Both computational simulation and comparison are finally carried out on a benchmark set and the results demonstrate the effectiveness and efficiency of the proposed QHH. `https://doi.org/10.1016/j.eswa.2021.115978`.

[33] Lingxuan Liu and Leyuan Shi. Automatic design of efficient heuristics for two-stage hybrid flow shop scheduling. *Symmetry*, 14(4):632, 2022. This paper addresses the two-stage hybrid flow shop scheduling problem with a batch processor in the first stage and a discrete processor in the second stage. Incompatible job families and limited buffer size are considered. This hybrid flow shop configuration commonly appears in manufacturing operations and the batch processor is always the bottleneck which breaks the symmetry of processing time. Since making a real-time high-quality schedule is challenging, we focus on the automatic design of efficient heuristics for this two-stage problem based on the genetic programming method. We develop a hyper-heuristic approach to automate the tedious trial-and-error design process of heuristics. The goal is to generate efficient dispatching rules for identifying complete schedules to minimize the total completion time. A genetic programming with cooperative co-evolution approach is proposed to evolve the schedule policy automatically. Numerical results demonstrate that the proposed approach outperforms both the constructive heuristic and meta-heuristic algorithms, and is capable of producing high-quality schedules within seconds. `https://www.mdpi.com/2073-8994/14/4/632`.

[34] Shahed Mahmud, Alireza Abbasi, Ripon K Chakrabortty, and Michael J Ryan. A self-adaptive hyper-heuristic based multi-objective optimization approach for integrated supply chain scheduling problems. *Knowledge-Based Systems*, page 109190, 2022. Recent global changes have prompted manufacturers to shift their production systems to make-to-order (MTO) supply chain (SC), enabling them to adapt customised customer requirements with their rapidly changing behaviours, reduce inventory costs, and obtain competitive advantages in the market. However, traditional MTO-based scheduling approaches fail to consider all the SC stages required for optimal schedules. This study proposes an integrated SC scheduling problem (ISCSP), where supplier, manufacturer and batching decisions are simultaneously optimised in response to heterogeneous customer requirements with time window constraints. Both economic and environmental sustainability for the supply portfolio is considered while the manufacturer is modelled using the flexible job shop scheduling (FJS) problem. Since the proposed ISCSP is an extension of the FJS problem, this can also be considered an

NP-hard problem, which cannot be solved by traditional optimisation techniques, particularly for larger instances. Thus, a self-adaptive multi-operator and multi-objective hyper-heuristic (SA(MO)2H) is designed, where the low-level heuristic utilises strengths of four solution updating heuristics and is intelligently guided by the reinforcement learning, to address the problem. The proposed SA(MO)2H integrates environmental sustainability into the evolutionary process to achieve the best possible supply portfolio, adopting the VIKORSORT approach. Finally, a rigorous experimental study on solving a wide range of instances is conducted to evaluate the performance of SA(MO)2H against its non-intelligent versions and five existing algorithms. Overall, the most beneficial facet of the developed ISCSP and SA(MO)2H is the visibility and meaningful managerial insights provided by the multi-portfolio solutions fostering the responsive relationship among SC stages. `https://doi.org/10.1016/j.knosys.2022.109190`.

[35] Oumayma Mellouli, Imad Hafidi, and Abdelmoutalib Metrane. A modified choice function hyper-heuristic with boltzmann and cauchy functions using the cooling schedule. In *23rd congres annuel de la Societe Francaise de Recherche Operationnelle et d'Aide a la Decision*, 2022. The resolution of combinatorial optimization problems has always been an interesting field for many researchers, who compete to improve the quality of the previous results in order to get computational and near-optimal solutions. Hyper-heuristics comes to light due to the limitations that heuristics and metaheuristics have presented where new problems appear or even in solving different instances of the same problem. They have two powerful characteristics: 1) they are problem-independent, and 2) they combine several heuristics and/or metaheuristics, that are simple to implement, and take advantage of their best performance to produce a highquality solution. The Modified Choice Function is a well-known hyper-heuristic that has proven its efficiency in solving various combinatorial optimization problems. However, the configuration of its parameters limits the range of heuristics that can be chosen. The parameters of any algorithm have a substantial impact on its success. Since they govern the algorithm's behavior throughout the search process, their values should be appropriately configured to get the best performance. In this study, we will propose new approaches to control the weight parameters of the Modified Choice Function, based on the Boltzmann and Cauchy Functions using the cooling schedule, which improves the diversification in the heuristic choice process. These methods are tested and compared to previous approaches over five problem domains from the combinatorial optimization literature. `https://hal.archives-ouvertes.fr/hal-03596157/file/ROADEF_2022_MELLOULI_Abstract.pdf`.

[36] Florian Mischek and Nysret Musliu. Reinforcement learning for cross-domain hyper-heuristics. In *Proceedings of the 31st International Joint Conference on Artificial Intelligence (IJCAI)*, 2022. In this paper, we propose a new hyper-heuristic approach that uses reinforcement learning to automatically learn the selection of low-level heuristics across a wide range of problem domains. We

provide a detailed analysis and evaluation of the algorithm components, including different ways to represent the hyper-heuristic state space and reset strategies to avoid unpromising areas of the solution space. Our methods have been evaluated using HyFlex, a well-known benchmarking framework for cross-domain hyper-heuristics, and compared with state-of-the-art approaches. The experimental evaluation shows that our reinforcement-learning based approach produces results that are competitive with the state-of-the-art, including the top participants of the Cross Domain Hyper-heuristic Search Competition 2011. `https://www.ijcai.org/proceedings/2022/0664.pdf`.

[37] Amir Nasiri, Ed Keedwell, Raphael Dorne, Mathias Kern, and Gilbert Owusu. A hyper-heuristic approach for the pdptw. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, pages 196–199, 2022. The one-to-one pickup and delivery problem with time-windows (PDPTW) is one of the most important problems in Operations Research (OR). In this problem a set of goods need to be transported in a given time-window with a fleet of vehicles. The pickup and delivery problem is one of the most challenging and important combinatorial optimisation problems as it has many real-world applications. Selection hyper-heuristics that learn heuristic utility during optimisation have been successfully applied to a variety of different optimisation problems including those in OR. In this paper we investigate the application of a sequence-based selection hyper-heuristic to the one-to-one, static and deterministic variant of the pickup and delivery problem with time-windows and will compare the results against two well known approaches in the Adaptive Large Neighbourhood Search and Grouping Genetic Algorithm. `https://dl.acm.org/doi/abs/10.1145/3520304.3528893`.

[38] Adriana Navajas-Guerrero, Diana Manjarres, Eva Portillo, and Itziar Landa-Torres. A hyper-heuristic inspired approach for automatic failure prediction in the context of industry 4.0. *Computers & Industrial Engineering*, page 108381, 2022. In the era of technological advances and Industry 4.0, massive data collection and analysis is a common approach followed by many industries and companies worldwide. One of the most important uses of data mining and Machine Learning techniques is to predict possible breaks or failures in industrial processes or machinery. This research designs and develops a hyper-heuristic inspired methodology to autonomously identify significant parameters of the time series that characterize the behaviour of relevant process variables enabling the prediction of failures. The proposed hyper-heuristic inspired approach is based on the combination of an optimization process performed by a meta-heuristic algorithm (Harmony Search) and feature based statistical methods for anomaly detection. It demonstrates its adaptability to different failure cases without expert domain knowledge and the capability of autonomously identifying most relevant parameters of the time series to detect the abnormal behaviour prior to the final failure. The proposed solution is validated against a real database of a cold stamping process yielding satisfactory results respect to a novel AUC_ROC based metric,

named AUC_MOD, and other conventional metrics, i.e., Specificity, Sensitivity and False Positive Rate. `https://doi.org/10.1016/j.cie.2022.108381`.

[39] Sai Panda, Yi Mei, and Mengjie Zhang. Simplifying dispatching rules in genetic programming for dynamic job shop scheduling. In *European Conference on Evolutionary Computation in Combinatorial Optimization (EvoCOP / EvoStar)*, pages 95–110. Springer, 2022. Evolving dispatching rules through Genetic Programming (GP) has been shown to be successful for solving Dynamic Job Shop Scheduling (DJSS). However, the GP-evolved rules are often very large and complex, and are hard to interpret. Simplification is a promising technique that can reduce the size of GP individuals without sacrificing effectiveness. However, GP with simplification has not been studied in the context of evolving DJSS rules. This paper proposes a new GP with simplification for DJSS, and analyses its performance in evolving both effective and simple/small rules. In addition to adopting the generic algebraic simplification operators, we also developed new problem-specific numerical and behavioural simplification operators for DJSS. The results show that the proposed approach can obtain better and simpler rules than the baseline GP and existing GP algorithms with simplification. Further analysis verified the effectiveness of the newly developed numerical and simplification operators. `https://link.springer.com/chapter/10.1007/978-3-031-04148-8_7`.

[40] Erick Rodríguez-Esparza, Antonio D Masegosa, Diego Oliva, and Enrique Onieva. A new hyper-heuristic based on adaptive simulated annealing and reinforcement learning for the capacitated electric vehicle routing problem. *arXiv preprint arXiv:2206.03185*, 2022. Electric vehicles (EVs) have been adopted in urban areas to reduce environmental pollution and global warming as a result of the increasing number of freight vehicles. However, there are still deficiencies in routing the trajectories of last-mile logistics that continue to impact social and economic sustainability. For that reason, in this paper, a hyper-heuristic (HH) approach called Hyper-heuristic Adaptive Simulated Annealing with Reinforcement Learning (HHASARL) is proposed. It is composed of a multi-armed bandit method and the self-adaptive Simulated Annealing (SA) metaheuristic algorithm for solving the problem called Capacitated Electric Vehicle Routing Problem (CEVRP). Due to the limited number of charging stations and the travel range of EVs, the EVs must require battery recharging moments in advance and reduce travel times and costs. The HH implemented improves multiple minimum best-known solutions and obtains the best mean values for some high-dimensional instances for the proposed benchmark for the IEEE WCCI2020 competition. `https://doi.org/10.48550/arXiv.2206.03185`.

[41] Francesco Paolo Saccomanno. An efficient approach for the two-dimensional bin packing problem. In *6th AIROYoung Workshop: Operation Research and Data Science in Public Services*, 2022. This work addresses the problem of packing irregular pieces into two-dimensional bins, in such a way that the number of bins used is minimized. To solve the problem under study, a set of simple basic

heuristics is developed, for the choice and placement of the pieces and for filling the empty spaces. In addition, a hyper-heuristic approach, aimed at effectively combining the basic heuristics, has been defined. The proposed hyper-heuristic is based on a machine learning mechanism, that dynamically selects low-level heuristics (i.e., the basic heuristics) to be applied at each iteration. The developed solution strategy is evaluated empirically on the basis of an extensive computational phase, carried out on irregular packing benchmark instances derived from the scientific literature. A comparison with the state-of-art solution approaches is also carried out. The computational results are very encouraging and underline that the proposed solution strategy outperforms the state-of-art in terms of both solution quality and efficiency. `https://ayw2022.uniroma3.it/wp-content/uploads/2022/02/Francesco_Saccomanno_6AYW.pdf`.

[42] Valdivino Alexandre de Santiago Júnior and Camila Pereira Sales. Metaheuristics and hyper-heuristics based on evolutionary algorithms for software integration testing. In *Proceedings of International Joint Conference on Advances in Computational Intelligence*, pages 131–151. Springer, 2022. Hyper-heuristics have been identified as optimisation algorithms that would have better generalisation capabilities than metaheuristics. In this article, we present a controlled experiment that evaluates four metaheuristics (evolutionary algorithms), two multi-objective (SPEA2, IBEA) and two many-objective (NSGA-III, MOMBI-II), and three selection hyper-heuristics (HRISE_R, HRISE_M, Choice Function) for the software integration testing problem. We relied on and improved our previous method which aims at generating integration test cases based on C++ source code and optimisation algorithms. Considering three different quality indicators and two types of evaluations (cross-domain and statistical analyses), results demonstrate that, for the algorithms and case studies considered in this research, classical metaheuristics, such as SPEA2 and IBEA, performed better compared to not only the most recent many-objective algorithms but also to the hyper-heuristics. This conclusion, based on empirical evidences, seems to be related to the well-known no free lunch theorems which assert that any two algorithms are equivalent when their performances are averaged across all possible problems. Hence, we claim that it is needed to carry out more rigorous experiments, in the context of optimisation, to better answer the question of generalisation in practical terms. `https://link.springer.com/chapter/10.1007/978-981-19-0332-8_10`.

[43] Mohd Khaled Y Shambour and Esam A Khan. A late acceptance hyper-heuristic approach for the optimization problem of distributing pilgrims over mina tents. *Journal of Universal Computer Science*, 28(4):396–413, 2022. About three million Muslims are traveling annually to Makkah in Saudi Arabia to perform the rituals of Hajj (i.e. the pilgrimage), the fifth pillar of Islam. It requires the pilgrims to move to several holy sites while performing the Hajj ritual, including Mina, Arafat, and Muzdalifah sites. However, pilgrims spend most of their time in prepared tent-camps at the Mina site during the days of Hajj. Among the

challenges that the organizers face in the Hajj is the distribution of pilgrims over the camps of Mina while considering a range of constraints, which is considered a real-world optimization problem. This paper introduces a hyper-heuristic approach to optimize the distribution process of pilgrims over Mina tent-camps in an efficient manner, named the hyper-heuristic Mina tents distribution algorithm (HyMTDA). The proposed algorithm, iteratively, selects one heuristic among four predefined low-level heuristics to produce a new solution; thereafter the late move acceptance strategy is applied as a judgment to accept or reject the new solution. The performed simulations show that the proposed HyMTDA can effectively explore the search space and avoid falling into local minima during the iterations process. Moreover, comparisons show that HyMTDA outperforms other heuristic algorithms in the literature in terms of solution quality and convergence rate. `https://lib.jucs.org/article/72900/`.

[44] Chunjian Shang, Liang Ma, Yong Liu, and Shuo Sun. The sorted-waste capacitated location routing problem with queuing time: A cross-entropy and simulated-annealing-based hyper-heuristic algorithm. *Expert Systems with Applications*, 201:117077, 2022. Waste sorting is an imperative and significant issue in China, of which sorted-waste collection and transportation are indispensable parts. Despite its vital yet practical significance, few studies research mathematical models or algorithms of waste collection and transportation from the perspective of waste sorting. To address this issue, we extend a novel transportation model for the waste management system, namely, capacitated location routing problem with queuing time (CLRPQT) and design a cross-entropy and simulated-annealing based hyper-heuristic algorithm (CE-SAHH) for it. The main idea of this paper is three-fold: (1) As a particular property of this problem, source nodes cannot but need to be served by more than one vehicle that causes queuing time between a heterogeneous fleet of vehicles, which is novel in terms of the proposed model; (2) For the methodological contribution, a character encoding scheme, new decoding procedure, and local search strategy are designed embedded in the proposed method; (3) An integration of simulated annealing strategy and the cross-entropy-based hyper-heuristic algorithm is developed to overcome the combinatorial optimization problem with a more complex solution of this study. Finally, the results and analysis of three numeric experiments on benchmark datasets, new instances of CLRPQT, and simulation data in Shanghai, China, verify the effectiveness and universality of the proposed model and method. `https://doi.org/10.1016/j.eswa.2022.117077`.

[45] Zhongshi Shao, Weishi Shao, and Dechang Pi. Ls-hh: A learning-based selection hyper-heuristic for distributed heterogeneous hybrid blocking flow-shop scheduling. *IEEE Transactions on Emerging Topics in Computational Intelligence*, 2022. As the development of economic globalization, the distributed manufacturing has become common in modern industries. The scheduling of production resources in multiple production centers becomes an emerging topic.

This paper is the first attempt to address a distributed heterogeneous hybrid blocking flow-shop scheduling problem (DHHFSP-B) with the minimization of makespan. Compared with the traditional single flow-shop scheduling, DHHFSP-B considers the collaborative production of multiple hybrid flow lines with heterogeneous layout and processing performance as well as no intermediate buffers. We firstly present a mixed-integer linear programming model to formulate DHHFSP-B and then propose a learning-based selection hyper-heuristic framework (LS-HH) for solving it. The LS-HH contains high-level strategy and low-level heuristics. In the high-level strategy, a learning probability model is built to provide the guidance to choose the suitable perturbation heuristic during the optimization process. A simulated annealing-like move acceptance is employed to determine the updating of incumbent domain solution and prevent the search from trapping into local optimum. In the low-level heuristics, a constructive heuristic is proposed based on a novel assignment rule to create the initial domain solution. Four problem-specific perturbation heuristics and a variable neighborhood search-based improvement operator are employed to search the solution space. A comprehensive computational experiment is conducted. The comparative results show that the LS-HH significantly outperforms the Gurobi solver and several closely relevant optimization methods in solving the DHHFSP-B. `https://ieeexplore.ieee.org/abstract/document/9782097`.

[46] Emilio Singh and Nelishia Pillay. A study of ant-based pheromone spaces for generation constructive hyper-heuristics. *Swarm and Evolutionary Computation*, page 101095, 2022. Research into the applicability of ant-based optimisation techniques for hyper-heuristics is largely limited. This paper expands upon the existing body of research by presenting a novel ant-based generation constructive hyper-heuristic and then investigates how different pheromone maps affect its performance. Previous work has focused on applying ant-based optimisation techniques that work in the solution space directly to the heuristic space and we hypothesise that this may be problematic for the hyper-heuristic's efficacy. The focus of this analysis is primarily on how the pheromone map, 2D and 3D, of ant-based methods, can be used for this hyper-heuristic task. 2D pheromone maps are the predominant pheromone map type used by ant-based algorithms. Thus the comparison here is between the existing 2D pheromone map and the newly introduced 3D pheromone map. The analysis consists of multiple experiments with algorithms in the TSP and 1DBPP domain which are assessed in terms of optimality and generality. The results of the experiment demonstrate key differences in performance between the two different pheromone spaces. The 3D pheromone map showed better generality and optimality in the 1DBPP domain whereas the 2D pheromone map showed better generality and only marginally better optimality for the TSP domain. The analysis indicated that the different pheromone maps work most optimally for different types of optimisation problems. The hybrid method showed some improvements in generality but showed little improvements in optimality overall. `https://doi.org/10.1016/j.swevo.2022.101095`.

[47] Vinod Chandra SS and Anand HS. Nature inspired meta heuristic algorithms for optimization problems. *Computing*, 104(2):251–269, 2022. Optimization and decision making problems in various fields of engineering have a major impact in this current era. Processing time and utilizing memory is very high for the currently available data. This is due to its size and the need for scaling from zettabyte to yottabyte. Some problems need to find solutions and there are other types of issues that need to improve their current best solution. Modelling and implementing a new heuristic algorithm may be time consuming but has some strong primary motivation - like a minimal improvement in the solution itself can reduce the computational cost. The solution thus obtained was better. In both these situations, designing heuristics and meta-heuristics algorithm has proved it's worth. Hyper heuristic solutions will be needed to compute solutions in a much better time and space complexities. It creates a solution by combining heuristics to generate automated search space from which generalized solutions can be tuned out. This paper provides in-depth knowledge on nature-inspired computing models, meta-heuristic models, hybrid meta heuristic models and hyper heuristic model. This work's major contribution is on building a hyper heuristics approach from a meta-heuristic algorithm for any general problem domain. Various traditional algorithms and new generation meta heuristic algorithms has also been explained for giving readers a better understanding. `https://link.springer.com/article/10.1007/s00607-021-00955-5`.

[48] Alexander Steenson, Ender Özcan, Ahmed Kheiri, Barry McCollum, and Paul McMullan. An online learning selection hyper-heuristic for educational timetabling. 2022. Examination and course timetabling are computationally difficult real-world resource allocation problems. In 2007, an International Timetabling Competition (ITC) consisting of three classes: (i) examination timetabling, (ii) post enrollment-based, and (iii) curriculum-based course timetabling was organised. One of the competing algorithms, referred to as CPSolver, successfully achieved the first place in two out of these three tracks. This study investigates the performance of various multi-stage selection hyper-heuristics sequencing low-level heuristics/operators extending the CPSolver framework which executes hill climbing and two well-known local search metaheuristics in stages. The proposed selection hyper-heuristic is a multi-stage approach making use of a matrix which maintains transitional probabilities between each low-level heuristic to select the next heuristic in the sequence. A second matrix tracks the probabilities of ending the sequence on a given low-level heuristic. The best configuration for the selection hyper-heuristic is explored tailoring the heuristic selection process for the given timetabling problem class. The empirical results on the ITC 2007 problem instances show that the proposed selection hyper-heuristics can reduce the number of soft constraint violations, producing improved solutions over CPSolver as well as some other previously proposed solvers, particularly, in examination and curriculum-based course timetabling. `https://eprints.lancs.ac.uk/id/eprint/146836/`.

[49] Marta Leonina Tessitore, Marcella Sama, and Dario Pacciarelli. Automatic design of dispatching rules for job shop scheduling problems. In *6th AIROYoung Workshop: Operation Research and Data Science in Public Services*, 2022. A wide range of heuristics and meta-heuristics have been developed over the last decades to successfully tackle hard combinatorial optimization problems, such as timetabling, production scheduling, and vehicle routing problems. However, designing efficient heuristics that provide good quality solutions in reasonable time on large scale optimization problems is typically problem-specific and requires an in-depth problem knowledge. In the last years, the automatic design of dispatching rules has received increasing attention, emerging as a way to compete with state-of-the-art problem-specific approaches, offering more generalized techniques able to deliver good quality solutions for a variety of scheduling problems, by directly searching in the heuristics' space. As a result, a growing number of articles focusing on hyper-heuristic methods have been applied to Job Shop Scheduling (JSS) problems. The current state-of-the-art on hyperheuristic works related to JSS problems comprises methods that are broadly concerned with intelligently selecting or generating a suitable heuristic for given problems. This work provides a comprehensive overview of existing selection and generation hyper-heuristic approaches for JSS problems, and presents critical discussion, current research trends and directions for future application of hyper-heuristics models to real-life problems or specific case-studies. `https://ayw2022.uniroma3.it/wp-content/uploads/2022/01/TESSITORE_MARTALEONINA_6AYW.pdf`.

[50] Zhao Tong, Hongjian Chen, Bilan Liu, Jinhui Cai, and Shuo Cai. A novel intelligent hyper-heuristic algorithm for solving optimization problems. *Journal of Intelligent & Fuzzy Systems*, (Preprint):1–13, 2022. In recent years, solving combinatorial optimization problems involves more complications, high dimensions, and multi-objective considerations. Combining the advantages of other evolutionary algorithms to enhance the performance of a unique evolutionary algorithm and form a new hybrid heuristic algorithm has become a way to strengthen the performance of the algorithm effectively. However, the intelligent hybrid heuristic algorithm destroys the integrity, universality, and robustness of the original algorithm to a certain extent and increases its time complexity. This paper implements a new idea ML to choose heuristics (a heuristic algorithm combined with machine learning technology) which uses the Q-learning method to learn different strategies in genetic algorithm. Moreover, a selection-based hyper-heuristic algorithm is obtained that can guide the algorithm to make decisions at different time nodes to select appropriate strategies. The algorithm is the hybrid strategy using Q-learning on StudGA (HSQ-StudGA). The experimental results show that among the 14 standard test functions, the evolutionary algorithm guided by Q-learning can effectively improve the quality of arithmetic solution. Under the premise of not changing the evolutionary structure of the algorithm, the hyper-heuristic algorithm represents a new method to solve combinatorial optimization problems. `https://content.iospress.com/articles/`

journal-of-intelligent-and-fuzzy-systems/ifs211250.

[51] Alonso Vela, Jorge M Cruz-Duarte, José Carlos Ortiz-Bayliss, and Ivan Amaya. Beyond hyper-heuristics: A squared hyper-heuristic model for solving job shop scheduling problems. *IEEE Access*, 10:43981–44007, 2022. Hyper-heuristics (HHs) stand as a relatively recent approach to solving optimization problems. There are different kinds of HHs. One of them deals with how low-level heuristics must be combined to deliver an improved solution to a set of problem instances. Literature commonly refers to them as selection hyper-heuristics. One of their advantages is that the strengths of each heuristic can be fused into a high-level solver. However, one of their drawbacks is that sometimes this generalization scheme does not suffice. Additionally, it is not easy to reuse these HHs since the model cannot be easily tweaked. So, in this work, we develop a hyper-heuristic model with an additional layer of generalization. The rationale behind it is to preserve the general structure of selecting an adequate solver for a particular situation but to use HHs instead of low-level heuristics. We call this model a Squared Hyper-Heuristic (SHH). To validate our proposal, we pursue a four-stage methodology that covers several testing scenarios. Our data reveal that, under proper conditions, our model can outperform the base HHs. Moreover, it is flexible enough to allow for an increased number of layers so that the complexity of the final model can be tuned. Additionally, different kinds of instances can be used to train each stage of the model, thus setting the groundwork for developing a transfer learning approach for hyper-heuristics. https://doi.org/10.1109/ACCESS.2022.3169503.

[52] Sandra M Venske, Carolina P Almeida, Ricardo Lüders, and Myriam R Delgado. Selection hyper-heuristics for the multi and many-objective quadratic assignment problem. *Computers & Operations Research*, page 105961, 2022. Hyper-heuristics (HH) emerged as more generalized and robust solutions for combinatorial optimization, being successfully addressed to solve several real-world problems. Implemented within an association of MOEA/DD and Differential Evolution, four selection hyper-heuristics (high-level heuristics) are studied in this work: Thompson Sampling, Probability Matching, Adaptive Pursuit and Self-Adaptive Differential Evolution. In the proposal, low-level heuristics rely on crossover performed by operators taken from a candidate pool. The HH selection is based on operators' previous performance during the evolutionary process, using a warm-up phase necessary to provide proper information regarding the most efficient operators. A discard mechanism is also considered to eliminate from the pool operators with similar performance. To evaluate the proposed approach, Quadratic Assignment Problem (QAP) instances are considered with 2, 3, 5, 7 and 10 objectives, totaling 148 instances with different dimensions and correlations between the flow matrices. Statistical tests indicate that the best version of the proposed approach, named HHMOEA/DD, outperforms those with fixed crossover operator and different literature approaches. In addition, the experiments indicate results'

improvement by the joined inclusion of the warm-up and operator discard mechanisms. `https://doi.org/10.1016/j.cor.2022.105961`.

[53] Shaolin Wang, Yi Mei, and Mengjie Zhang. Local ranking explanation for genetic programming evolved routing policies for uncertain capacitated arc routing problems. In *Proceedings of the Genetic and Evolutionary Computation Conference*, pages 314–322, 2022. The Uncertain Capacitated Arc Routing Problem (UCARP) is a well-known combinatorial optimisation problem that has many real-world applications. Genetic Programming is usually utilised to handle UCARP by evolving effective routing policies, which can respond to the uncertain environment in real-time. Previous studies mainly focus on the effectiveness of the routing policies but ignore the interpretability. In this paper, we focus on post-hoc interpretability, which explains a pre-trained complex routing policy. Unlike the existing explanation methods for classification/regression models, the behaviour of a routing policy is characterised as a ranking process rather than predicting a single output. To address this issue, this paper proposes a Local Ranking Explanation (LRE) method for GP-evolved routing policies for UCARP. Given a UCARP decision situation, LRE trains a linear model that gives the same ranks of the candidate tasks as those of the explained routing policy. The experimental results demonstrate that LRE can obtain more interpretable linear models that have highly correlated and consistent behaviours with the original routing policy in most decision situations. By analysing coefficients and attribute importance of the linear model, we managed to provide a local explanation of the original routing policy in a decision situation. `https://dl.acm.org/doi/abs/10.1145/3512290.3528723`.

[54] Felix Winter and Nysret Musliu. A hyper-heuristic approach for artificial teeth scheduling. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, pages 767–769, 2022. Finding efficient machine schedules in the area of teeth manufacturing is a challenging task, as complex constraints need to be fulfilled and multiple cost objectives should be minimized. This paper investigates a hyper-heuristic solution approach for the artificial teeth scheduling problem which originates from reallife production sites. We propose low-level heuristic strategies which can be utilized by state-of-the-art selection-based hyperheuristic strategies to efficiently solve large problem instances. An extensive set of experiments on the benchmark instances shows that the proposed approach can improve results for several realistic scenarios. `https://dl.acm.org/doi/pdf/10.1145/3520304.3528938`.

[55] Yassine Yaakoubi and Roussos Dimitrakopoulos. Learning to schedule heuristics for the simultaneous stochastic optimization of mining complexes. *arXiv preprint arXiv:2202.12866*, 2022. The simultaneous stochastic optimization of mining complexes (SSOMC) is a large-scale stochastic combinatorial optimization problem that simultaneously manages the extraction of materials from multiple mines and their processing using interconnected facilities to generate a set of final products, while taking into account material supply (geological) uncertainty

to manage the associated risk. Although simulated annealing has been shown to outperform comparing methods for solving the SSOMC, early performance might dominate recent performance in that a combination of the heuristics' performance is used to determine which perturbations to apply. This work proposes a data-driven framework for heuristic scheduling in a fully self-managed hyper-heuristic to solve the SSOMC. The proposed learn-to-perturb (L2P) hyper-heuristic is a multi-neighborhood simulated annealing algorithm. The L2P selects the heuristic (perturbation) to be applied in a self-adaptive manner using reinforcement learning to efficiently explore which local search is best suited for a particular search point. Several state-of-the-art agents have been incorporated into L2P to better adapt the search and guide it towards better solutions. By learning from data describing the performance of the heuristics, a problem-specific ordering of heuristics that collectively finds better solutions faster is obtained. L2P is tested on several real-world mining complexes, with an emphasis on efficiency, robustness, and generalization capacity. Results show a reduction in the number of iterations by 30-50% and in the computational time by 30-45%. `https://doi.org/10.48550/arXiv.2202.12866`.

[56] Yannik Zeiträg, José Rui Figueira, Nuno Horta, and Rui Neves. Surrogate-assisted automatic evolving of dispatching rules for multi-objective dynamic job shop scheduling using genetic programming. *Expert Systems with Applications*, page 118194, 2022. Dispatching rules are simple but efficient heuristics to solve multi-objective job shop scheduling problems, particularly useful to face the challenges of dynamic shop environments. A promising method to automatically evolve non-dominated rules represents multi-objective genetic programming based hyper-heuristic (MO-GP-HH). The aim of such methods is to approximate the Pareto front of non-dominated dispatching rules as good as possible in order to provide a sufficient set of efficient solutions from which the decision maker can select the most preferred one. However, one of the main drawbacks of existing approaches is the computational demanding simulation-based fitness evaluation of the evolving rules. To efficiently allocate the computational budget, surrogate models can be employed to approximate the fitness. Two possible ways, that estimate the fitness either based on a simplified problem or based on samples of fully evaluated individuals making use of machine learning techniques are investigated in this paper. Several representatives of both categories are first examined with regard to their selection accuracy and execution time. Furthermore, we developed a surrogate-assisted MO-GP-HH framework, incorporating a pre-selection task in the NSGA-II algorithm. The most promising candidates are consequently implemented in the framework. Using a dynamic job shop scenario, the two proposed algorithms are compared to the original one without using surrogates. With the aim to minimize the mean flowtime and maximum tardiness, experimental results demonstrate that the proposed algorithms outperform the former. Making use of surrogates leads to a reduction in computational costs of up to 70%. Another interesting finding shows that the enhanced ability to

identify duplicates based on the phenotypic characterization of individuals is particularly helpful in increasing diversity within a population. This study illustrates the positive effect of this mechanism on the exploration of the entire Pareto front. https://doi.org/10.1016/j.eswa.2022.118194.

[57] Hua-Xin Zhang and Chun-Miao Zhang. Multiobjective green time-dependent location-routing problem and algorithms. *Advances in Operations Research*, 2022, 2022. To reduce the logistic cost and carbon emission and improve customer satisfaction, this study proposes a multiobjective green time-dependent location routing problem (MOGTDLRP) model in which the objectives are to minimize the distribution total cost, delivery time, and fuel consumption. This model will be solved by several hyperheuristic algorithms which include the high-level heuristics and the low-level heuristics. There are three acceptance criterions for the solution: improving and equal, all moves and accept all solutions, and dynamic acceptance criteria. Through the case, the performance of the algorithm and the influence of various factors on the solution are analyzed in this study. The experimental results show that the proposed model can effectively reduce logistic costs, carbon emissions, and vehicle travel time. https://www.hindawi.com/journals/aor/2022/1811689/.

[58] Yuchang Zhang, Ruibin Bai, Rong Qu, Chaofan Tu, and Jiahuan Jin. A deep reinforcement learning based hyper-heuristic for combinatorial optimisation with uncertainties. *European Journal of Operational Research*, 300(2):418–427, 2022. In the past decade, considerable advances have been made in the field of computational intelligence and operations research. However, the majority of these optimisation approaches have been developed for deterministically formulated problems, the parameters of which are often assumed perfectly predictable prior to problem-solving. In practice, this strong assumption unfortunately contradicts the reality of many real-world problems which are subject to different levels of uncertainties. The solutions derived from these deterministic approaches can rapidly deteriorate during execution due to the over-optimisation without explicit consideration of the uncertainties. To address this research gap, a deep reinforcement learning based hyper-heuristic framework is proposed in this paper. The proposed approach enhances the existing hyper-heuristics with a powerful data-driven heuristic selection module in the form of deep reinforcement learning on parameter-controlled low-level heuristics, to substantially improve their handling of uncertainties while optimising across various problems. The performance and practicality of the proposed hyper-heuristic approach have been assessed on two combinatorial optimisation problems: a real-world container terminal truck routing problem with uncertain service times and the well-known online 2D strip packing problem. The experimental results demonstrate its superior performance compared to existing solution methods for these problems. Finally, the increased interpretability of the proposed deep reinforcement learning hyper-heuristic has

been exhibited in comparison with the conventional deep reinforcement learning methods. `https://doi.org/10.1016/j.ejor.2021.10.032`.

[59] Binghai Zhou and Lingwei Zhao. An adaptive melody search-based hyper heuristic algorithm for material feeding scheduling optimization in a novel hybrid kitting system. *SSRN 4149535*, 2022. Facing highly diversified market demands in the automotive industry, changing variants of components produced in mixed-model assembly lines (MMALs) has led to an increasing attention towards the material-feeding processes. Therefore, this paper originally proposes a novel type of material-feeding mode called hybrid kitting, whose line-side stock and AGV workload are alleviated compared to those of the stationary kitting mode, while the conveyor wear and labor cost are less than those of the travelling kitting mode, leading to a better adaptation to MMALs. Since energy-saving and JIT principles are the two major concerns in production systems, a bi-objective mathematical model is established aiming to collaboratively minimize the multi-load AGV energy consumption as well as the kit conveyor depreciation cost in the hybrid kitting-based material-feeding system. Due to the NP-hard nature of the problem, a modified melody search-based hyper-heuristic algorithm (MMSA-HH) is proposed where a modified melody search algorithm (MSA) is applied as the high-level heuristic (HLH). Seven low-level heuristic (LLH) operators are designed to facilitate the local search of algorithm and prevent the algorithm from premature convergence. In addition, based on the basic MSA, the melody composition rules are redesigned of to enrich the diversity of solutions, and the adaptive adjustment of parameters are used to balance the local search and global search. To evaluate the performance of the MMSA-HH, computational experiments are performed by comparing it with three benchmark meta-heuristic algorithms, which are harmony search-based hyper-heuristic algorithm (HSA-HH), MSA, and NSGA-II. The results reveal the effectiveness and efficiency of the MMSA-HH when solving the specific problem in our paper. Finally, the managerial insights are given through comparing the impacts of kit container size, AGV type, and different kitting modes on the two objective functions. `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4149535`.

[60] Zilong Zhuang, Yue Li, Yanning Sun, Wei Qin, and Zhao-Hui Sun. Network-based dynamic dispatching rule generation mechanism for real-time production scheduling problems with dynamic job arrivals. *Robotics and Computer-Integrated Manufacturing*, 73:102261, 2022. Although the concept of Industrial 4.0 has been well accepted, only few studies have dealt with real-time production scheduling of smart factories. Due to the advantages of simplicity, efficiency and quick response, heuristic rules have become the most promising technology to solve such problems. However, they suffer some drawbacks, such as high development and maintenance costs, low solution quality, and excessive emphasis on local information. To design heuristics from the perspective of system optimization and ensure the performance of heuristics in real-time production scheduling environ-

ments, this study develops a network-based dynamic dispatching rule generation mechanism. The complex network theory is introduced to extract a series of low-level heuristics from the perspective of system optimization, while the automatic heuristic generation problem is formulated as a multiple attribute decision making problem. Given that the dispersity of local features indicates their value for decision-making, the entropy weighting method is employed to automatically produce an adequate combination of the provided easy-to-implement low-level heuristics. Finally, the open shop scheduling problem with dynamic job arrivals is taken as an example to evaluate the effectiveness of the proposed algorithm. Numerical results demonstrate the excellent performance of the proposed algorithm in terms of algorithm effectiveness and computational time. `https://doi.org/10.1016/j.rcim.2021.102261`.

[61] Stephen A Adubi, Olufunke O Oladipupo, and Oludayo O Olugbara. Configuring the perturbation operations of an iterated local search algorithm for cross-domain search: A probabilistic learning approach. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 1372–1379. IEEE, 2021.

[62] Azza OM Ahmed, Shahd MY Osman, Terteel EH Yousif, and Ahmed Kheiri. A reinforcement learning hyper-heuristic for water distribution network optimisation. In *2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, pages 1–4. IEEE, 2021. The Water Distribution Networks (WDNs) optimisation problem focuses on finding the combination of pipes from a collection of discrete sizes available to construct a network of pipes with minimum monetary cost. It is one of the most significant problems faced by WDN engineers. This problem belongs to the class of difficult combinatorial optimisation problems, whose optimal solution is hard to find, due to its large search space. Hyper-heuristics are high-level search algorithms that explore the space of heuristics rather than the space of solutions in a given optimisation problem. In this work, different selection hyper-heuristics were proposed and empirically analysed in the WDN optimisation problem, with the goal of minimising the network's cost. New York Tunnels network benchmark was used to test the performance of these hyper-heuristics including the Reinforcement Learning (RL) hyper-heuristic method, that succeeded in achieving improved results. `https://ieeexplore.ieee.org/abstract/document/9429683`.

[63] Gözde Alp and Ali Fuat Alkaya. Hyperheuristic based migrating birds optimization algorithm for a fairness oriented shift scheduling problem. *Mathematical Problems in Engineering*, 2021, 2021. The purpose of this paper is twofold. First, it introduces a new hybrid computational intelligence algorithm to the optimization community. This novel hybrid algorithm has hyperheuristic (HH) neighborhood search movements embedded into a recently introduced migrating birds optimization (MBO) algorithm. Therefore, it is called HHMBO. Second, it gives the necessary mathematical model for a shift scheduling problem of a manufacturing company defined by including the fairness perspective, which is typically

ignored especially in manufacturing industry. Therefore, we call this complex optimization problem fairness oriented integrated shift scheduling problem (FOSSP). HHMBO is applied on FOSSP and is compared with the well-known simulated annealing, hyperheuristics, and classical MBO algorithms through extended computational experiments on several synthetic datasets. Experiments demonstrate that the new hybrid computational intelligence algorithm is promising especially for large sized instances of the specific problem defined here. HHMBO has a high exploration capability and is a promising technique for all optimization problems. To justify this assertion, we applied HHMBO to the well-known quadratic assignment problem (QAP) instances from the QAPLIB. HHMBO was up to 14.6% better than MBO on converging to the best known solutions for QAP benchmark instances with different densities. We believe that the novel hybrid method and the fairness oriented model presented in this study will give new insights to the decision-makers in the industry as well as to the researchers from several disciplines. `https://www.hindawi.com/journals/mpe/2021/6756588/`.

[64] Mazhar Ansari Ardeh, Yi Mei, and Mengjie Zhang. Surrogate-assisted genetic programming with diverse transfer for the uncertain capacitated arc routing problem. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 628–635. IEEE, 2021. The Uncertain Capacited Arc Routing Problem (UCARP) is an important routing problem that can model uncertainties of real-world scenarios. Genetic Programming (GP) is a powerful method for evolving routing policies for vehicles to enable them make real-time decisions and handle environmental uncertainties. When facing various problem domains, knowledge transfer can improve the effectiveness of the GP training. Previous studies have demonstrated that due to the existence of duplicated GP individuals in the source domain, the existing transfer learning methods do not perform satisfactorily for UCARP. To address this issue, in this work, we propose a method for detecting duplicates in the source domain and initialising the GP population in the target domain with phenotypically unique individuals. Additionally, since the presence of duplicates can limit the number of good GP individuals, we propose a surrogate-assisted initialisation approach that is able to generate much more diversely distributed initial individuals in the target domain. Our experiments demonstrate that our proposed transfer learning method can significantly improve the effectiveness of GP for training new UCARP routing policies. Compared with the state-of-the-art GP with knowledge transfer, the proposed approach can obtain significantly better solutions on a wide range of UCRP instances, in terms of both initial and final quality. `https://ieeexplore.ieee.org/abstract/document/9504817`.

[65] Oluwasegun Julius Aroba, Nalindren Naicker, and Timothy Adeliyi. A hyper-heuristic heterogeneous multisensor node scheme for energy efficiency in larger wireless sensor networks using deec-gaussian algorithm. *Mobile Information Systems*, 2021, 2021. A wireless sensor network (WSN) is an intellect-sustainable network that comprises multiple spatially distributed sensor nodes and several

sink nodes that collect data from sensors. WSNs remain an active research area in the literature due to challenging factors such as the selection of sensor location according to a given premise, finding optimal routing algorithm, and ensuring energy efficiency and consumption. Minimizing energy and prolonging the network lifetime in the WSNs are the focus of this research work. In the literature, a clustering approach is used in grouping sensor nodes into clusters and is seen as an effective technique used in optimizing energy consumption in WSNs. Hence, in this paper, we put forward a novel clustering-based approach by amalgamating the Gaussian elimination method with the Distributed Energy-Efficient Clustering to produce DEEC_Gaussian (DEEC_Gaus) to stabilize energy efficiency optimization in WSNs. We took the advantages of DEEC and Gaussian elimination algorithms to resolve energy efficiency problems in WSNs. DEEC presents attributes such as increased heterogeneity performance level, clustering stability in operation, and energy efficiency which helps to prolong network lifetime while the Gaussian elimination algorithm added an additional advantage to improve and optimize energy efficiency, to aggregate packets of operations performed in the network lifestyle of energy efficiency in WSNs. The simulations were carried out using MATLAB software with 1000 to 1500 nodes. The performance of the proposed work was compared with state-of-the-art algorithms such as DEEC, DDEEC, and EDEEC_E. The simulated results presented show that the proposed DEEC-Gauss outperformed the three other conventional algorithms in terms of network lifetime, first node dead, tenth node dead, alive nodes, and the overall timing of the packets received at the base station. The results showed that the proposed hyper-heuristic heterogeneous multisensor DEEC-Gauss algorithm presented an average percentage of 3.0% improvement for the tenth node dead (TND) and further improvement of 4.8% for the first node dead (FND). When the performance was compared to the state-of-the-art algorithms in larger networks, the overall delivery was greatly improved and optimized. `https://www.hindawi.com/journals/misy/2021/6658840/`.

[66] Oluwasegun Julius Aroba, Nalindren Naicker, and Timothy Adeliyi. An innovative hyperheuristic, gaussian clustering scheme for energy-efficient optimization in wireless sensor networks. *Journal of Sensors*, 2021, 2021. Energy stability on sensor nodes in wireless sensor networks (WSNs) is always an important challenge, especially during data capturing and transmission of packets. The recent advancement in distributed clustering algorithms in the extant literature proposed for energy efficiency showed refinements in deployment of sensor nodes, network duration stability, and throughput of information data that are channelled to the base station. However, much scope still exists for energy improvements in a heterogeneous WSN environment. This research study uses the Gaussian elimination method merged with distributed energy efficient clustering (referred to as DEEC-Gauss) to ensure energy efficient optimization in the wireless environment. The rationale behind the use of the novel DEEC-Gauss clustering algorithm is that it fills the gap in the literature as researchers have not been able

to use this scheme before to carry out energy-efficient optimization in WSNs with 100 nodes, between 1,000 and 5000 rounds and still achieve a fast time output. In this study, using simulation, the performance of highly developed clustering algorithms, namely, DEEC, EDEEC_E, and DDEEC, was compared to the proposed Gaussian Elimination Clustering Algorithm (DEEC-Gauss). The results show that the proposed DEEC-Gauss Algorithm gives an average percentage of 4.2% improvement for the first node dead (FND), a further 2.8% improvement for the tenth node dead (TND), and the overall time of delivery was increased and optimized when compared with other contemporary algorithms. `https://www.hindawi.com/journals/js/2021/6666742/`.

[67] Anil Arpaci, Jun Chen, John Drake, and Tim Glover. Intelligent strategies to combine move heuristics in selection hyper-heuristics for real-world fibre network design optimisation. In *2021 IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 01–08. IEEE, 2021. Increasing competition in today's telecommunication industry drives the need for more cost effective services. In order to reduce the cost of designing a fibre network with low capital expenditure, automation and optimisation of network design has become crucial. British Telecom's network design software, BT NetDesign, has been developed for the purpose of network design and optimisation using a rich set of network/graph-based heuristics and the simulated annealing (SA) search method. Although NetDesign provides several different ways of navigating the search space via different move heuristics, the existing search method (SA) does not consistently reach the near-global optimum as the size of network increases. To deal with larger networks, this study utilises an intelligent approach based on the well-known Luby sequence to combine move heuristics, using two separate learning schemes: frequency based and bigram statistics. These two strategies are rigorously evaluated on network instances of different sizes. Experimental results on real-world case studies indicate that a bigram scheme with a longer warm-up period to learn heuristic combinations can reach high quality solutions for large networks. `https://ieeexplore.ieee.org/abstract/document/9659994`.

[68] R Aswanandini and C Deepa. Network intrusion classification using configuration optimized support vector machines. In *2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA)*, pages 1–6. IEEE, 2021. Cyber security has been undergoing various advancements in technology in recent years among which the use of big data analytics to process large network data is driving the change. The extraction and analysis of the network intrusion data using big data analytics have provided high detection accuracy with minimized complexity than the traditional data classification methods. Support Vector Machines (SVM) has been utilized extensively utilized for network intrusion classification and has provided high performance. However, the SVM based models have often suffered from problems of high training time and model complexity. This paper aims at developing a big

data analytics model using optimized SVM to classify the intrusion datasets. In this model, the hybrid algorithm of Hyper-Heuristic Particle Swarm optimization (HHPSO) is derived for optimizing the configuration of the SVM. This can significantly reduce the model complexity and also reduce the training time. For achieving this objective, hyper-heuristic optimization is combined with Particle Swarm optimization (PSO) to optimize the margin parameter, kernel type and kernel parameter for enhancing accuracy and decreasing model complexity of the SVM model. Two datasets NSL-KDD and ISCX-IDS are used here to perform the experiments in MATLAB. The results indicate that the proposed model has achieved better performance than the compared models in terms of accuracy and time. `https://ieeexplore.ieee.org/abstract/document/9675522`.

[69] HaoJie Chen, Guofu Ding, Shengfeng Qin, and Jian Zhang. A hyper-heuristic based ensemble genetic programming approach for stochastic resource constrained project scheduling problem. *Expert Systems with Applications*, 167:114174, 2021. In project scheduling studies, to the best of our knowledge, the hyper-heuristic collaborative scheduling is first-time applied to project scheduling with random activity durations. A hyper-heuristic based ensemble genetic programming (HH-EGP) method is proposed for solving stochastic resource constrained project scheduling problem (SRCPSP) by evolving an ensemble of priority rules (PRs). The proposed approach features with (1) integrating the critical path method into the resource-based policy class to generate schedules; (2) improving the existing single hyper-heuristic project scheduling research to construct a suitable solution space for solving SRCPSP; and (3) bettering genetic evolution of each subpopulation from a decision ensemble with three different local searches in corporation with discriminant mutation and discriminant population renewal. In addition, a sequence voting mechanism is designed to deal with collaborative decision-making in the scheduling process for SRCPSP. The benchmark PSPLIB is performed to verify the advantage of the HH-EGP over heuristics, meta-heuristics and the single hyper-heuristic approaches. `https://www.sciencedirect.com/science/article/abs/pii/S0957417420309118`.

[70] Xiaowu Chen, Guozhang Jiang, Yongmao Xiao, Gongfa Li, and Feng Xiang. A hyper heuristic algorithm based genetic programming for steel production scheduling of cyber-physical system-oriented. *Mathematics*, 9(18):2256, 2021. Intelligent manufacturing is the trend of the steel industry. A cyber-physical system oriented steel production scheduling system framework is proposed. To make up for the difficulty of dynamic scheduling of steel production in a complex environment and provide an idea for developing steel production to intelligent manufacturing. The dynamic steel production scheduling model characteristics are studied, and an ontology-based steel cyber-physical system production scheduling knowledge model and its ontology attribute knowledge representation method are proposed. For the dynamic scheduling, the heuristic scheduling rules were established. With the method, a hyper-heuristic algorithm based on genetic programming is pre-

sented. The learning-based high-level selection strategy method was adopted to manage the low-level heuristic. An automatic scheduling rule generation framework based on genetic programming is designed to manage and generate excellent heuristic rules and solve scheduling problems based on different production disturbances. Finally, the performance of the algorithm is verified by a simulation case. https://www.mdpi.com/2227-7390/9/18/2256.

[71] Mario GCA Cimino, Domenico Minici, Manilo Monaco, Stefano Petrocchi, and Gigliola Vaglini. A hyper-heuristic methodology for coordinating swarms of robots in target search. *Computers and Electrical Engineering*, 95:107420, 2021. Target search aims to discover elements of various complexity in a physical environment, by minimizing the overall discovery time. Different swarm intelligence algorithms have been proposed in the literature, inspired by biological species. Despite the success of bio-inspired techniques (bio-heuristics), there are relevant algorithm selection and parameterization costs associated with every new type of mission and with new instances of known missions. In this paper, evolutionary optimization is proposed for achieving significant improvements of the mission performance. Although adaptive, the logic of bio-heuristics is nevertheless constrained by models of biological species. To generate more adaptable logics, a novel design approach based on hyper-heuristics is proposed, in which the differential evolution optimizes the aggregation and tuning of modular heuristics for a given application domain. A modeling and optimization testbed has been developed and publicly released. Experimental results on real-world scenarios show that the hyper-heuristics based on stigmergy and flocking significantly outperform the adaptive bio-heuristics. https://doi.org/10.1016/j.compeleceng.2021.107420.

[72] Rebeka Čorić, Mateja umić, and Domagoj Jakobovic. Genetic programming hyperheuristic parameter configuration using fitness landscape analysis. *Applied Intelligence*, 51(10):7402–7426, 2021. Fitness landscape analysis is a tool that can help us gain insight into a problem, determine how hard it is to solve a problem using a given algorithm, choose an algorithm for solving a given problem, or choose good algorithm parameters for solving the problem. In this paper, fitness landscape analysis of hyperheuristics is used for clustering instances of three scheduling problems. After that, good parameters for tree-based genetic programming that can solve a given scheduling problem are calculated automatically for every cluster. Additionally, we introduce tree editing operators which help in the calculation of fitness landscape features in tree based genetic programming. A heuristic is proposed based on introduced operators, and it calculates the distance between any two trees. The results show that the proposed approach can obtain parameters that offer better performance compared to manual parameter selection. https://link.springer.com/article/10.1007/s10489-021-02227-3.

[73] Joao Guilherme Cavalcanti Costa, Yi Mei, and Mengjie Zhang. An evolutionary hyper-heuristic approach to the large scale vehicle routing problem. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 2109–2116. IEEE,

2021. The Large Scale Vehicle Routing Problem (LSVRP) is a classical combinatorial optimisation problem that serves several customers on a graph using a set of vehicles. Due to the NP-hardness and large problem size, LSVRP cannot be efficiently solved by exact approaches. Heuristic methods such as the Iterative Local Search or the Hybrid Genetic Algorithm still struggle for finding effective solutions for large scale instances. For these methods to deal with the large search space, pruning techniques are applied in order to limit the number of explored solutions. However, effective pruning is a hard task, requiring domain knowledge to craft good ways of limiting the search space without losing the ability to find better solutions. Hyper-heuristics are types of methods that aim to reduce domain knowledge on the creation of heuristics, and in this work, we also apply them for effective heuristic pruning. Our Evolutionary Hyper-Heuristic (EHH) automatically evolves limits to the solution search space together with the heuristic utilised to build and improve solutions for the LSVRP. We utilise a Guided Local Search (GLS) as the base algorithm in which our EHH searches for the best heuristic configuration. Our results show that the EHH can find better solutions for most LSVRP test instances when compared to the manually designed pruning of the GLS. `https://ieeexplore.ieee.org/abstract/document/9504818`.

[74] Joao Guilherme Cavalcanti Costa, Yi Mei, and Mengjie Zhang. Learning initialisation heuristic for large scale vehicle routing problem with genetic programming. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 1864–1871. IEEE, 2021. The Large Scale Vehicle Routing Problem is a classical NP-hard problem. It has several applications in the industry and has always been the focus of studies and development of new, ever more complex, techniques to solve it. An important group of these techniques are Local Search-based, which are sensitive to the initial solution given to them. However, finding effective initial solutions is not a trivial task, requiring domain knowledge for building them. Although some Genetic Programming Hyper-Heuristics (GPHH) have tried to build better heuristics automatically, they barely give an advantage for improving the solution afterwards. This paper aims to show that Genetic Programming can identify better regions of the search space, where the initial solutions can be improved more efficiently with optimisation steps. This is done by developing new terminals and a new fitness function, which are based on the width of the routes, a metric that was recently found to be an important feature for good solutions. The obtained results show that the proposed approach finds better final solutions than when using classical initial heuristics or other GPHH, for both time efficiency and effectiveness. `https://ieeexplore.ieee.org/abstract/document/9504938`.

[75] Jorge M Cruz-Duarte, Ivan Amaya, Jose C Ortiz-Bayliss, Santiago E Conant-Pablos, Hugo Terashima-Marín, and Yong Shi. Hyper-heuristics to customise metaheuristics for continuous optimisation. *Swarm and Evolutionary Computation*, 66:100935, 2021. Literature is prolific with metaheuristics for solving continuous optimisation problems. But, in practice, it is difficult to choose one

appropriately for several reasons. First and foremost, 'new' metaheuristics are being proposed at an alarmingly fast rate, rendering impossible to know them all. Moreover, it is necessary to determine a good enough set of parameters for the selected approach. Hence, this work proposes a strategy based on a hyper-heuristic model powered by Simulated Annealing for customising population-based metaheuristics. Our approach considers search operators from 10 well-known techniques as building blocks for new ones. We test this strategy on 107 continuous benchmark functions and in up to 50 dimensions. Besides, we analyse the performance of our approach under different experimental conditions. The resulting data reveal that it is possible to obtain good-performing metaheuristics with diverse configurations for each case of study and in an automatic fashion. In this way, we validate the potential of the proposed framework for devising metaheuristics that solve continuous optimisation problems with different characteristics, similar to those from practical engineering scenarios. https://doi.org/10.1016/j.swevo.2021.100935.

[76] Jorge M Cruz-Duarte, Ivan Amaya, Jose Carlos Ortiz-Bayliss, and Nelishia Pillay. Naive hyper-heuristic online learning to generate unfolded population-based metaheuristics to solve continuous optimization problems. In *IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–8. IEEE, 2021. Optimization is a field that never runs out nor becomes irrelevant. Nowadays, it is pretty hard to find a solver from the overpopulation of metaheuristics that properly deals with a given problem. This is even considered an additional problem. In this work, we propose a novel and simple methodology for solving the Metaheuristic Composition Optimization Problem, which involves designing heuristic-based procedures that solve continuous optimization problems. This methodology implements a naive online learning that identifies the most relevant search operators to include in the candidate heuristic-based procedures. For representing these procedures, we adopt our previously proposed unfolded metaheuristic model. We prove the feasibility of this approach via a two-fold experiment employing several continuous optimization problems. Our data revealed that the learning procedure is worthwhile, finding adequate solutions for problems in up to 50 dimensions. https://ieeexplore.ieee.org/abstract/document/9659917.

[77] Jorge M Cruz-Duarte, José C Ortiz-Bayliss, Ivan Amaya, and Nelishia Pillay. Global optimisation through hyper-heuristics: Unfolding population-based metaheuristics. *Applied Sciences*, 11(12):5620, 2021. Optimisation has been with us since before the first humans opened their eyes to natural phenomena that inspire technological progress. Nowadays, it is quite hard to find a solver from the overpopulation of metaheuristics that properly deals with a given problem. This is even considered an additional problem. In this work, we propose a heuristic-based solver model for continuous optimisation problems by extending the existing concepts present in the literature. We name such solvers 'unfolded' metaheuristics (uMHs) since they comprise a heterogeneous sequence of

simple heuristics obtained from delegating the control operator in the standard metaheuristic scheme to a high-level strategy. Therefore, we tackle the Metaheuristic Composition Optimisation Problem by tailoring a particular uMH that deals with a specific application. We prove the feasibility of this model via a two-fold experiment employing several continuous optimisation problems and a collection of diverse population-based operators with fixed dimensions from ten well-known metaheuristics in the literature. As a high-level strategy, we utilised a hyper-heuristic based on Simulated Annealing. Results demonstrate that our proposed approach represents a very reliable alternative with a low computational cost for tackling continuous optimisation problems with a tailored metaheuristic using a set of agents. We also study the implication of several parameters involved in the uMH model and their influence over the solver performance. `https://www.mdpi.com/2076-3417/11/12/5620`.

[78] Jianshuang Cui and Jingwen Yu. Research on solving combinatorial optimization problems based on hyper-heuristic algorithms. In *2021 2nd International Conference on Computer Science and Management Technology (ICCSMT)*, pages 463–468. IEEE, 2021. Due to the single mechanism of traditional heuristic algorithms and meta-heuristic algorithms, different algorithms for different problems or the same problem need to be customized. To solve these shortcomings, scholars have begun to study hyper-heuristic algorithms. This paper proposes a tabu search hyper-heuristic algorithm based on random selection to solve multiple combinatorial optimization problems. The algorithm model divides into high level and low level. The low level comprises meta-heuristic operators with multiple heterogeneous mechanisms and meta-heuristic operators with different parameter combinations of the same algorithm. According to the tabu search algorithm based on random selection, the high level automatically selects operators. Because the model organically integrates the tabu search algorithm and different meta-heuristic algorithms, it has a certain scalability. To verify the effect of the algorithm, two cases of combined optimization problems of CVRP and MRCPSP from the international benchmark case library for experiments. Experimental results show that the tabu search hyper-heuristic algorithm based on random selection has an excellent performance in multiple performance indicators such as target value and versatility. It can apply to different combinatorial optimization problems. `https://ieeexplore.ieee.org/abstract/document/9787046`.

[79] Kateryna Czerniachowska and Marcin Hernes. Simulated annealing hyper-heuristic for a shelf space allocation on symmetrical planograms problem. *Symmetry*, 13(7):1182, 2021. The allocation of products on shelves is an important issue from the point of view of effective decision making by retailers. In this paper, we investigate a practical shelf space allocation model which takes into account the number of facings, capping, and nesting of a product. We divide the shelf into the segments of variable size in which the products of the specific types could be placed. The interconnections between products are modelled with the

help of categorizing the products into specific types as well as grouping some of them into clusters. This results in four groups of constraints-shelf constraints, shelf type constraints, product constraints, position allocation constraints-that are used in the model for aesthetic symmetry of a planogram. We propose a simulated annealing algorithm with improvement and reallocation procedures to solve the planogram profit maximization problem. Experiments are based on artificial data sets that have been generated according to real-world conditions. The efficiency of the designed algorithm has been estimated using the CPLEX solver. The computational tests demonstrate that the proposed algorithm gives valuable results in an acceptable time. https://www.mdpi.com/2073-8994/13/7/1182.

[80] Robertas Damasevicius and Rytis Maskeliunas. Agent state flipping based hybridization of heuristic optimization algorithms: A case of bat algorithm and krill herd hybrid algorithm. *Algorithms*, 14(12):358, 2021. This paper describes a unique meta-heuristic technique for hybridizing bio-inspired heuristic algorithms. The technique is based on altering the state of agents using a logistic probability function that is dependent on an agent's fitness rank. An evaluation using two bio-inspired algorithms (bat algorithm (BA) and krill herd (KH)) and 12 optimization problems (cross-in-tray, rotated hyper-ellipsoid (RHE), sphere, sum of squares, sum of different powers, McCormick, Zakharov, Rosenbrock, De Jong No. 5, Easom, Branin, and Styblinski-Tang) is presented. Furthermore, an experimental evaluation of the proposed scheme using the industrial three-bar truss design problem is presented. The experimental results demonstrate that the hybrid scheme outperformed the baseline algorithms (mean rank for the hybrid BA-KH algorithm is 1.279 vs. 1.958 for KH and 2.763 for BA). https://www.mdpi.com/1999-4893/14/12/358.

[81] Augusto Dantas and Aurora Pozo. Online selection of heuristic operators with deep q-network: A study on the hyflex framework. In *Brazilian Conference on Intelligent Systems*, pages 280–294. Springer, 2021. General and adaptive strategies have been a highly pursued goal of the optimization community, due to the domain-dependent set of configurations (operators and parameters) that is usually required for achieving high quality solutions. This work investigates a Deep Q-Network (DQN) selection strategy under an online selection Hyper-Heuristic algorithm and compares it with two state-of-the-art Multi-Armed Bandit (MAB) approaches. We conducted the experiments on all six problem domains from the HyFlex Framework. With our definition of state representation and reward scheme, the DQN was able to quickly identify the good and bad operators, which resulted on better performance than the MAB strategies on the problem instances that a more exploitative behavior deemed advantageous. https://link.springer.com/chapter/10.1007/978-3-030-91702-9_19.

[82] Augusto Dantas, Alexander Fiabane do Rego, and Aurora Pozo. Using deep q-network for selection hyper-heuristics. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, pages 1488–1492, 2021. Hyper-

Heuristics is an active research field that aims to automatically select (or generate) the best low-level heuristic in each step of the search process. This work investigates a Hyper-Heuristic with a Deep Q-Network (DQN) selection strategy and compares it with two state-of-the-art approaches, namely the Dynamic MAB and the Fitness-Rate-Rank MAB. The experiments conducted on two domains from the HyFlex framework showed that the DQN approach outperformed the others on the Vehicle Routing Problem and was competitive on the Traveling Salesman Problem. This indicates that the DQN is a robust selection strategy that is less sensitive to the domain than the MAB based approaches. `https://dl.acm.org/doi/abs/10.1145/3449726.3463187`.

[83] Kasi Viswanath Dasari, Venkatesh Pandiri, and Alok Singh. Multi-start heuristics for the profitable tour problem. *Swarm and Evolutionary Computation*, 64:100897, 2021. This paper is concerned with an interesting variant of the traveling salesman problem (TSP) called a profitable tour problem (PTP). Unlike TSP, in PTP there is no need to visit all the cities, and each city is associated with a profit which the salesman gets in case he visits that city. Like TSP, a travel cost is incurred in visiting a city that depends on the city visited last before visiting the city in consideration. The goal of the problem is to maximize the total profit minus total travel cost. In this paper, we have proposed three methods, viz. a multi-start hyper-heuristic (MSHH), a multi-start iterated local search (MS-ILS) and a multi-start general variable neighborhood search (MS-GVNS) to solve the PTP. MSHH uses eight different low level heuristics, whereas MS-ILS and MS-GVNS utilize variable neighborhood descent search over five different neighborhoods for local search. To evaluate the performance of the proposed approaches, a set of benchmark instances is generated based on the publicly available TSPLIB instances. Computational results on these instances show the effectiveness of our proposed approaches. `https://doi.org/10.1016/j.swevo.2021.100897`.

[84] Vinicius Renan de Carvalho, Ender Ozcan, and Jaime Simao Sichman. Comparative analysis of selection hyper-heuristics for real-world multi-objective optimization problems. *Applied Sciences*, 11(19):9153, 2021. As exact algorithms are unfeasible to solve real optimization problems, due to their computational complexity, meta-heuristics are usually used to solve them. However, choosing a meta-heuristic to solve a particular optimization problem is a non-trivial task, and often requires a time-consuming trial and error process. Hyper-heuristics, which are heuristics to choose heuristics, have been proposed as a means to both simplify and improve algorithm selection or configuration for optimization problems. This paper novel presents a novel cross-domain evaluation for multi-objective optimization: we investigate how four state-of-the-art online hyper-heuristics with different characteristics perform in order to find solutions for eighteen real-world multi-objective optimization problems. These hyper-heuristics were designed in previous studies and tackle the algorithm selection problem from different perspectives: Election-Based, based on Reinforcement Learning and based on a mathematical

function. All studied hyper-heuristics control a set of five Multi-Objective Evolutionary Algorithms (MOEAs) as Low-Level (meta-)Heuristics (LLHs) while finding solutions for the optimization problem. To our knowledge, this work is the first to deal conjointly with the following issues: (i) selection of meta-heuristics instead of simple operators (ii) focus on multi-objective optimization problems, (iii) experiments on real world problems and not just function benchmarks. In our experiments, we computed, for each algorithm execution, Hypervolume and IGD+ and compared the results considering the Kruskal-Wallis statistical test. Furthermore, we ranked all the tested algorithms considering three different Friedman Rankings to summarize the cross-domain analysis. Our results showed that hyper-heuristics have a better cross-domain performance than single meta-heuristics, which makes them excellent candidates for solving new multi-objective optimization problems. `https://www.mdpi.com/2076-3417/11/19/9153`.

[85] Shinta Dewi, Raras Tyasnurita, and Febriyora Surya Pratiwi. Solving examination timetabling problem within a hyper-heuristic framework. *Bulletin of Electrical Engineering and Informatics*, 10(3):1611–1620, 2021. Scheduling exams in colleges are a complicated job that is difficult to solve conventionally. Exam timetabling is one of the combinatorial optimization problems where there is no exact algorithm that can answer the problem with the optimum solution and minimum time possible. This study investigated the University of Toronto benchmark dataset, which provides 13 real instances regarding the scheduling of course exams from various institutions. The hard constraints for not violate the number of time slots must be fulfilled while paying attention to fitness and running time. Algorithm of largest degree, hill climbing, and tabu search within a hyper-heuristic framework is investigated with regards to each performance. This study shows that the Tabu search algorithm produces much lower penalty value for all datasets by reducing 18-58% from the initial solution. `https://www.beei.org/index.php/EEI/article/view/2996`.

[86] Gabriel Duflo, Grégoire Danoy, El-Ghazali Talbi, and Pascal Bouvry. A q-learning based hyper-heuristic for generating efficient uav swarming behaviours. In *Asian Conference on Intelligent Information and Database Systems*, pages 768–781. Springer, 2021. The usage of Unmanned Aerial Vehicles (UAVs) is gradually gaining momentum for commercial applications. These however often rely on a single UAV, which comes with constraints such as its range of capacity or the number of sensors it can carry. Using several UAVs as a swarm makes it possible to overcome these limitations. Many metaheuristics have been designed to optimise the behaviour of UAV swarms. Manually designing such algorithms can however be very time-consuming and error prone since swarming relies on an emergent behaviour which can be hard to predict from local interactions. As a solution, this work proposes to automate the design of UAV swarming behaviours thanks to a Q-learning based hyper heuristic. Experimental results demonstrate that it is possible to obtain efficient swarming heuristics in-

dependently of the problem size, thus allowing a fast training on small instances. `https://link.springer.com/chapter/10.1007/978-3-030-73280-6_61`.

[87] Ibrahim SI Eltayeb and Ali SA Ahmed. A comparison of selection hyper-heuristic approaches on the conference scheduling optimization problem. In *International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, pages 1–6. IEEE, 2021. The conference scheduling problem is a NP-hard combinatorial optimization problem. Conference scheduling involves organizing presentations into sessions which are assigned to time periods and rooms. This includes assuring a feasible utilization of time periods and rooms, and avoiding individual schedule conflicts. The problem increases in complexity by considering the preferences of presenters. Compared to other similar scheduling problems, the conference scheduling problem is relatively unexplored. This paper describes a method to generate feasible initial schedules, and then employ selection hyper-heuristics to find optimal solutions for the problem. Experiments using the GR-AM, SR-IE, SR-SA, TS-IE, SR-AM, SR-OI hyper-heuristic algorithms were carried out on two problem instances: LargeConference, and SmallConference. Empirical results show that the GR-AM algorithm is the most suitable for small conferences, and still works well on larger scale conferences, but further experimentation indicates that the TS-IE algorithm produces better results on a larger conferences. `https://ieeexplore.ieee.org/abstract/document/9429603`.

[88] Huali Fan, Hegen Xiong, and Mark Goh. Genetic programming-based hyper-heuristic approach for solving dynamic job shop scheduling problem with extended technical precedence constraints. *Computers & Operations Research*, 134:105401, 2021. xtended technical precedence constraints (ETPC) in dynamic job shop scheduling problem (DJSP) are the precedence constraints existing between different jobs instead of the conventional technical precedence constraints existing in the operations of the same job. This paper presents the mathematical programming model of the DJSP with ETPC to minimize the mean weighted tardiness of the jobs. The mathematical model contributes to the solution and modelling of the DJSP with ETPC and it is used to solve small-sized problems to optimality. To solve industry-sized problems, a constructive heuristic called the dispatching rule (DR) is employed. This paper investigates the use of genetic programming (GP) as a hyper-heuristic in the automated generation of the problem-specific DRs for solving the problem under consideration. The genetic programming-based hyper heuristic (GPHH) approach constructs the DRs which are learned from the training instances and then verified on the test instances by the simulation experiments. To enhance the efficiency of the approach when evolving effective DRs to solve the problem, the approach is improved with strategies which consist of a problem-specific attribute selection for GP and a threshold condition mechanism for fitness evaluation. The simulation results verify the effectiveness and efficiency of the evolved DRs to the problem under consideration by comparing against the existing classical DRs. The statistical analysis of the sim-

ulation results shows that the evolved DRs outperform the selected benchmark DRs on the problem under study. The sensitivity analysis also shows that the DRs generated by the GPHH approach are robust under different scheduling performance measures. Moreover, the effects of the model parameters, including the percentage of jobs with ETPC and the machine utilization, on the performance of the DRs are investigated. `https://doi.org/10.1016/j.cor.2021.105401`.

[89] ZHOU Feng-shun, HU Rong, QIAN Bin, ZHANG Chang-sheng, and XIANG Feng-hong. Hyper-heuristic three-dimensional estimation of distribution algorithm for solving distributed permutation flow-shop and vehicle transportation integrated scheduling problem. *ACTA ELECTONICA SINICA*, 49(12):2419, 2021. Aiming at a kind of widely existing distributed permutation flow-shop and vehicle transportation integrated scheduling problem(DPFVTISP), this paper establishes the problem model and proposes a hyper-heuristic three-dimensional estimation of distribution algorithm(HH3DEDA) to solve it. Firstly, a novel coding and decoding rules adopting the greedy strategy is designed via analyzing the characteristics of DPFVTISP. Secondly, in order to search different regions in the solution space of DPFVTISP, ten kinds of low-layer heuristic operations, i.e., ten kinds of effective neighborhood operations, are designed, and their permutations are regarded as high-layer individuals. At the same time, the three-dimensional estimation of distribution algorithm (3DEDA) is used in the high layer to learn and accumulate the information of block structures and their positions in the high-quality high-layer individuals, and then new low-layer individuals or permutations are generated by sampling the probability model in 3DEDA. Furthermore, in the low layer, an ordered series of heuristic operations presenting by each new individual generated in the high layer is regarded as a new heuristic algorithm to execute further neighborhood search in the problem's solution space. Finally, simulations and comparisons demonstrate that HH3DEDA can effectively solve the DPFVTISP. `https://www.ejournal.org.cn/EN/10.12263/DZXB.20201057`.

[90] Guanqiang Gao, Yi Mei, Bin Xin, Ya-Hui Jia, and Will N Browne. Automated coordination strategy design using genetic programming for dynamic multipoint dynamic aggregation. *IEEE Transactions on Cybernetics*, 2021. The multipoint dynamic aggregation (MPDA) problem of the multirobot system is of great significance for its real-world applications such as bush fire elimination. The problem is to design the optimal plan for a set of heterogeneous robots to complete some geographically distributed tasks collaboratively. In this article, we consider the dynamic version of the problem, where new tasks keep appearing after the robots are dispatched from the depot. The dynamic MPDA problem is a complicated optimization problem due to several characteristics, such as the collaboration of robots, the accumulative task demand, the relationships among robots and tasks, and the unpredictable task arrivals. In this article, a new model of the problem considering these characteristics is proposed. To solve the problem, we develop a new genetic programming hyperheuristic (GPHH) method to evolve reactive

coordination strategies (RCSs), which can guide the robots to make decisions in real time. The proposed GPHH method contains a newly designed effective RCS heuristic template to generate the execution plan for the robots according to a GP tree. A new terminal set of features related to both robots and tasks and a cluster filter that assigns the robots to urgent tasks are designed. The experimental results show that the proposed GPHH significantly outperformed the state-of-the-art methods. Through further analysis, useful insights such as how to distribute and coordinate robots to execute different types of tasks are discovered. `https://ieeexplore.ieee.org/abstract/document/9445736`.

[91] İlker Gölcük and Fehmi Burcin Ozsoydan. Q-learning and hyper-heuristic based algorithm recommendation for changing environments. *Engineering Applications of Artificial Intelligence*, 102:104284, 2021. A considerable amount of research has been devoted to solving static optimization problems via bio-inspired metaheuristic algorithms. However, most of the algorithms assume that all problem-related data remain unchanged during the optimization process, which is not a realistic assumption. Recently, dynamic optimization problems (DOPs) grabbed remarkable attention from the research community. However, the literature still lacks clear guidelines on selecting the most appropriate bio-inspired algorithm under changing environments. Due to the availability of many design choices, the selection of a suitable bio-inspired metaheuristic algorithm becomes an immediate challenge. This study proposes an algorithm recommendation architecture using Q-learning and hyper-heuristic approaches to help decision-makers select the most suitable bio-inspired algorithm for a given problem. To this end, Artificial Bee Colony (ABC), Manta Ray Foraging Optimization (MRFO), Salp Swarm Algorithm (SSA), and Whale Optimization Algorithm (WOA) are employed as low-level optimizers so that the Q-learning and hyper-heuristic automatically select the optimizer in each cycle of the optimization process. The proposed algorithms are implemented in dynamic multidimensional knapsack problems, a natural extension of the well-known 0-1 knapsack problem. The performances of the recommender and standalone bio-inspired algorithms are evaluated through a comprehensive experimental analysis including appropriate statistical tests. Thus, the significant differences among the algorithms are revealed. The obtained results point out the efficiencies of the Q-learning-based algorithm recommender and MRFO in solving the dynamic multidimensional knapsack problem. `https://www.sciencedirect.com/science/article/abs/pii/S0952197621001317`.

[92] Abhishek Gupta, Harvendra Singh Bhadauria, and Annapurna Singh. Load balancing based hyper heuristic algorithm for cloud task scheduling. *Journal of Ambient Intelligence and Humanized Computing*, 12(6):5845–5852, 2021. The cloud computing environment provides computing assets in a pay-per-use way for IT service providers. Guaranteeing QoS amid job scheduling is a most noticeable need. This paper proposed an algorithm that expects to accomplish all-around adjusted load crosswise over virtual machines for minimizing makespan time. The proposed

algorithm provides balanced scheduling solutions by employing the honey bee load balancing and improvement detection operator to conclude which low-level heuristic is to be utilized to search improved candidate solutions. The consequences of the proposed task scheduling algorithm are matched with existing heuristic-based scheduling procedures. The experimental consequences demonstrate that our approach is efficient when it is compared with the existing algorithms. `https://link.springer.com/article/10.1007/s12652-020-02127-3`.

[93] Ahmed Hassan and Nelishia Pillay. Dynamic heuristic set selection for cross-domain selection hyper-heuristics. In *International Conference on the Theory and Practice of Natural Computing*, pages 33–44. Springer, 2021. Selection hyper-heuristics have proven to be effective in solving various real-world problems. Hyper-heuristics differ from traditional heuristic approaches in that they explore a heuristic space rather than a solution space. These techniques select constructive or perturbative heuristics to construct a solution or improve an existing solution respectively. Previous work has shown that the set of problem-specific heuristics made available to the hyper-heuristic for selection has an impact on the performance of the hyper-heuristic. Hence, there have been initiatives to determine the appropriate set of heuristics that the hyper-heuristic can select from. However, there has not been much research done in this area. Furthermore, previous work has focused on determining a set of heuristics that is used throughout the lifespan of the hyper-heuristic with no change to this set during the application of the hyper-heuristic. This paper investigates dynamic heuristic set selection (DHSS) which applies dominance to select the set of heuristics at different points during the lifespan of a selection hyper-heuristic. The DHSS approach was evaluated on the benchmark set for the CHeSC cross-domain hyper-heuristic challenge. DHSS was found to improve the performance of the best performing hyper-heuristic for this challenge. `https://link.springer.com/chapter/10.1007/978-3-030-90425-8_3`.

[94] Libin Hong, John R Woodward, Ender Özcan, and Fuchang Liu. Hyper-heuristic approach: automatically designing adaptive mutation operators for evolutionary programming. *Complex & Intelligent Systems*, 7(6):3135–3163, 2021. Genetic programming (GP) automatically designs programs. Evolutionary programming (EP) is a real-valued global optimisation method. EP uses a probability distribution as a mutation operator, such as Gaussian, Cauchy, or Levy distribution. This study proposes a hyper-heuristic approach that employs GP to automatically design different mutation operators for EP. At each generation, the EP algorithm can adaptively explore the search space according to historical information. The experimental results demonstrate that the EP with adaptive mutation operators, designed by the proposed hyper-heuristics, exhibits improved performance over other EP versions (both manually and automatically designed). Many researchers in evolutionary computation advocate adaptive search operators (which do adapt over time) over non-adaptive operators (which do not alter over time). The core

motive of this study is that we can automatically design adaptive mutation operators that outperform automatically designed non-adaptive mutation operators. https://link.springer.com/article/10.1007/s40747-021-00507-6.

[95] Zeyu Hou, Wangmei Lao, Yu Wang, and Wenxi Lu. Homotopy-based hyper-heuristic searching approach for reciprocal feedback inversion of groundwater contamination source and aquifer parameters. *Applied Soft Computing*, 104:107191, 2021. Groundwater contamination source identification is critical for taking effective measures to design remediation strategies, assess contamination risks, and confirm contamination responsibilities. To resolve the equifinality problem resulting from simultaneous inversion of contamination source characteristics and aquifer parameters at dense non-aqueous phase liquid-contaminated sites, two reciprocal optimization frames for separately identifying the contamination sources and aquifer parameters were designed and connected. The two sets of identification results were corrected stepwise by means of a feedback correction iteration process, thereby sufficiently improving the identification accuracy. The ensemble learning machine (ESLM) incorporating Kriging, radical basis function neural network, support vector regression, and wavelet kernel extreme learning machine with swarm intelligence (SI) algorithm was embedded into the reciprocal inversion iterations to replace the multiphase flow simulation model for significantly improving the computational efficiency. To improve the optimization efficiency, a hyper-heuristic homotopy algorithm was constructed for segmentally searching the global optimum in wider areas with low dependence on initial values. Results showed that the combined application of SI-based ensemble learning machine (SI-ESLM) and hyper-heuristic homotopy algorithm effectively accomplished the simultaneous identification of contamination sources and aquifer parameters with high efficiency, while maintaining high accuracy. The SI-ESLM sufficiently approximated the outputs of the multiphase flow simulation model with increased certainty (.9977), while the mean relative error was limited to 1.5388%. Compared to traditional heuristic algorithms, this application of reciprocal inversion iterations and the hyper-heuristic homotopy algorithm significantly reduced the mean relative error of identification results from 6.51% to 1.03%. https://www.sciencedirect.com/science/article/abs/pii/S1568494621001149.

[96] Rehab Ali Ibrahim, Mohamed Abd Elaziz, Ahmed A Ewees, Mohammed El-Abd, and Songfeng Lu. New feature selection paradigm based on hyper-heuristic technique. *Applied Mathematical Modelling*, 98:14–37, 2021. Feature selection (FS) is a crucial step for effective data mining since it has largest effect on improving the performance of classifiers. This is achieved by removing the irrelevant features and using only the relevant features. Many metaheuristic approaches exist in the literature in attempt to address this problem. The performance of these approaches differ based on the settings of a number of factors including the use of chaotic maps, opposition-based learning (OBL) and the percentage of the population that OBL will be applied to, the metaheuristic (MH) algo-

rithm adopted, the classifier utilized, and the threshold value used to convert real solutions to binary ones. However, it is not an easy task to identify the best settings for these different components in order to determine the relevant features for a specific dataset. Moreover, running extensive experiments to fine tune these settings for each and every dataset will consume considerable time. In order to mitigate this important issue, a hyper-heuristic based FS paradigm is proposed. In the proposed model, a two-stage approach is adopted to identify the best combination of these components. In the first stage, referred to as the training stage, the Differential Evolution (DE) algorithm is used as a controller for selecting the best combination of components to be used by the second stage. In the second stage, referred to as the testing stage, the received combination will be evaluated using a testing set. Empirical evaluation of the proposed framework is based on numerous experiments performed on the most popular 18 datasets from the UCI machine learning repository. Experimental results illustrates that the generated generic configuration provides a better performance than eight other metaheuristic algorithms over all performance measures when applied to the UCI dataset. Moreover, The overall paradigm ranks at number one when compared against state-of-the-art algorithms. Finally, the generic configuration provides a very competitive performance for high dimensional datasets. `https://doi.org/10.1016/j.apm.2021.04.018`.

[97] Jian-Jiao Ji, Yi-Nan Guo, Xiao-Zhi Gao, Dun-Wei Gong, and Ya-Peng Wang. Q-learning-based hyperheuristic evolutionary algorithm for dynamic task allocation of crowdsensing. *IEEE Transactions on Cybernetics*, 2021. Task allocation is a crucial issue of mobile crowdsensing. The existing crowdsensing systems normally select the optimal participants giving no consideration to the sudden departure of mobile users, which significantly affects the sensing quality of tasks with a long sensing period. Furthermore, the ability of a mobile user to collect high-precision data is commonly treated as the same for different types of tasks, causing the unqualified data for some tasks provided by a competitive user. To address the issue, a dynamic task allocation model of crowdsensing is constructed by considering mobile user availability and tasks changing over time. Moreover, a novel indicator for comprehensively evaluating the sensing ability of mobile users collecting high-quality data for different types of tasks at the target area is proposed. A new Q-learning-based hyperheuristic evolutionary algorithm is suggested to deal with the problem in a self-learning way. Specifically, a memory-based initialization strategy is developed to seed a promising population by reusing participants who are capable of completing a particular task with high quality in the historical optima. In addition, taking both sensing ability and cost of a mobile user into account, a novel comprehensive strength-based neighborhood search is introduced as a low-level heuristic (LLH) to select a substitute for a costly participant. Finally, based on a new definition of the state, a Q-learning-based high-level strategy is designed to find a suitable LLH for each state. Empirical results of 30 static and 20 dynamic experiments expose that this hyperheuris-

tic achieves superior performance compared to other state-of-the-art algorithms. https://ieeexplore.ieee.org/abstract/document/9557762.

[98] Jakob Vigerust Kallestad. Developing an intelligent hyperheuristic for combinatorial optimization problems using deep reinforcement learning. Master's thesis, The University of Bergen, 2021. There exist many problem-specific heuristic frameworks for solving combinatorial optimization problems. These can perform well for specific use-cases, however when applied to other problem domains these frameworks often do not generalize well. Metaheuristic frameworks serve as an alternative that aims to be more generalizable to several problems, yet these frameworks can suffer from poor selection of low-level heuristics during the search. The adaptive layer of the metaheuristic framework of Adaptive Large Neighborhood Search (ALNS) is an example of a heuristic selection mechanism that selects low-level heuristics based on their recent performance during the search. In this thesis, we propose a hyperheuristic selection framework that uses Deep Reinforcement Learning (Deep RL) to more efficiently select heuristics during the search compared to the adaptive layer of ALNS. Our framework uses the representation power of Deep Learning (DL) together with the decision making capability of Deep RL for processing search states (containing useful information of the search) in order to efficiently select heuristics at each step of the search. In this thesis, we introduce Deep Reinforcement Learning Hyperheuristic (DRLH), a general framework for solving combinatorial optimization problems. Our experiments show that DRLH is able to come up with better heuristic selection strategies compared to ALNS and a simple Uniform Random Selection (URS) framework, resulting in better solutions. Additionally, we show that DRLH is not negatively affected by having a large pool of heuristics to choose from, while ALNS does not perform well under these conditions, as it is unable to work efficiently when given a large pool of heuristics to select from. https://bora.uib.no/bora-xmlui/handle/11250/2827078.

[99] Neeti Kashyap, A Charan Kumari, and Rita Chhikara. A hybrid hyper-heuristic flower pollination algorithm for service composition problem in iot. *Recent Advances in Computer Science and Communications (Formerly: Recent Patents on Computer Science)*, 14(6):1962–1973, 2021. Objectives: The modern science applications have non-continuous and multivariate nature due to which the traditional optimization methods suffer a lack of efficiency. Flower pollination is a natural interesting procedure in the real world. The novel optimization algorithms can be designed by employing the evolutionary capability of the flower pollination to optimize resources. Methods: This paper introduces the hybrid algorithm named Hybrid Hyper-Heuristic Flower Pollination Algorithm, HHFPA. It uses a combination of Flower Pollination Algorithm (FPA) and Hyper- Heuristic Evolutionary Algorithm (HypEA). This paper compares the basic FPA with the proposed algorithm named HHFPA. FPA is inspired by the pollination process of flowers whereas the hyper-heuristic evolutionary algorithm operates on the

heuristics search space that contains all the heuristics to find a solution for a given problem. The proposed algorithm is implemented to solve the Quality of Service (QoS) based Service Composition Problem (SCoP) in Internet of Things (IoT). With increasing services with same functionality on the web, selecting a suitable candidate service based on non-functional characteristics such as QoS has become an inspiration for optimization. Results: This paper includes experimental results showing better outcomes to find the best solution using the proposed algorithm as compared to Basic FPA. Conclusion: The empirical analysis also reveals that HHFPA outperformed basic FPA in solving the SCoP with more convergence rates. `https://doi.org/10.2174/2666255813666191220152741`.

[100] Wakas S Khalaf. Ensemble bat algorithm based on hyper heuristic approach for solving unconstrained optimization problems. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 12(10):5466–5478, 2021. Maintaining convergence and diversification in solving optimization is one of the most important challenges facing metaheuristic algorithms in general and the bat algorithm in particular. Many researchers have suggested some improvements to preserve the ability of the algorithm to find good solutions in a timely manner and also to move away as much as possible from landing on the local optimization zone. In this paper, a hyper-heuristic method was proposed to incorporate the behavior of three optimized algorithms from the bat algorithm. The method is based on the distribution of a specific implementation probability for each used algorithm and then updating this probability iteratively according to the results of each algorithm, and then we use random selection to determine the algorithm used in the current iteration. Some nonlinear models proposed in CEC2005 used to compare the efficiency of the proposed algorithm and compare its results with some state-of-the-art algorithms. `https://turcomat.org/index.php/turkbilmat/article/view/5352`.

[101] Ahmed Kheiri, Angeliki Gretsista, Ed Keedwell, Guglielmo Lulli, Michael G Epitropakis, and Edmund K Burke. A hyper-heuristic approach based upon a hidden markov model for the multi-stage nurse rostering problem. *Computers & Operations Research*, 130:105221, 2021. The importance of the nurse rostering problem in complex healthcare environments should not be understated. The nurses in a hospital should be assigned to the most appropriate shifts and days so as to meet the demands of the hospital as well as to satisfy the requirements and requests of the nurses as much as possible. Nurse rostering represents a challenging and demanding combinatorial optimisation problem. To address it, general and efficient methodologies, such as selection hyper-heuristics, have emerged. In this paper, we will consider the multi-stage nurse rostering formulation, posed by the second international nurse rostering competition's problem. We introduce a sequence-based selection hyper-heuristic that utilises a statistical Markov model. The proposed methodology incorporates a dedicated algorithm for building feasible initial solutions and a series of low-level heuristics with different dynamics that

respect the characteristics of the competition's problem formulation. Empirical results and analysis suggest that the proposed approach has significant potential for difficult problem instances. `https://doi.org/10.1016/j.cor.2021.105221`.

[102] Sunil Kumar, Saroj Ratnoo, and Jyoti Vashishtha. Hyper-heuristic evolutionary approach for constructing decision tree classifiers. *Journal of Information and Communication Technology*, 20(2):249–276, 2021. Decision tree models have earned a special status in predictive modeling since these are considered comprehensible for human analysis and insight. Classification and Regression Tree (CART) algorithm is one of the renowned decision tree induction algorithms to address the classification as well as regression problems. Finding optimal values for the hyper parameters of a decision tree construction algorithm is a challenging issue. While making an effective decision tree classifier with high accuracy and comprehensibility, we need to address the question of setting optimal values for its hyper parameters like the maximum size of the tree, the minimum number of instances required in a node for inducing a split, node splitting criterion and the amount of pruning. The hyper parameter setting influences the performance of the decision tree model. As researchers, we know that no single setting of hyper parameters works equally well for different datasets. A particular setting that gives an optimal decision tree for one dataset may produce a sub-optimal decision tree model for another dataset. In this paper, we present a hyper heuristic approach for tuning the hyper parameters of Recursive and Partition Trees (rpart), which is a typical implementation of CART in statistical and data analytics package R. We employ an evolutionary algorithm as hyper heuristic for tuning the hyper parameters of the decision tree classifier. The approach is named as Hyper heuristic Evolutionary Approach with Recursive and Partition Trees (HEARpart). The proposed approach is validated on 30 datasets. It is statistically proved that HEARpart performs significantly better than WEKA's J48 algorithm in terms of error rate, F-measure, and tree size. Further, the suggested hyper heuristic algorithm constructs significantly comprehensible models as compared to WEKA's J48, CART and other similar decision tree construction strategies. The results show that the accuracy achieved by the hyper heuristic approach is slightly less as compared to the other comparative approaches. `https://doi.org/10.32890/jict2021.20.2.5`.

[103] Zheng Liu and Wei Xiong. A dqn-based hyperheuristic algorithm for emergency scheduling of earth observation satellites. In *the 2nd International Conference on Electronics, Communications and Information Technology (CECIT)*, pages 39–47. IEEE, 2021. With the surge of emergency task demand, large-scale Earth observation satellite emergency scheduling has become a practical problem which is urgent to be solved. In view of this situation, this paper analyzes the constrains and conflict relationship in this problem, and proposes a DQN-based hyperheuristic algorithm. The algorithm includes encoding and decoding, deep Q-network and several low-level heuristic operators. A Markov decision model of this problem is

established and 7 low-level heuristic operators are designed according the feature of this problem. After training, DQN behaves well when selecting operators for the scheduling scheme. Finally, several groups of comparative experiments verify the algorithm's ability in solving large-scale satellite emergency scheduling problems. `https://ieeexplore.ieee.org/abstract/document/9742260`.

[104] Teodoro Macias-Escobar, Laura Cruz-Reyes, and Bernabé Dorronsoro. A study on the use of hyper-heuristics based on meta-heuristics for dynamic optimization. In *Fuzzy Logic Hybrid Extensions of Neural and Optimization Algorithms: Theory and Applications*, pages 295–314. Springer, 2021. The study of dynamic multi-objective optimization problems (DMOP) is an area that has recently been receiving increased attention from researchers. Within the literature, various alternatives have been proposed to solve DMOPs, among them are the dynamic multi-objective evolutionary algorithms (DMOEA), which use stochastic methods to obtain solutions close to the optimum. With the constant proposal of new DMOPs with different challenges and properties, as well as DMOEAs to solve them, the issue of determining which alternatives are adequate for each problem arises. Hyper-heuristics are methodologies that use multiple heuristics to solve a problem. This allows them to effectively cover a wider spectrum of characteristics of optimization problems. This advantage also involves DMOPs, since a suitable hyper-heuristic can satisfactorily solve a greater number of problems compared to DMOEAs used individually. This paper presents a guide, as well as a checklist to support researchers in the design of hyper-heuristics to solve DMOPs using DMOEAs as their heuristics. This work also presents two case studies which include state-of-the-art proposals that follow each step of the proposed guide, the obtained results were efficient and satisfactory, which shows the effectiveness of this guide. `https://link.springer.com/chapter/10.1007/978-3-030-68776-2_18`.

[105] Jordan MacLachlan and Yi Mei. Look-ahead genetic programming for uncertain capacitated arc routing problem. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 1872–1879. IEEE, 2021. Genetic Programming Hyper-Heuristic (GPHH) has been successfully applied to evolve routing policies for the Uncertain Capacitated Arc Routing Problem (UCARP). However, the current GPHH approaches have a limitation that they only consider myopic information of the current decision step. In this paper, we proposed incorporating look-ahead information to the decision process of GP-evolved routing policies. We designed a number of potentially promising chains of candidate tasks, and expand the candidate task pool to consider both the single tasks and task chains. This way, the routing policy can consider the look-ahead information incorporated in the considered task chains. The proposed GP with Chain Policies (GPCP) was compared with the standard GPHH on a range of UCARP instances, and the results showed that the task chains can improve the effectiveness of the routing policies sometimes. The better performance of a routing policy largely depends on whether it can balance the selections of single

tasks and task chains, and whether it can stick to the whole selected chain rather than only the first task of the chain. In addition, there are some abnormal runs with serious overfitting issue that we will address in our future work. https://ieeexplore.ieee.org/abstract/document/9504785.

[106] Atiya Masood, Gang Chen, and Mengjie Zhang. Feature selection for evolving many-objective job shop scheduling dispatching rules with genetic programming. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 644–651. IEEE, 2021. SS (Job Shop Scheduling) is a significant and challenging combinatorial optimization issue. Dispatching rules have been successfully used to determine scheduling decisions in the JSS challenges. Genetic programming (GP) has been widely used to discover and develop dispatching rules for various scheduling problems. However, there has been relatively little research into feature selection in GP-HH for many-objective JSS. In many conflicting objective contexts, it's also vital to quantify the contribution of features. This work presents a new two-stage GP-HH methodology for many-objective JSS with feature selection for changing rules. The quality of the solutions (dispatching rules) after incorporating the many-objective algorithm with feature selection is investigated in this paper. On a four-objective JSS problem, the suggested algorithm (FS-GP-NSGA-III) is compared to the standard GP-NSGA-III. The experimental results show that using GP to pick relevant features improves the algorithm's performance. Furthermore, the proposed technique generates rules that are minimal in size and easy to understand. https://ieeexplore.ieee.org/abstract/document/9504895.

[107] Yi Mei, Mazhar Ansari Ardeh, and Mengjie Zhang. Knowledge transfer in genetic programming hyper-heuristics. In *Automated Design of Machine Learning and Search Algorithms*, pages 149–169. Springer, 2021. Genetic Programming Hyper-heuristics (GPHHs) have been successfully applied in various problem domains for automatically designing heuristics such as dispatching rules in scheduling and routing policies in vehicle routing. In the real world, it is normal to encounter related problem domains, such as the vehicle routing problem with different objectives, constraints, and/or graph topology. On one hand, different heuristics are required for different problem domains. On the other hand, the knowledge learned from solving previous related problem domains can be helpful for solving the current one. Most existing studies solve different problem domains in isolation, and train/evolve the heuristic for each of them from scratch. In this chapter, we investigate different mechanisms to improve the effectiveness and efficiency of the heuristic retraining by employing knowledge transfer. Specifically, in the context of GPHH, we explored the following two transfer strategies: (1) useful subtrees and (2) importance of terminals, and verified their effectiveness in a case study of the uncertain capacitated arc routing problem. https://link.springer.com/chapter/10.1007/978-3-030-72069-8_9.

[108] Mustafa Mısır. Algorithm selection on adaptive operator selection: a case study on genetic algorithms. In *International Conference on Learning and Intelligent*

Optimization, pages 237–251. Springer, 2021. The present study applies Algorithm Selection (AS) to Adaptive Operator Selection (AOS) for further improving the performance of the AOS methods. AOS aims at delivering high performance in solving a given problem through combining the strengths of multiple operators. Although the AOS methods are expected to outperform running each operator separately, there is no one AOS method can consistently perform the best. Thus, there is still room for improvement which can be provided by using the best AOS method for each problem instance being solved. For this purpose, the AS problem on AOS is investigated. The underlying AOS methods are applied to choose the crossover operator for a Genetic Algorithm (GA). The Quadratic Assignment Problem (QAP) is used as the target problem domain. For carrying out AS, a suite of simple and easy-to-calculate features characterizing the QAP instances is introduced. The corresponding empirical analysis revealed that AS offers improved performance and robustness by utilizing the strenghts of different AOS approaches. https://link.springer.com/chapter/10.1007/978-3-030-92121-7_20.

[109] Mustafa Mısır. Hyper-heuristics: Autonomous problem solvers. In *Automated Design of Machine Learning and Search Algorithms*, pages 109–131. Springer, 2021. Algorithm design is a general task for any problem-solving scenario. For Search and Optimization, this task becomes rather challenging due to the immense algorithm design space. Those existing design options are usually traversed to devise algorithms by the human algorithm development experts together with the specialists on the target problem domains. The resulting algorithms are mostly problem-specific as they are unable to solve a different problem than the current target. Unlike the traditionally developed algorithms, Hyper-heuristics are known as problem-independent solvers pursuing the grand goal of generality. Generality, in this context, means that effectively solving different problems with a single algorithm under varying experimental conditions. This generality element is chased by performing a high-level search across the algorithm space differently than the majority of the algorithms directly operating on the solution space. In that respect, by design, a hyper-heuristic can be applied to any problem with a search space of quantifiable solutions. This flexibility coming from their easy-to-use nature has been validated in various academic and real-world applications. The present chapter provides a general overview of hyper-heuristics while discussing their shortcomings and recipes for future hyper-heuristic research. https://link.springer.com/chapter/10.1007/978-3-030-72069-8_7.

[110] Seyed Ziae Mousavi Mojab, Seyedmohammad Shams, Farshad Fotouhi, and Hamid Soltanian-Zadeh. Epistonet: An ensemble of deep convolutional neural networks using mixture of discriminative experts for detecting covid-19 on chest x-ray images. *Clinical Cancer Research*, 27(6_Supplement):P05–P05, 2021. The Coronavirus has spread across the globe and infected millions of people, having devastating effect on the global public health and economies. A fast diagnostic system should be implemented to mitigate the impact of the virus and save lives.

In this study, we propose a decision tree-based ensemble model using two mixtures of discriminative experts (MoE) to classify COVID-19 and non-COVID-19 lung infections on chest X-ray images. The Epistocracy algorithm, a hyper-heuristic evolutionary method, is employed to optimize the neural networks used in this work. Using this approach can help detect COVID-19 cases and accelerate treatment of those who need it the most. Data: we collected 2,500 chest X-ray images from Henry Ford Health System consisting of 1,250 Covid images and 1,250 non-Covid images. The input images have been cropped and resized to 224 by 224 pixels. Out of 2,500 images, we left out 500 images containing 250 Covid and 250 non-Covid for testing. The rest, 2,000 images, were used 80% for training and 20% for validation. Methods and Results: To improve the accuracy of the proposed model, first we divided our 2,000 images into 5 different clusters using K-Means clustering algorithm with VGG16 feature extractor to help build strong discriminative expert models to be used in our proposed classifier. We trained VGG16, VGG19, InceptionV3, InceptionResNetV2, MobileNetV2, EfficientNetB7, Xception, and DenseNet201 to classify each cluster into Covid and non-Covid cases. The best result was obtained from VGG16 as a base model with a deep neural network as a head model optimized by Epistocracy algorithm. Then we built a mixture of transfer learning-based experts consisting of 5 different VGG16 models supervised by InceptionV3 as a gating network. Finally, we built a decision tree-based ensemble model to determine the classification of the data using two different MoEs with highest accuracies. As a result, for initial clusters c1, c2, c3, c4, and c5 we obtained validation accuracy of 92.50%, 86.30%, 86.51%, 85.34%, and 93.62% respectively. The first MoE had 93.75% accuracy on validation, and the second MoE had 94.25%. The final ensemble model on average obtained 94% accuracy on the testing dataset. More specifically, we got 96% accuracy on Covid images and 92% accuracy on non-Covid. Conclusion: we showed that an ensemble model consisting of two mixtures of cluster-based discriminative convolutional neural network experts can be used to detect Covid from non-Covid with high accuracy, and Epistocracy algorithm can be effectively used to optimize the hyper-parameters of the proposed models. `https://aacrjournals.org/clincancerres/article/27/6_Supplement/P05/671853/Abstract-P05-EpistoNet-An-ensemble-of-deep`.

[111] Seyed Ziae Mousavi Mojab, Seyedmohammad Shams, Hamid Soltanian-Zadeh, and Farshad Fotouhi. Epistocracy algorithm: A novel hyper-heuristic optimization strategy for solving complex optimization problems. *arXiv preprint arXiv:2102.00292*, 2021. This paper proposes a novel evolutionary algorithm called Epistocracy which incorporates human socio-political behavior and intelligence to solve complex optimization problems. The inspiration of the Epistocracy algorithm originates from a political regime where educated people have more voting power than the uneducated or less educated. The algorithm is a self-adaptive, and multi-population optimizer in which the evolution process takes place in parallel for many populations led by a council of leaders. To avoid stagnation in poor

local optima and to prevent a premature convergence, the algorithm employs multiple mechanisms such as dynamic and adaptive leadership based on gravitational force, dynamic population allocation and diversification, variance-based step-size determination, and regression-based leadership adjustment. The algorithm uses a stratified sampling method called Latin Hypercube Sampling (LHS) to distribute the initial population more evenly for exploration of the search space and exploitation of the accumulated knowledge. To investigate the performance and evaluate the reliability of the algorithm, we have used a set of multimodal benchmark functions, and then applied the algorithm to the MNIST dataset to further verify the accuracy, scalability, and robustness of the algorithm. Experimental results show that the Epistocracy algorithm outperforms the tested state-of-the-art evolutionary and swarm intelligence algorithms in terms of performance, precision, and convergence. `https://arxiv.org/abs/2102.00292`.

[112] Seyed Ziae Mousavi Mojab, Seyedmohammad Shams, Farshad Fotouhi, and Hamid Soltanian-Zadeh. Epistonet: an ensemble of epistocracy-optimized mixture of experts for detecting covid-19 on chest x-ray images. *Scientific Reports*, 11(1):1–13, 2021. The Coronavirus has spread across the world and infected millions of people, causing devastating damage to the public health and global economies. To mitigate the impact of the coronavirus a reliable, fast, and accurate diagnostic system should be promptly implemented. In this study, we propose EpistoNet, a decision tree-based ensemble model using two mixtures of discriminative experts to classify COVID-19 lung infection from chest X-ray images. To optimize the architecture and hyper-parameters of the designed neural networks, we employed Epistocracy algorithm, a recently proposed hyper-heuristic evolutionary method. Using 2500 chest X-ray images consisting of 1250 COVID-19 and 1250 non-COVID-19 cases, we left out 500 images for testing and partitioned the remaining 2000 images into 5 different clusters using K-means clustering algorithm. We trained multiple deep convolutional neural networks on each cluster to help build a mixture of strong discriminative experts from the top-performing models supervised by a gating network. The final ensemble model obtained 95% accuracy on COVID-19 images and 93% accuracy on non-COVID-19. The experimental results show that EpistoNet can accurately, and reliably be used to detect COVID-19 infection in the chest X-ray images, and Epistocracy algorithm can be effectively used to optimize the hyper-parameters of the proposed models. `https://www.nature.com/articles/s41598-021-00524-y`.

[113] Seyed Ziae Mousavi Mojab, Seyedmohammad Shams, Hamid Soltanian-Zadeh, and Farshad Fotouhi. Epistocracy algorithm: A novel hyper-heuristic optimization strategy for solving complex optimization problems. In *Intelligent Computing*, pages 408–426. Springer, 2021. This paper proposes a novel evolutionary algorithm called Epistocracy which incorporates human socio-political behavior and intelligence to solve complex optimization problems. The inspiration of the Epistocracy algorithm originates from a political regime where educated

people have more voting power than the uneducated or less educated. The algorithm is a self-adaptive, and multi-population optimizer in which the evolution process takes place in parallel for many populations led by a council of leaders. To avoid stagnation in poor local optima and to prevent a premature convergence, the algorithm employs multiple mechanisms such as dynamic and adaptive leadership based on gravitational force, dynamic population allocation and diversification, variance-based step-size determination, and regression-based leadership adjustment. The algorithm uses a stratified sampling method called Latin Hypercube Sampling (LHS) to distribute the initial population more evenly for exploration of the search space and exploitation of the accumulated knowledge. To investigate the performance and evaluate the reliability of the algorithm, we have used a set of multimodal benchmark functions, and then applied the algorithm to the MNIST dataset to further verify the accuracy, scalability, and robustness of the algorithm. Experimental results show that the Epistocracy algorithm outperforms the tested state-of-the-art evolutionary and swarm intelligence algorithms in terms of performance, precision, and convergence. `https://link.springer.com/chapter/10.1007/978-3-030-80126-7_31`.

[114] Felipe Martins Müller and Iaê Santos Bonilha. Hyper-heuristic based on aco and local search for dynamic optimization problems. *Algorithms*, 15(1):9, 2021. Hyper-heuristics comprise a set of approaches that are motivated (at least in part) by the objective of intelligently combining heuristic methods to solve hard optimization problems. Ant colony optimization (ACO) algorithms have been proven to deal with Dynamic Optimization Problems (DOPs) properly. Despite the good results obtained by the integration of local search operators with ACO, little has been done to tackle DOPs. In this research, one of the most reliable ACO schemes, the MAX-MIN Ant System (MMAS), has been integrated with advanced and effective local search operators, resulting in an innovative hyper-heuristic. The local search operators are the Lin-Kernighan (LK) and the Unstringing and Stringing (US) heuristics, and they were intelligently chosen to improve the solution obtained by ACO. The proposed method aims to combine the adaptation capabilities of ACO for DOPs and the good performance of the local search operators chosen in an adaptive way and based on their performance, creating in this way a hyper-heuristic. The travelling salesman problem (TSP) was the base problem to generate both symmetric and asymmetric dynamic test cases. Experiments have shown that the MMAS provides good initial solutions to the local search operators and the hyper-heuristic creates a robust and effective method for the vast majority of test cases. `https://www.mdpi.com/1999-4893/15/1/9`.

[115] Samina Naz, Hammad Majeed, and Farrukh Aslam Khan. Memory augmented hyper-heuristic framework to solve multi-disciplinary problems inspired by cognitive problem solving skills. *Neural Computing and Applications*, 33(4):1367–1378, 2021. This paper proposes a new framework, named Deja-Vu+, which is an extension of Deja Vu framework, a classic study on hyper-heuristic frame-

work with 2R (Record and Recall) modules. Deja-Vu+ has the ability to handle two other domains, namely regression and unsupervised learning. The extension examines the strength of Deja-Vu+ for solving regression and unsupervised learning tasks. The regression problems are treated here as multiclass classification tasks, and unsupervised learning tasks are considered as clustering problems. The proposed framework is tested on a number of regression and unsupervised learning benchmark problems and has shown promising results to handle regression as classification. The framework attains an overall average accuracy of 70% for regression and clustering data sets. Deja-Vu+ is knowledge-rich hyper-heuristic framework, which is capable enough to transfer knowledge successfully. This knowledge transfer improves the performance of learning by avoiding the extensive heuristic search process. Our experimental results show that using previously attained knowledge to reduce the computational effort is beneficial in solving multi-disciplinary machine learning problems. `https://link.springer.com/article/10.1007/s00521-020-05016-0`.

[116] Lanang Alun Nugraha. Optimasi travelling thief problem menggunakan algoritma tree physiology optimization berbasis hiper heuristik. *JATISI (Jurnal Teknik Informatika dan Sistem Informasi)*, 8(4):1810–1820, 2021. Traveling thief problem is a combination of the traveling salesman problem and the knapsack problem. Traveling thief problem itself is an NP-Hard problem, so most of the problems are solved using a heuristic algorithm and it continues to grow over time. The algorithm used in this study is simple random for the selection of low level heuristics (LLH) and tree physiology optimization (TPO) for the move acceptance step using the Hyper-Heuristics model. In previous research, the TPO algorithm is able to produce competitive values with good computation time, while Hyper-Heuristics modeling can produce consistent values on various data. The research was started by modeling the TPO algorithm into Hyper-Heuristics and tested it with data from TSPLib. From the results of the trials conducted, it can be seen how the performance of the new algorithm on the data being tested. Based on the results obtained from this study, it can be concluded that the LLH TPO algorithm can process TTP data with sizes below 100 quite well, as evidenced by better results than the previous genetic programming based hyper-heuristic (GPHS) method, but the data above 100 LLH TPO performance decreased when compared to the GPHS method. `https://jurnal.mdp.ac.id/index.php/jatisi/article/view/1167`.

[117] Frumen Olivas, Ivan Amaya, José Carlos Ortiz-Bayliss, Santiago E Conant-Pablos, and Hugo Terashima-Marín. Enhancing hyperheuristics for the knapsack problem through fuzzy logic. *Computational Intelligence and Neuroscience*, 2021, 2021. Hyperheuristics rise as powerful techniques that get good results in less computational time than exact methods like dynamic programming or branch and bound. These exact methods promise the global best solution, but with a high computational time. In this matter, hyperheuristics do not promise the global

best solution, but they promise a good solution in a lot less computational time. On the contrary, fuzzy logic provides the tools to model complex problems in a more natural way. With this in mind, this paper proposes a fuzzy hyperheuristic approach, which is a combination of a fuzzy inference system with a selection hyperheuristic. The fuzzy system needs the optimization of its fuzzy rules due to the lack of expert knowledge; indeed, traditional hyperheuristics also need an optimization of their rules. The fuzzy rules are optimized by genetic algorithms, and for the rules of the traditional methods, we use particle swarm optimization. The genetic algorithm will also reduce the number of fuzzy rules, in order to find the best minimal fuzzy rules, whereas traditional methods already use very few rules. Experimental results show the advantage of using our approach instead of a traditional selection hyperheuristic in 3200 instances of the 0/1 knapsack problem. `https://www.hindawi.com/journals/cin/2021/8834324/`.

[118] Pietro S Oliveto. Rigorous performance analysis of hyper-heuristics. In *Automated Design of Machine Learning and Search Algorithms*, pages 45–71. Springer, 2021. We provide an overview of the state-of-the-art in the time complexity analysis of selection hyper-heuristics for combinatorial optimisation. These algorithms aim at automating the optimisation process by using a set of low-level heuristics and a machine learning mechanism to decide online which heuristic is the most appropriate one at the current stage. We mainly focus on work that establishes the performance gains that simple and sophisticated hyper-heuristics can achieve compared to the low-level heuristics applied in isolation, and that compares the expected runtime of the hyper-heuristics against the best possible one achievable with the given set of low-level heuristics. We cover examples where mixing heuristics is necessary, as well as others where learning from the past performance of the applied heuristics is crucial for the algorithms to be efficient. We emphasise that simple and sophisticated hyper-heuristics from the literature can achieve optimal performance for some standard unimodal and multimodal benchmark functions. Problem characteristics are highlighted for which more or less machine learning sophistication is required, and insights are provided of how a rigorous theory can guide the design of more efficient hyper-heuristics. `https://link.springer.com/chapter/10.1007/978-3-030-72069-8_4`.

[119] Jia Hui Ong and Jason Teo. Systematic review and open challenges in hyper-heuristics usage on expensive optimization problems with limited number of evaluations. In *2021 IEEE Symposium on Industrial Electronics & Applications (ISIEA)*, pages 1–6. IEEE, 2021. Ever since the early introduction of optimization by Kantorovich in 1939 the science and engineering researchers have created vast categories of optimization problems. Throughout the years, these optimization problems moved from classical problems to more challenging complex problems and these transformations were direct results of industrials demands. Consequently, this has given rise to one of the new classes of challenging optimization problems known as expensive optimization. A prob-

lem is considered expensive when it involves very high computational costs due to the complex evaluations of high-dimensional and time-consuming objective functions. In this paper, the past researches that were done in this new research domain are presented followed by a discussion of the hyper-heuristics history and how hyper-heuristics is used in solving expensive optimization problems especially in expensive optimization with a limited number of evaluations. `https://ieeexplore.ieee.org/abstract/document/9509993`.

[120] Lucero Ortiz-Aguilar, Martín Carpio, Alfonso Rojas-Domínguez, Manuel Ornelas-Rodriguez, HJ Puga-Soberanes, and Jorge A Soria-Alcaraz. A methodology to determine the subset of heuristics for hyperheuristics through metalearning for solving graph coloring and capacitated vehicle routing problems. *Complexity*, 2021, 2021. In this work, we focus on the problem of selecting low-level heuristics in a hyperheuristic approach with offline learning, for the solution of instances of different problem domains. The objective is to improve the performance of the offline hyperheuristic approach, identifying equivalence classes in a set of instances of different problems and selecting the best performing heuristics in each of them. A methodology is proposed as the first step of a set of instances of all problems, and the generic characteristics of each instance and the performance of the heuristics in each one of them are considered to define the vectors of characteristics and make a grouping of classes. Metalearning with statistical tests is used to select the heuristics for each class. Finally, we used the Naive Bayes to test the set instances with k-fold cross-validation, and we compared all results statistically with the best-known values. In this research, the methodology was tested by applying it to the problems of capacitated vehicle routing (CVRP) and graph coloring (GCP). The experimental results show that the proposed methodology can improve the performance of the offline hyperheuristic approach, correctly identifying the classes of instances and applying the appropriate heuristics in each case. This is based on the statistical comparison of the results obtained with those of the state of the art of each instance. `https://www.hindawi.com/journals/complexity/2021/6660572/`.

[121] Paola P Oteiza, Juan I Ardenghi, and Nélida B Brignole. Parallel hyper-heuristics for process engineering optimization. *Computers & Chemical Engineering*, 153:107440, 2021. This paper presents the general framework of a parallel cooperative hyper-heuristic optimizer (PCHO) to solve systems of nonlinear algebraic equations with equality and inequality constraints. The algorithm comprises the classical metaheuristics called Genetic Algorithms, Simulated Annealing and Particle Swarm Optimization, whose parameters are adaptively chosen during the executions. A Master-Worker architecture was designed and implemented, where the Master processor ranks the solution candidates informed by the metaheuristics and immediately communicates the most promising candidate to update all Workers. Algorithmic performance was tested with general models, most of them corresponding to PSE process systems. The results confirmed the efficiency of the

proposed approach since both online parameter retuning and parallel processing sped up the search. https://www.sciencedirect.com/science/article/abs/pii/S0098135421002180.

[122] Imen Oueslati and Moez Hammami. Honey bee cooperative hyperheuristic. *Procedia Computer Science*, 192:2871–2880, 2021. Hyperheuristics form a new concept that provides a more general procedure for optimization. Their goal is to manage existing low-level heuristics to solve a large number of problems without specific parameter tuning. In this paper, we propose three hyperheuristics based on honey bees behaviour: Bee colony optimization HyperHeuristic BCOH2, Honey bee Mating Optimization HyperHeuristic HBMOH2 and Honey Bee Cooperative HyperHeuristic HBCH2 which cooperates between the two mentioned hyperheuristics. The proposed hyperheuristics are implemented under the Hyflex platform. Tested on the MAX-SAT and the Bin Packing problems, our algorithms showed good results compared to hyperheuristics participating in the CHeSC competition [13]. https://doi.org/10.1016/j.procs.2021.09.058.

[123] Fehmi Burcin Ozsoydan and Müjgan Sağir. Iterated greedy algorithms enhanced by hyper-heuristic based learning for hybrid flexible flowshop scheduling problem with sequence dependent setup times: a case study at a manufacturing plant. *Computers & operations research*, 125:105044, 2021. Metaheuristic algorithms offer unique opportunities in problem solving. Although they do not guarantee optimality, it has been shown by numerous publications that they can achieve excellent results in acceptable time. Particularly in real-life production systems, which are mostly comprised of complex discrete optimization problems, the merit should be finding appropriate and efficient solutions in shorter periods rather than waiting for the optimum solution in whole shift. Accordingly, this paper presents a learning iterated greedy search metaheuristic to minimize the maximum completion time in a hybrid flexible flowshop problem with sequence dependent setup times encountered at a manufacturing plant. The proposed algorithm is comprised of four main phases. The first phase employs NEH heuristic to generate an initial solution. Additionally, in order to introduce diversity, some replications are occasionally allowed to start with random solutions. Destruction mechanism to perturb the current solution is used in the next phase. It is followed by a construction procedure, which is used to repair the partial solution obtained after destruction. Finally, a descent neighborhood search enhanced by a hyper-heuristic based learning is applied to the repaired solution in the fourth phase. Thus, algorithm adaptively learns and promotes the most efficient low-level heuristic out of a heuristics pool and encourages the metaheuristic algorithm in using the promoted low-level heuristic in the final phase. The proposed algorithm along with its several extensions is tested by using real data taken from the mentioned production system. Next, by making use of the same data, the developed algorithms are also compared to eight different algorithms, which are shown to be promising in the related literature. Finally, appropriate statistical tests are

applied to demonstrate possible significant improvements among all tested algorithms. https://doi.org/10.1016/j.cor.2020.105044.

[124] Venkatesh Pandiri and Alok Singh. A simple hyper-heuristic approach for a variant of many-to-many hub location-routing problem. *Journal of Heuristics*, 27(5):791–868, 2021. This paper addresses a variant of the many-to-many hub location-routing problem. Given an undirected edge-weighted complete graph G=(V,E), this problem consists in finding a subset of V designated as hub nodes, partitioning all the nodes of V into cycles such that each cycle has exactly one hub node, and determining a Hamiltonian cycle on the subgraph induced by hub nodes. The objective is to minimize the total cost resulting from all these cycles. This problem is referred to as Many-to-Many p-Location-Hamiltonian Cycle Problem (MMpLHP) in this paper. To solve this problem, one has to deal with aspects of subset selection, grouping, and permutation. The characteristics of MMpLHP change according to the values of its constituent parameters. Hence, this problem can be regarded as a general problem which encompasses a diverse set of problems originating from different combinations of values of its constituent parameters. Such a general problem can be tackled effectively by suitably selecting and combining several different heuristics each of which cater to a different characteristic of the problem. Keeping this in mind, we have developed a simple multi-start hyper-heuristic approach for MMpLHP. Further, we have investigated two different selection mechanisms within the proposed approach. Experimental results and their analysis clearly demonstrate the superiority of our approach over best approaches known so far for this problem. https://link.springer.com/article/10.1007/s10732-021-09477-x.

[125] Lie Meng Pang, Hisao Ishibuchi, and Ke Shang. Using a genetic algorithm-based hyper-heuristic to tune moea/d for a set of benchmark test problems. In *International Conference on Evolutionary Multi-Criterion Optimization*, pages 164–177. Springer, 2021. The multi-objective evolutionary algorithm based on decomposition (MOEA/D) is one of the most popular algorithms in the EMO community. In the last decade, the high performance of MOEA/D has been reported in many studies. In general, MOEA/D needs a different implementation for a different type of problems with respect to its components such as a scalarizing function, a neighborhood structure, a normalization mechanism and genetic operators. For MOEA/D users who do not have the in-depth knowledge about the algorithm, it is not easy to implement an appropriate algorithm that is suitable for their problems at hand. In our previous studies, we have suggested an offline genetic algorithm-based hyper-heuristic method to tune MOEA/D for a single problem. However, in real-world situations, users may want to use an algorithm with robust performance over many problems. In this paper, we improve the offline genetic algorithm-based hyper-heuristic method for tuning a set of problems. The offline hyper-heuristic procedure is applied to 26 benchmark test problems. The obtained MOEA/D implementations are compared with six decomposition-

based EMO algorithms. The experimental results show that the tuned MOEA/D outperformed the compared algorithms on many test problems. The tuned MOEA/D also shows good (and stable) performance over a set of test problems. `https://link.springer.com/chapter/10.1007/978-3-030-72062-9_14`.

[126] Lie Meng Pang, Hisao Ishibuchi, and Ke Shang. Using a genetic algorithm-based hyper-heuristic to tune moea/d for a set of various test problems. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 1486–1494. IEEE, 2021. The multi-objective evolutionary algorithm based on decomposition (MOEA/D) is one of the most popular algorithms in the field of evolutionary multi-objective optimization (EMO). Even though MOEA/D has been widely used in many studies, it is likely that the performance of MOEA/D is not always optimized since the same MOEA/D implementation is often used on various problems with different characteristics. However, obtaining an appropriate implementation of MOEA/D for a different problem is not always easy, since there exists a wide variety of choices for the components and parameters in MOEA/D. In this paper, we examine the use of a genetic algorithm-based hyper-heuristic procedure to offline tune MOEA/D on a single test problem, a set of similar test problems, and a set of various test problems. A total of 26 benchmark test problems are used in our study. Experimental results show that the MOEA/D tuned for a set of various test problems does not always perform well. It is also shown that the MOEA/D tuned for a single test problem and for a set of similar test problems always has high performance. Our experimental results strongly suggest the necessity of using a tuning procedure to obtain a different MOEA/D implementation for a different type of problems. `https://ieeexplore.ieee.org/abstract/document/9504748`.

[127] Lucas Marcondes Pavelski, Marie-Eleonore Kessaci, and Myriam Delgado. Dynamic learning in hyper-heuristics to solve flowshop problems. In *Brazilian Conference on Intelligent Systems*, pages 155–169. Springer, 2021. Hyper-heuristics (HHs) are algorithms suitable for designing heuristics. HHs perform the search divided in two levels: they look for heuristic components in the high level and the heuristic is used, in the low level, to solve a set of instances of one or more problems. Different from offline HHs, hyper-heuristics with dynamic learning select or generate heuristics during the search. This paper proposes a hyper-heuristic associated with a dynamic learning strategy for selecting Iterated Greedy (IG) components. The proposal is capable of selecting appropriate values for six IG components: local search, perturbation, destruction size, neighborhood size, destruction position and local search focus. The proposed HH is tested with six dynamic adaptation strategies: random, epsilon-greedy, probability matching, multi-armed bandit, LinUCB, and Thompson Sampling (TS). The hyper-parameters of each strategy are tuned by irace. As a testbed, we use several instances with four different sizes (20, 50, 100 and 200 jobs) of three different formulations of flowshop problems (permutation, no-wait, no-idle), two distinct objectives (makespan, flowtime), and four processing time distributions (uni-

form, exponential and job or machine correlated). The results show that different strategies are most suitable for adapting different IG components, TS performs quite well for all components and, except for local search, using adaptation is always beneficial when compared with the IG running with standard parameters. `https://link.springer.com/chapter/10.1007/978-3-030-91702-9_11`.

[128] Nelishia Pillay and Rong Qu. *Automated Design of Machine Learning and Search Algorithms.* Springer, 2021. This book presents recent advances in automated machine learning (AutoML) and automated algorithm design and indicates the future directions in this fast-developing area. Methods have been developed to automate the design of neural networks, heuristics and metaheuristics using techniques such as metaheuristics, statistical techniques, machine learning and hyper-heuristics. The book first defines the field of automated design, distinguishing it from the similar but different topics of automated algorithm configuration and automated algorithm selection. The chapters report on the current state of the art by experts in the field and include reviews of AutoML and automated design of search, theoretical analyses of automated algorithm design, automated design of control software for robot swarms, and overfitting as a benchmark and design tool. Also covered are automated generation of constructive and perturbative low-level heuristics, selection hyper-heuristics for automated design, automated design of deep-learning approaches using hyper-heuristics, genetic programming hyper-heuristics with transfer knowledge and automated design of classification algorithms. The book concludes by examining future research directions of this rapidly evolving field. The information presented here will especially interest researchers and practitioners in the fields of artificial intelligence, computational intelligence, evolutionary computation and optimisation. `https://link.springer.com/book/10.1007/978-3-030-72069-8`.

[129] I Gusti Agung Premananda and Ahmad Muklason. Complex university timetabling using iterative forward search algorithm and great deluge algorithm. *Khazanah Informatika: Jurnal Ilmu Komputer dan Informatika*, 7(2):39–46, 2021. University timetabling is an issue that has received more attention in the field of operations research. Course scheduling is the process of arranging time slots and room for a class by paying attention to existing limitations. This problem is an NP-Hard problem, which means the computation time to find a solution increases exponentially with the size of the problem. Solutions to problems of this kind generally use a heuristic approach, which tries to find a sufficiently good (not necessarily optimal) solution in a reasonable time. We go through two stages in solving the timetabling problem. The first stage is to schedule all classes without breaking any predefined rules. The second stage optimizes the timetable generated in the first stage. This study attempts to solve the class timetabling problem issued in a competition called the 2019 International Timetabling Competition (ITC 2019). In the first stage, we use the Iterative Forward Search (IFS) algorithm to eliminate timetable candidates and to generate

a schedule. In the second stage, we employ the Great Deluge algorithm with a hyper-heuristic approach to optimize the solution produced in the first stage. We have tested the method using 30 datasets by taking 1,000,000 iterations on each dataset. The result is an application that does schedule elimination and uses the IFS algorithm to produce a schedule that does not violate any of the hard constraints on 30 ITC 2019 datasets. The implementation of the Great Deluge algorithm optimizes existing schedules with an average penalty reduction of 42%. `https://journals.ums.ac.id/index.php/khif/article/view/12879`.

[130] Wei Qin, Zilong Zhuang, Zizhao Huang, and Haozhe Huang. A novel reinforcement learning-based hyper-heuristic for heterogeneous vehicle routing problem. *Computers & Industrial Engineering*, 156:107252, 2021. This study investigates a practical heterogeneous vehicle routing problem that involves routing a predefined fleet with different vehicle capacities to serve a series of customers to minimize the maximum routing time of vehicles. The comprehensive utilization of different types of vehicles brings great challenges for problem modeling and solving. In this study, a mixed-integer linear programming (MILP) model is formulated to obtain optimal solutions for small-scale problems. To further improve the quality of solutions for large-scale problems, this study develops a reinforcement learning-based hyper-heuristic, which introduces several meta-heuristics with different characteristics as low-level heuristics and policy-based reinforcement learning as a high-level selection strategy. Moreover, deep learning is used to extract hidden patterns within the collected data to combine the advantages of low-level heuristics better. Numerical experiments have been conducted and results indicate that the proposed algorithm exceeds the MILP solution on large-scale problems and outperforms the existing meta-heuristic algorithms. `https://doi.org/10.1016/j.cie.2021.107252`.

[131] Abdolreza Rasouli Kenari and Mahboubeh Shamsi. A hyper-heuristic selector algorithm for cloud computing scheduling based on workflow features. *OPSEARCH*, 58(4):852–868, 2021. This study focuses on the presentation of a new algorithm for scheduling workflows on heterogeneous distributed systems such as cloud computing. Since heterogeneous distributed systems deal with different types of resources, scheduling of applications on cloud resources plays an important role in the computing environment. Due to being heterogeneous and dynamic properties of resources as well as large numbers of tasks with different characteristics and dependencies among tasks, scheduling tasks on cloud computing is referred to as an NP-hard problem. Heuristic methods are one of the common approaches to solve this problem. Heuristic algorithms according to the specifications of resources and workflow structure could be superior to the rule-based methods. However, it is difficult to define which heuristic algorithm is performed better than the rest. Therefore, the choice of appropriate heuristic algorithms based on the circumstances can be effective. Moreover, the hyper-heuristic algorithm obtains higher performance. In this study, a new method is presented to im-

prove the Hyper-Heuristic Scheduling Algorithm for the cloud using the decision tree method to select a convenient heuristic algorithm based on the characteristics of resources and workflows by considering evaluation criteria such as cost and Makespan. Finally, the presented algorithm is evaluated by Workflowsim and using RapidMiner. The simulation results demonstrate that our proposed algorithm outperforms existing approaches in terms of Makespan and Accuracy. `https://link.springer.com/article/10.1007/s12597-021-00508-6`.

[132] Shof Rijal Ahlan Robbani. Penyelesaian urban transit routing problem menggunakan algoritma hyper-heuristics berbasis modified particle swarm optimization based on gravitational field interactions. *JATISI (Jurnal Teknik Informatika dan Sistem Informasi)*, 8(4):1984–1997, 2021. Traffic congestion can be overcome by public transport. The optimal implementation of public transport is necessary to determine a best route. To get optimal route of public transport, it is necessary to do some combination experiments between the distance from the starting point and the destination. So that the problem can be said as a combinatoric problem. VRP is a combinatoric problem. Therefore, the problem can use a metaheuristic method. In this studies, Modified Particle Swarm Optimization algorithm with a Hyper-heuristic approach used to solve problem public transport routes. Data used is the Mumford and Mandl dataset used in several previous studies. Research was conducted by comparing results of the solutions generated by proposed methods with results of previous studies. Therefore, can find out the advantages and disadvantages of proposed methods. Based on this studies, MPSO-GI algorithm with the Hyper-Heuristics approach can be implemented and solve an UTRP. MPSO-GI algorithm with Hyper-Heuristics approach succeeded in improving hill-climbing solutions in almost all datasets with stable values. MPSO-GI algorithm with the Hyper-Heuristics approach are superior in producing passenger cost solutions on the Mandl4, Mandl6, Mandl7, Mandl8 datasets and operator costs on the Mandl4 and Mandl6 datasets when compared to previous studies. `https://doi.org/10.35957/jatisi.v8i4.1233`.

[133] Sergey Rodzin and Lada Rodzina. Hyper-heuristics: Method of differential evolution and bat method for selecting classification features. In *Computer Science On-line Conference*, pages 545–556. Springer, 2021. The paper proposes a hyper-heuristic GEBA algorithm for selecting significant classification features and evaluating the classification accuracy. The GEBA algorithm combines the bat echolocation algorithm and a modified version of the differential evolution algorithm. The experiments used the well-known k nearest neighbor classifier (KNN) and the decision tree-based classifier (CART). The effectiveness of the proposed GEBA algorithm was evaluated using a set of reference data sets from the UCI world library. The performance of the GEBA algorithm for solving the problem of selecting significant classification features was compared with the competing algorithms of bats, crows, and gray wolves, and the hybrid algorithm of particle swarm and gravity search. The proposed algorithm leads in the av-

erage and best values of the fitness function for most of the tested data sets and is also statistically significant compared to competing algorithms for the Wilcoxon T-test and the Friedman test with a confidence level of 0.95. The stability and accuracy of the GEBA algorithm are higher than that of competing algorithms on most reference datasets. A comparative analysis of the convergence rate of algorithms on a set of reference data sets for a given number of iterations showed that the GEBA algorithm converges faster to global optima than competing algorithms. The algorithm is planned to be used for solving traveling salesman problems, integer programming and minimax problems, medical image segmentation problems, and multidimensional optimization problems. https://link.springer.com/chapter/10.1007/978-3-030-77445-5_50.

[134] Melissa Sánchez, Jorge M Cruz-Duarte, José C Ortiz-Bayliss, and Ivan Amaya. Sequence-based selection hyper-heuristic model via map-elites. *IEEE Access*, 9:116500–116527, 2021. Although the number of solutions in combinatorial optimization problems (COPs) is finite, some problems grow exponentially and render exact approaches unfeasible. So, approximate methods, such as heuristics, are customary. Each heuristic usually specializes in specific kinds of problems. Hence, other approaches seek to merge their strengths. One of them is selection hyper-heuristics. However, they usually provide scarce information about their sensitivity. Illumination algorithms may fix this issue since they focus on exploration rather than exploitation while preserving the best solutions under different criteria. Still, literature falls short when merging both approaches, representing a knowledge gap. This work tests the feasibility of using an illumination algorithm, MAP-Elites (ME), for tuning a sequence-based selection hyper-heuristic model for Balanced Partition problems. We choose ME since other researchers have successfully applied it to a different COP. So, we may achieve a hyper-heuristic that represents the best combination of heuristics while simultaneously gaining intel on the performance of diverse alternatives. Our approach operates by creating a multi-dimensional map, where each design variable represents the application of a heuristic. Afterward, ME generates mutated sequences and tests them to determine if they represent a better-performing solution. We consider 1500 instances that include easy and hard instances, analyzed under different scenarios to test our approach. We also include limit instances that are neither easy nor hard. Our resulting data support the proposed approach, as it performs toe-to-toe with a synthetic oracle and may even outperform it. This represents an outstanding result, since a brute-force approach is needed to achieve such an oracle. So, merging ME and hyper-heuristics is a path worth pursuing. We also present how each parameter affects the model performance and identify the critical and virtually irrelevant ones. This serves as the groundwork for future works that focus on exploiting the most relevant parameters. https://ieeexplore.ieee.org/abstract/document/9520416.

[135] Xavier Sanchez-Diaz, Jose Carlos Ortiz-Bayliss, Ivan Amaya, Jorge M Cruz-

Duarte, Santiago Enrique Conant-Pablos, and Hugo Terashima-Marin. A feature-independent hyper-heuristic approach for solving the knapsack problem. *Applied Sciences*, 11(21):10209, 2021. Recent years have witnessed a growing interest in automatic learning mechanisms and applications. The concept of hyper-heuristics, algorithms that either select among existing algorithms or generate new ones, holds high relevance in this matter. Current research suggests that, under certain circumstances, hyper-heuristics outperform single heuristics when evaluated in isolation. When hyper-heuristics are selected among existing algorithms, they map problem states into suitable solvers. Unfortunately, identifying the features that accurately describe the problem state-and thus allow for a proper mapping-requires plenty of domain-specific knowledge, which is not always available. This work proposes a simple yet effective hyper-heuristic model that does not rely on problem features to produce such a mapping. The model defines a fixed sequence of heuristics that improves the solving process of knapsack problems. This research comprises an analysis of feature-independent hyper-heuristic performance under different learning conditions and different problem sets. `https://doi.org/10.3390/app112110209`.

[136] Fabian Schäfer, Manuel Walther, Dominik G Grimm, and Alexander Hübner. Combining machine learning and optimization for the operational patient-bed assignment problem. *Available at SSRN*, 2021. This paper develops a multi-objective decision support model for solving the patient bed assignment problem. Assigning inpatients to hospital beds impacts patient satisfaction and the workload of nurses and doctors. The assignment is subject to unknown patient arrivals and lengths of stay, in particular for emergency patients. Hospitals therefore need to deal with uncertainty on actual bed requirements and potential shortage situations as bed capacities are limited. This paper contributes by improving the anticipation of emergency patients using machine learning (ML) approaches, incorporating weather data, time and dates, important local and regional events, as well as current and historical occupancy levels. Drawing on real-life data from a large case hospital, we were able to improve forecasting accuracy for emergency inpatient arrivals. We achieved an up to 17% better root mean square error when using ML methods compared to a baseline approach relying on averages for historical arrival rates. Second, we develop a new hyper-heuristic for solving real-life problem instances based on the pilot method and a specialized greedy look-ahead heuristic. When applying the hyper-heuristic in test sets we were able to increase the objective function by up to 3% in a single problem instance and up to 4% in a time series analysis compared to current approaches in literature. We achieved an improvement of up to 2.2% compared to a baseline approach from literature by combining the emergency patient admission forecasting and the hyper-heuristic on real-life situations. `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3919282`.

[137] Darius Scheepers and Nelishia Pillay. A study of transfer learning in a gen-

eration constructive hyper-heuristic for one dimensional bin packing. In *IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–7. IEEE, 2021. The research presented in this paper investigates the use of transfer learning in a genetic programming generation constructive hyper-heuristic for discrete optimisation, namely, the one dimensional bin packing problem (1BPP). The source hyper-heuristic solves easy and medium problem instances from the Scholl benchmark set and the target hyper-heuristic solves the hard problem instances in the same benchmark set. Performance is assessed in terms of objective value, i.e. the number of bins, computational effort and generality of the hyper-heuristic. This study firstly compares the performance of two transfer learning approaches previously shown to be effective for generation constructive hyper-heuristics, for the one dimensional bin packing problem. Both these approaches performed better than not using transfer learning, with the approach transferring the best elements from each generation of the source hyper-heuristic to the target hyper-heuristic (TL2) producing the best results. The study then investigated transferring knowledge on an area of the search space rather than a point in the search space. Three approaches were developed and evaluated for this purpose. Two of these approaches were able to improve the performance of TL2 on three of the ten problem instances with respect to objective value. `https://ieeexplore.ieee.org/abstract/document/9660092`.

[138] Justin Schrack, Roy Ortega, Kevin Dabu, Daniel Truong, Michal Aibin, and Ania Aibin. Combining tabu search and genetic algorithm to determine optimal nurse schedules. In *2021 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE)*, pages 1–7. IEEE, 2021. The nurse scheduling problem (NSP) deals with assigning nurses to shifts in a schedule. These assignments must be made based on several hard and soft constraints specific to each nurse. Our solution attempts to solve this problem for smaller-scale clinics or private offices by creating weekly schedules that require only two nurses per shift and have only two shifts per day. We used thirty-four nurses with no specific specializations and can complete all nurse-related activities required by the clinic as sample data. Each nurse in the data pool can be scheduled more than once a week. Using techniques from genetic algorithms and tabu search, our algorithm assesses multiple possible solutions and returns only the most viable schedule based on the soft constraints. `https://ieeexplore.ieee.org/abstract/document/9569111`.

[139] Bianca NK Senzaki, Sandra M Venske, and Carolina P Almeida. Hyper-heuristic based nsga-iii for the many-objective quadratic assignment problem. In *Brazilian Conference on Intelligent Systems*, pages 170–185. Springer, 2021. The Quadratic Assignment Problem (QAP) can be subdivided into different versions, being present in several real-world applications. In this work, it is used a version that considers many objectives. QAP is an NP-hard problem, so approximate algorithms are used to address it. This work analyzes a Hyper-Heuristic (HH) that selects genetic operators to be applied during the evolutionary pro-

cess. HH is based on the NSGA-III framework and on the Thompson Sampling approach. Our main contribution is the analysis of the use of a many objective algorithm using HH for QAP, as this problem was still under-explored in the context of many objective optimization. Furthermore, we analyze the behavior of operators forward the changes related to HH (TS). The proposal was tested considering 42 instances with 5, 7 and 10 objectives. The results, interpreted using the Friedman statistical test, were satisfactory when compared to the original algorithm (without HH), as well as when compared to algorithms in the literature: MOEA/DD, MOEA/D, SPEA2, NSGA-II and MOEA/D-DRA. `https://link.springer.com/chapter/10.1007/978-3-030-91702-9_12`.

[140] Salama Shady, Toshiya Kaihara, Nobutada Fujii, and Daisuke Kokuryo. Evolving dispatching rules using genetic programming for multi-objective dynamic job shop scheduling with machine breakdowns. *Procedia CIRP*, 104:411–416, 2021. Dynamic Job Shop Scheduling Problem (DJSSP) is an NP-hard problem that has a great impact on production performance in practice. The design of Dispatching Rules (DRs) is very challenging because many shop attributes need to be investigated. Therefore, this paper proposes a Genetic Programming (GP) approach to generate DRs automatically for multi-objective DJSSP considering machine breakdowns. Computational experiments are conducted to compare the GP rule performance with 12 literature rules. The results indicate the superiority of the GP rule in minimizing mean flow time and makespan simultaneously. Finally, the best evolved rule is analyzed, and the significant attributes are extracted. `https://doi.org/10.1016/j.procir.2021.11.069`.

[141] Emilio Singh and Nelishia Pillay. Ant-based generation constructive hyper-heuristics for the movie scene scheduling problem. In *International Conference on the Theory and Practice of Natural Computing*, pages 109–120. Springer, 2021. The task of generation constructive hyper-heuristics concerns itself with generating new heuristics for problem domains via some kind of mechanism that combines low-level heuristic components into new heuristics. The movie scene scheduling problem is a recently developed combinatorial problem for which there are relatively few low-level heuristics. This paper focused on the application of a novel ant-based generation constructive hyper-heuristic to develop new constructive heuristics for the problem. The ant-based generation constructive hyper-heuristic was applied to create components that were themselves produced from existing heuristics and domain knowledge regarding the movie scene scheduling problem. The results of the research demonstrated that the ant-based hyper-heuristic was successful in the domain. It outperformed the existing set of human-derived constructive heuristics across a wide variety of problem classes and over several instances within the movie scene scheduling problem. The success of this research suggests that other hyper-heuristic methods, such as a generation perturbative one, could be applied to the movie scene scheduling problem in the future. `https://link.springer.com/chapter/10.1007/978-3-030-90425-8_9`.

[142] Emilio Singh and Nelishia Pillay. Ant-based hyper-heuristics for the movie scene scheduling problem. In *International Conference on Artificial Intelligence and Soft Computing*, pages 342–353. Springer, 2021. The paper provides a study of the use of hyper-heuristics on the movie scene scheduling problem. In particular, the paper extends the definition of the movie scene scheduling problem to include a new method of calculating the solution quality. The study is also a novel application of hyper-heuristics to the movie scene scheduling problem and demonstrates one potential method for using hyper-heuristics as a solution method for the given problem. This includes the development of new low-level heuristics for the problem that are presented as well. The study showed that hyper-heuristics could be applied to the problem doing better than a random approach but that work would need to be done on improving the low-level perturbative heuristics. The study also showed that the new formulation would be tenable as a problem definition with little change to the underlying problem itself. https://link.springer.com/chapter/10.1007/978-3-030-87897-9_31.

[143] Hong-Bo Song and Jian Lin. A genetic programming hyper-heuristic for the distributed assembly permutation flow-shop scheduling problem with sequence dependent setup times. *Swarm and Evolutionary Computation*, 60:100807, 2021. In this paper, a genetic programming hyper heuristic (GP-HH) algorithm is proposed to solve the distributed assembly permutation flow-shop scheduling problem with sequence dependent setup times (DAPFSP-SDST) and the objective of makespan minimization. The main idea is to use genetic programming (GP) as the high level strategy to generate heuristic sequences from a pre-designed low-level heuristics (LLHs) set. In each generation, the heuristic sequences are evolved by GP and then successively operated on the solution space for better solutions. Additionally, simulated annealing is embedded into each LLH to improve the local search ability. An effective encoding and decoding pair is also presented for the algorithm to obtain feasible schedules. Finally, computational simulation and comparison are both carried out on a benchmark set and the results demonstrate the effectiveness of the proposed GP-HH. The best-known solutions are updated for 333 out of the 540 benchmark instances. https://www.sciencedirect.com/science/article/abs/pii/S2210650220304600.

[144] Meeniga Sri Raghavendra, Priyanka Chawla, and Sukhpal Singh Gill. Deedsp: Deadline-aware and energy-efficient dynamic service placement in integrated internet of things and fog computing environments. *Transactions on Emerging Telecommunications Technologies*, 32(12):e4368, 2021. Fog computing has become adaptable and also as a promising infrastructure for providing elastic resources at the edge of the network. Fog computing reduces the transmission latency and consumption of bandwidth while processing the incoming requests from various Internet of Things (IoT) devices. Moreover, fog computing can support and facilitate geographically distributed applications with low and predictable latency. However, this technology also has significant research issues in its cur-

rent stage such as successful implementation of service location models. In this article, we propose a deadline-aware and energy-efficient dynamic service placement (DEEDSP) technique for fog computing that supports the placement of IoT based services. Further, hyper-heuristic algorithm based energy-efficient service placement technique is proposed to balance the energy-delay trade-off based on different service placement decision criteria (eg, minimum response time or energy consumption). The proposed algorithm is able to dynamically minimize the energy consumption of the system while ensuring that the response time satisfies a given time constraint. Finally, the proposed technique is evaluated in simulated fog computing environment and experimental results show that this technique performs better than state-of-the-art placement techniques in terms of energy and latency. `https://onlinelibrary.wiley.com/doi/abs/10.1002/ett.4368`.

[145] Ya Su, Ying Dai, and Yi Liu. A hybrid hyper-heuristic whale optimization algorithm for reusable launch vehicle reentry trajectory optimization. *Aerospace Science and Technology*, 119:107200, 2021. Trajectory optimization is essentially an optimal control problem (OCP) with highly nonlinear dynamic properties and complex constraints, and a critical part of spacecraft design. In this paper, a hybrid algorithm is proposed for automatic reentry trajectory optimization of reusable launch vehicle (RLV) without providing user-specified initial guesses and a priori knowledge about the optimal trajectory. The method combines the strong robustness and global optimization properties of hyper-heuristic whale optimization algorithm (HHWOA) with the efficient and accurate features of the Gauss pseudospectral method (GPM). HHWOA works as the first-stage optimizer aims to obtain an approximate solution to provide a high-quality initial guess for the GPM, while the GPM works as the second-stage optimizer aims to accelerate the search of the optimum neighborhood to obtain an accurate optimal solution. Additionally, to enhance the progress during the evolutionary process, HHWOA is equipped with opposition-based learning, differential evolution operators, chaotic map sequences and smoothing technique strategies. The utilization of such strategies can potentially smooth the flight trajectory and improve the global convergence of the algorithm, while the three OCPs have shown their superiority in HHWOA. In order to evaluate the performance of the hybrid algorithm, complex constrained RLV maximum cross-range reentry problems with three different path constraint scenarios are investigated. Furthermore, more discussion and experiments are likewise conducted to investigate the impact of the parameters on the performance of the algorithm. The results show that the proposed hybrid algorithm can be very effective in addressing RLV reentry trajectory optimization problems. `https://doi.org/10.1016/j.ast.2021.107200`.

[146] Mingquan Sun, Bangsheng Xing, and Daolong Yang. Research on the hyper-heuristic of sub-domain elimination strategies based on firefly algorithm. In *Journal of Physics: Conference Series*, volume 1966, page 012024. IOP Publishing, 2021. In this study, a hyper-heuristic named Sub-domain Elimination

Strategies based on Firefly Algorithm (SESFA) is proposed. First, a typical hyper-heuristic is usually using the high-level strategy selection or the combination of the low-level heuristics to obtain a new hyper-heuristic, each round of optimization process is carried out in the whole problem domain. However, SESFA evaluates the problem domain through the feedback information of the meta-heuristic at the lower level, eliminating the poor performance areas, and adjusting the underlying heuristic or adjusting the algorithm parameters to improve the overall optimization performance. Second, the problem domain segmentation function in SESFA can reduce the complexity of the objective function within a single sub-domain, which is conducive to improving the optimization efficiency of the underlying heuristic. Further, the problem domain segmentation function in SESFA also makes there is no direct correlation between different sub-domains, so different underlying heuristics can be adopted in different sub-domains, which is beneficial to the realization of parallel computing. Comparing SESFA with Firefly Algorithms with five standard test functions, the results show that SESFA has advantages in precision, stability and success rate. `https://iopscience.iop.org/article/10.1088/1742-6596/1966/1/012024/meta`.

[147] Sandra M Venske, Carolina P Almeida, and Myriam R Delgado. Comparing selection hyper-heuristics for many-objective numerical optimization. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 1921–1928. IEEE, 2021. Mechanisms for automatic selection of parameters/heuristics used by evolutionary algorithms can provide more robust and independent approaches. In this work we propose an approach composed of a selection hyper-heuristic implemented within the MOEA/DD (Multi-objective Evolutionary Algorithm based on Dominance and Decomposition) algorithm based on Differential Evolution. Four selection hyper-heuristics are considered in this study: Thompson Sampling, Probability Matching, Adaptive Pursuit and Self-Adaptive Differential Evolution. The hyper-heuristics are employed to choose the crossover operator selected from a pool of operators, according to a probability that reflects the operator's previous performance during the evolutionary process. The MaF benchmark is considered with 5, 10 and 15 objectives. This benchmark includes a diversity of characteristics, representing the challenges that real-world problems may pose. Statistical tests indicate that the proposed approach performs equally or even outperforms those with fixed crossover operator. `https://ieeexplore.ieee.org/abstract/document/9504934`.

[148] Shaolin Wang, Yi Mei, and Mengjie Zhang. An improved multi-objective genetic programming hyper-heuristic with archive for uncertain capacitated arc routing problem. In *2021 IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–8. IEEE, 2021. Genetic Programming Hyper-heuristic (GPHH) is an effective technique to deal with the Uncertain Capacitated Arc Routing Problem (UCARP). The GPHH can evolve a routing policy that can respond to the uncertain environment in real time. Previous studies have shown

that the GPHH can evolve effective routing policies. However, the size (number of nodes) in the GP-evolved routing policy is still not taken into account. Smaller routing policies, in general, may have greater generalisation and interpretability. As a result, we should optimise the effectiveness and the size simultaneously. Evolutionary Multi-Objective (EMO) techniques can be applied to optimise the size along with the effectiveness. EMO can evolve a Pareto front of routing policies. TSNSGPII-a is the state-of-the-art EMO approach for UCARP. It keeps an archive to store potential individuals lost during the evolutionary process and select them to breed new offspring. In this paper, we further improve TSNSGPII-a in the way to select between the current population and the archive as parents. In addition, we propose a validation stage to increase the reliability of the final routing policy. The experimental results showed that the newly proposed algorithm, named TSNSGPII-arv, can achieve better HV and I G D on a set of instances. The controlled experimental results indicated both schemes are effective. The routing policies evolved by TSNSGPII-arv are smaller than the baseline single-objective GPHH approach without losing effectiveness. `https://ieeexplore.ieee.org/abstract/document/9660154`.

[149] Shaolin Wang, Yi Mei, and Mengjie Zhang. A multi-objective genetic programming approach with self-adaptive α dominance to uncertain capacitated arc routing problem. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 636–643. IEEE, 2021. The Uncertain Capacitated Arc Routing Problem (UCARP) has a variety of real-world applications. Genetic Programming Hyper-heuristic (GPHH) is considered a promising technique to handle UCARP. Many scholars have shown the power of GPHH of evolving effective routing policies. However, the size of the evolved routing policies is ignored. Typically, smaller routing policies can have better interpretability and generalisation. Thus, it is necessary to optimise the size along with the effectiveness. The objective selection bias issue arises as the size is much easier to be optimised than effectiveness. The Pareto front is biased to the size gradually during the evolutionary process. To address this issue, we develop an alpha dominance criteria based Multi-Objective GP with a self-adaptive alpha scheme (alpha MOGP-sa). The basic idea of the alpha dominance criteria is to set tradeoff rates between objectives. For different instances, the search space can be very different. In this case, the self-adaptive alpha scheme is employed to automatically tuning the alpha value during the evolutionary process so that we can identify a valid alpha value for different instances. This paper examines the proposed algorithm in eight different problem instances. The experimental results showed that alpha MOGP-sa could effectively handle the objective selection bias issue, and evolve much better Pareto front on Hyper-Volume and Inverted Generational Distance than the current state-of-the-art MOGP approach for UCARP in terms of effectiveness and size on all instances. Also, alpha MOGP-sa can evolve much smaller routing policies than the state-of-art single-objective GPHH without sacrificing effectiveness. `https://ieeexplore.ieee.org/abstract/document/9504956`.

[150] Shaolin Wang, Yi Mei, Mengjie Zhang, and Xin Yao. Genetic programming with niching for uncertain capacitated arc routing problem. *IEEE Transactions on Evolutionary Computation*, 26(1):73–87, 2021. The uncertain capacitated arc routing problem is an important optimization problem with many real-world applications. Genetic programming is considered a promising hyper-heuristic technique to automatically evolve routing policies that can make effective real-time decisions in an uncertain environment. Most existing research on genetic programming hyper-heuristic for the uncertain capacitated arc routing problem only focused on the test performance aspect. As a result, the routing policies evolved by genetic programming are usually too large and complex, and hard to comprehend. To evolve effective, smaller, and simpler routing policies, this article proposes a novel genetic programming approach, which simplifies the routing policies during the evolutionary process using a niching technique. The simplified routing policies are stored in an external archive. We also developed new elitism, parent selection, and breeding schemes for generating offspring from the original population and the archive. The experimental results show that the newly proposed approach can achieve significantly better test performance than the current state-of-the-art genetic programming algorithms for the uncertain capacitated arc routing problem. The evolved routing policies are smaller, and thus potentially more interpretable. `https://ieeexplore.ieee.org/abstract/document/9475970`.

[151] Umar Rizki Kusumo Widayu, Ahmad Mukhlason, and Ika Nurkasanah. Automation and optimization of course timetabling using the iterated local search hyper-heuristic algorithm with the problem domain from the 2019 international timetabling competition. In *2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT)*, pages 134–138. IEEE, 2021. University Courses timetabling is scientifically known as a nondeterministic polynomial time (NP)-hard problem and is still an exciting topic to study due to the difficulty to find an exact algorithm that can solve the problem in polynomial time. Prior studies in the scientific literature have recognized the importance of automation and optimization of course timetabling problems, especially for the university level that require a fast and effective method to timetable thousands of courses at the beginning of the academic period. The complexity of this problem has attracted the interest of competition, namely the International Timetabling Competition (ITC) 2019, to raise ideas of algorithms to solve the problem. This study investigates the performance of Iterated Local Search-Hill Climbing (ILS-HC) and Iterated Local Search-Simulated Annealing (ILS-SA), Algorithms within hyper-heurism in solving university course timetabling problem of ITC 2019 problem domain and datasets. Tested over tiny and small datasets of ITC 2019 problems, the experimental results show that ILS-SA outperforms ILS-HC for both datasets. Specifically, over tiny dataset, ILS-SA could minimize the objective function to 6 compared to 37 as result of ILS-HC algorithm. While over small datasets ILS-SA outperforms ILSHC by 776 compared to 1034. `https://ieeexplore.ieee.org/abstract/document/9431892`.

[152] Chin-Chia Wu, Danyu Bai, Juin-Han Chen, Win-Chin Lin, Lining Xing, Jia-Cheng Lin, and Shuenn-Ren Cheng. Several variants of simulated annealing hyper-heuristic for a single-machine scheduling with two-scenario-based dependent processing times. *Swarm and Evolutionary Computation*, 60:100765, 2021. Many practical productions are full of significant uncertainties. For example, the working environment may change, machines may breakdown, workers may become unstable, etc. In such an environment, job processing times should not be fixed numbers. In light of this situation, we investigate a single-machine problem with two-scenario-based processing times, where the goal is to minimize the maximum total completion times over two scenarios. When the uncertainty of the job processing times is confronted, the robust version of this problem is NP-hard, even for very restricted cases. To solve this problem, we derive some dominance rules and a lower bound for developing branch-and-bound algorithms to find optimal solutions. As for determining approximate solutions, we propose five heuristics, adopting combined two-scenario-based dependent processing times, to produce initial solutions and then improve each with a pairwise interchange. Further, we propose a simulated annealing hyper-heuristic incorporating the proposed seven low level heuristics to solve this problem as well. Finally, the performances of all proposed algorithms are tested and reported. `https://doi.org/10.1016/j.swevo.2020.100765`.

[153] Binzi Xu, Yi Mei, Yan Wang, Zhicheng Ji, and Mengjie Zhang. Genetic programming with delayed routing for multiobjective dynamic flexible job shop scheduling. *Evolutionary Computation*, 29(1):75–105, 2021. Dynamic Flexible Job Shop Scheduling (DFJSS) is an important and challenging problem, and can have multiple conflicting objectives. Genetic Programming Hyper-Heuristic (GPHH) is a promising approach to fast respond to the dynamic and unpredictable events in DFJSS. A GPHH algorithm evolves dispatching rules (DRs) that are used to make decisions during the scheduling process (i.e., the so-called heuristic template). In DFJSS, there are two kinds of scheduling decisions: the routing decision that allocates each operation to a machine to process it, and the sequencing decision that selects the next job to be processed by each idle machine. The traditional heuristic template makes both routing and sequencing decisions in a non-delay manner, which may have limitations in handling the dynamic environment. In this article, we propose a novel heuristic template that delays the routing decisions rather than making them immediately. This way, all the decisions can be made under the latest and most accurate information. We propose three different delayed routing strategies, and automatically evolve the rules in the heuristic template by GPHH. We evaluate the newly proposed GPHH with Delayed Routing (GPHH-DR) on a multiobjective DFJSS that optimises the energy efficiency and mean tardiness. The experimental results show that GPHH-DR significantly outperformed the state-of-the-art GPHH methods. We further demonstrated the efficacy of the proposed heuristic template with delayed routing, which suggests the importance of delaying

the routing decisions. https://direct.mit.edu/evco/article-abstract/29/1/75/97343/Genetic-Programming-with-Delayed-Routing-for.

[154] Binzi Xu, Liang Tao, Xiongfeng Deng, and Wei Li. An evolved dispatching rule based scheduling approach for solving djss problem. In *2021 40th Chinese Control Conference (CCC)*, pages 6524–6531. IEEE, 2021. Dynamic job shop scheduling (DJSS) has been shown as a realistic and complex combinatorial optimization problem, which is characterized by complexity, dynamics, and uncertainty. Though dispatching rules (DRs) have been seen as a suitable method for solving DJSS problem, it is hard to manually design a DR with good scheduling performance considering all the aspects, much less a general DR for the complex dynamic environment of the job shop. This paper presents a genetic programming hyper-heuristic (GPHH) based DR evaluation approach to automatically generate customized DRs, in which job shop configuration, objective, and other information are considered. After testing it on the single objective DJSS problems with six different scenarios, the experimental result indicates that the proposed method can effectively evolve better DRs for different DJSS problems than manually designed DRs. Besides, the role of four key parameters in GPHH, including the number of generations, the population size, and the maximal depth, have been deeply analyzed based on the corresponding experiments. https://ieeexplore.ieee.org/abstract/document/9549754.

[155] Bowei Xu, Depei Jie, Junjun Li, Yongsheng Yang, Furong Wen, and Haitao Song. Integrated scheduling optimization of u-shaped automated container terminal under loading and unloading mode. *Computers & Industrial Engineering*, 162:107695, 2021. This paper proposes an integrated scheduling optimization model based on mixed integer programming to analytically characterize the U-shaped automated container terminal layout and handling technology. We focus on dual trolley quay cranes, conflict-free automated guided vehicles (AGVs) and dual cantilever rail cranes under loading and unloading mode, which have rarely been simultaneously studied in the literature, as most prior research has addressed traditional container terminals. We eliminate the waiting time during the interaction between AGV and dual cantilever rail crane to realize spatiotemporal synchronization and minimize the completion time of all tasks. We employ a reinforcement learning based hyper-heuristic genetic algorithm to solve the model, specifically, better solution results for reward and punishment mechanism incorporating reinforcement learning, higher versatility independent of specific problems, stronger scalability of low-level algorithms. We investigate which algorithm is better by comparing the proposed algorithm with bi-level genetic algorithm, adaptive genetic algorithm, hybrid genetic algorithm and cuckoo search algorithm. We conduct small-sized and large-sized experiments to validate the performance of the proposed model and algorithm. The results show that the proposed model and algorithm can not only avoid the con-

flicts among AGVs but also significantly improve handling efficiency. https://www.sciencedirect.com/science/article/abs/pii/S0360835221005994.

[156] Meng Xu, Fangfang Zhang, Yi Mei, and Mengjie Zhang. Genetic programming with archive for dynamic flexible job shop scheduling. In *2021 IEEE Congress on Evolutionary Computation (CEC)*, pages 2117–2124. IEEE, 2021. Genetic programming (GP) has achieved great success in evolving effective scheduling rules to make real-time decisions in dynamic flexible job shop scheduling (DFJSS). To improve generalization, a commonly used strategy is to change the training simulation(s) at each generation of the GP process. However, with such a simulation rotation, GP may lose potentially promising individuals that happen to perform poorly in one particular generation. To address this issue, this paper proposed a new multi-tree GP with archive (MTAGP) to evolve the routing and sequencing rules for DFJSS. The archive is used to store the potentially promising individuals of each generation during evolution of genetic programming. The individuals in the archive can then be fully utilized when the simulation is changed in subsequent generations. Through extensive experimental tests, the MTAGP algorithm proposed in this paper is more effective than the multi-tree GP without archive algorithm in a few scenarios. Further experiments were carried out to analyze the use of the archive and some possible guesses were ruled out. We argue that the use of archives does increase the diversity of the population. However, the number of individuals in the archive that ranked in the top five of the new population is small. Therefore, the archive may not be able to greatly improve the performance. In the future, we will investigate better ways to use the archive and better ways to update individuals in the archive. https://ieeexplore.ieee.org/abstract/document/9504752.

[157] Hitesh Yadav, Rita Chhikara, and A Charan Kumari. A novel hybrid approach for feature selection in software product lines. *Multimedia Tools and Applications*, 80(4):4919–4942, 2021. Software Product Line (SPL) customizes software by combining various existing features of the software with multiple variants. The main challenge is selecting valid features considering the constraints of the feature model. To solve this challenge, a hybrid approach is proposed to optimize the feature selection problem in software product lines. The Hybrid approach 'Hyper-PSOBBO' is a combination of Particle Swarm Optimization (PSO), Biogeography-Based Optimization (BBO) and hyper-heuristic algorithms. The proposed algorithm has been compared with Bird Swarm Algorithm (BSA), PSO, BBO, Firefly, Genetic Algorithm (GA) and Hyper-heuristic. All these algorithms are performed in a set of 10 feature models that vary from a small set of 100 to a high-quality data set of 5000. The detailed empirical analysis in terms of performance has been carried out on these feature models. The results of the study indicate that the performance of the proposed method is higher to other state-of-the-art algorithms. https://link.springer.com/article/10.1007/s11042-020-09956-6.

[158] Tailong Yang, Shuyan Zhang, and Cuixia Li. A multi-objective hyper-heuristic algorithm based on adaptive epsilon-greedy selection. *Complex & Intelligent Systems*, 7(2):765–780, 2021. A variety of meta-heuristics have shown promising performance for solving multi-objective optimization problems (MOPs). However, existing meta-heuristics may have the best performance on particular MOPs, but may not perform well on the other MOPs. To improve the cross-domain ability, this paper presents a multi-objective hyper-heuristic algorithm based on adaptive epsilon-greedy selection (HH_EG) for solving MOPs. To select and combine low-level heuristics (LLHs) during the evolutionary procedure, this paper also proposes an adaptive epsilon-greedy selection strategy. The proposed hyper-heuristic can solve problems from varied domains by simply changing LLHs without redesigning the high-level strategy. Meanwhile, HH_EG does not need to tune parameters, and is easy to be integrated with various performance indicators. We test HH_EG on the classical DTLZ test suite, the IMOP test suite, the many-objective MaF test suite, and a test suite of a real-world multi-objective problem. Experimental results show the effectiveness of HH_EG in combining the advantages of each LLH and solving cross-domain problems. `https://link.springer.com/article/10.1007/s40747-020-00230-8`.

[159] William B Yates and Edward C Keedwell. Offline learning with a selection hyper-heuristic: An application to water distribution network optimisation. *Evolutionary computation*, 29(2):187–210, 2021. A sequence-based selection hyper-heuristic with online learning is used to optimise 12 water distribution networks of varying sizes. The hyper-heuristic results are compared with those produced by five multiobjective evolutionary algorithms. The comparison demonstrates that the hyper-heuristic is a computationally efficient alternative to a multiobjective evolutionary algorithm. An offline learning algorithm is used to enhance the optimisation performance of the hyper-heuristic. The optimisation results of the offline trained hyper-heuristic are analysed statistically, and a new offline learning methodology is proposed. The new methodology is evaluated, and shown to produce an improvement in performance on each of the 12 networks. Finally, it is demonstrated that offline learning can be usefully transferred from small, computationally inexpensive problems, to larger computationally expensive ones, and that the improvement in optimisation performance is statistically significant, with 99% confidence. `https://direct.mit.edu/evco/article/29/2/187/97360/Offline-Learning-with-a-Selection-Hyper-Heuristic`.

[160] Şeyda Yıldırım-Bilgi and A Şima Etaner-Uyar. A classification-based heuristic approach for dynamic environments. In *Recent Advances in Soft Computing and Cybernetics*, pages 113–124. Springer, 2021. Some of the earlier studies on dynamic environments focus on understanding the nature of the changes. However, very few of them use the information obtained to characterize the change for designing better solver algorithms. In this paper, a classification-based single point search algorithm, which makes use of the characterization informa-

tion to react differently under different change characteristics, is introduced. The mechanisms it employs to react to the changes resemble hyper-heuristic approaches previously proposed for dynamic environments. Experiments are performed to understand the underlying components of the proposed method as well as to compare its performance with similar single point search-based hyper-heuristic approaches proposed for dynamic environments. The experimental results are promising and show the strength of the proposed heuristic approach. https://link.springer.com/chapter/10.1007/978-3-030-61659-5_10.

[161] Kamal Z Zamli, Md Kader, Saiful Azad, Bestoun S Ahmed, et al. Hybrid henry gas solubility optimization algorithm with dynamic cluster-to-algorithm mapping. *Neural Computing and Applications*, 33(14):8389–8416, 2021. This paper discusses a new variant of Henry Gas Solubility Optimization (HGSO) Algorithm, called Hybrid HGSO (HHGSO). Unlike its predecessor, HHGSO allows multiple clusters serving different individual meta-heuristic algorithms (i.e., with its own defined parameters and local best) to coexist within the same population. Exploiting the dynamic cluster-to-algorithm mapping via penalized and reward model with adaptive switching factor, HHGSO offers a novel approach for meta-heuristic hybridization consisting of Jaya Algorithm, Sooty Tern Optimization Algorithm, Butterfly Optimization Algorithm, and Owl Search Algorithm, respectively. The acquired results from the selected two case studies (i.e., involving team formation problem and combinatorial test suite generation) indicate that the hybridization has notably improved the performance of HGSO and gives superior performance against other competing meta-heuristic and hyper-heuristic algorithms. https://link.springer.com/article/10.1007/s00521-020-05594-z.

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[163] Fangfang Zhang, Yi Mei, Su Nguyen, Kay Chen Tan, and Mengjie Zhang. Multitask genetic programming-based generative hyperheuristics: A case study in dynamic scheduling. *IEEE Transactions on Cybernetics*, 2021. Evolutionary multitask learning has achieved great success due to its ability to handle multiple tasks simultaneously. However, it is rarely used in the hyperheuristic domain,

which aims at generating a heuristic for a class of problems rather than solving one specific problem. The existing multitask hyperheuristic studies only focus on heuristic selection, which is not applicable to heuristic generation. To fill the gap, we propose a novel multitask generative hyperheuristic approach based on genetic programming (GP) in this article. Specifically, we introduce the idea in evolutionary multitask learning to GP hyperheuristics with a suitable evolutionary framework and individual selection pressure. In addition, an origin-based offspring reservation strategy is developed to maintain the quality of individuals for each task. To verify the effectiveness of the proposed approach, comprehensive empirical studies have been conducted on the homogeneous and heterogeneous multitask dynamic flexible job shop scheduling. The results show that the proposed algorithm can significantly improve the quality of scheduling heuristics for each task in all the examined scenarios. In addition, the evolved scheduling heuristics verify the mutual help among the tasks in a multitask scenario. `https://ieeexplore.ieee.org/abstract/document/9382963`.

[164] Fangfang Zhang, Yi Mei, Su Nguyen, and Mengjie Zhang. Collaborative multifidelity-based surrogate models for genetic programming in dynamic flexible job shop scheduling. *IEEE Transactions on Cybernetics*, 2021. Dynamic flexible job shop scheduling (JSS) has received widespread attention from academia and industry due to its practical application value. It requires complex routing and sequencing decisions under unpredicted dynamic events. Genetic programming (GP), as a hyperheuristic approach, has been successfully applied to evolve scheduling heuristics for JSS due to its flexible representation. However, the simulation-based evaluation is computationally expensive since there are many calculations based on individuals for making decisions in the simulation. To improve training efficiency, this article proposes a novel multifidelity-based surrogate-assisted GP. Specifically, multifidelity-based surrogate models are first designed by simplifying the problem expected to be solved. In addition, this article proposes an effective collaboration mechanism with knowledge transfer for utilizing the advantages of multifidelity-based surrogate models to solve the desired problems. This article examines the proposed algorithm in six different scenarios. The results show that the proposed algorithm can dramatically reduce the computational cost of GP without sacrificing the performance in all scenarios. With the same training time, the proposed algorithm can achieve significantly better performance than its counterparts in most scenarios while no worse in others. `https://ieeexplore.ieee.org/abstract/document/9345417`.

[165] Fangfang Zhang, Yi Mei, Su Nguyen, and Mengjie Zhang. Correlation coefficient-based recombinative guidance for genetic programming hyperheuristics in dynamic flexible job shop scheduling. *IEEE Transactions on Evolutionary Computation*, 25(3):552–566, 2021. Dynamic flexible job shop scheduling (JSS) is a challenging combinatorial optimization problem due to its complex environment. In this problem, machine assignment and operation sequencing decisions

need to be made simultaneously under the dynamic environments. Genetic programming (GP), as a hyperheuristic approach, has been successfully used to evolve scheduling heuristics for dynamic flexible JSS. However, in traditional GP, recombination between parents may disrupt the beneficial building blocks by choosing the crossover points randomly. This article proposes a recombinative mechanism to provide guidance for GP to realize effective and adaptive recombination for parents to produce offspring. Specifically, we define a novel measure for the importance of each subtree of an individual, and the importance information is utilized to decide the crossover points. The proposed recombinative guidance mechanism attempts to improve the quality of offspring by preserving the promising building blocks of one parent and incorporating good building blocks from the other. The proposed algorithm is examined on six scenarios with different configurations. The results show that the proposed algorithm significantly outperforms the state-of-the-art algorithms on most tested scenarios, in terms of both final test performance and convergence speed. In addition, the rules obtained by the proposed algorithm have good interpretability. `https://ieeexplore.ieee.org/abstract/document/9344816`.

[166] Fangfang Zhang, Su Nguyen, Yi Mei, and Mengjie Zhang. Multitask learning in hyper-heuristic domain with dynamic production scheduling. In *Genetic Programming for Production Scheduling*, pages 249–269. Springer, 2021. This chapter attempts to solve multiple related dynamic scheduling tasks simultaneously, and adapts traditional multitask learning into the hyper-heuristic domain with genetic programming for this purpose. This chapter verifies the effectiveness of traditional multitask learning in genetic programming for dynamic scheduling and identifies a number of differences that need to be adapted. This chapter develops a multi-population multitask learning framework with genetic programming. In addition, this chapter proposes an effective origin-based offspring reservation strategy to keep the quality of individuals for one task and learn knowledge from other tasks. The learned scheduling heuristics show that the subpopulations do manage to learn from each other to solve tasks. `https://link.springer.com/chapter/10.1007/978-981-16-4859-5_13`.

[167] Hao Zhang and WK Chan. Plum: Exploration and prioritization of model repair strategies for fixing deep learning models. In *2021 8th International Conference on Dependable Systems and Their Applications (DSA)*, pages 140–151. IEEE, 2021. The accuracy of DL models may not meet the user's expectations. To tackle this problem, existing work proposed diverse approaches, such as using more optimized training processes and training samples to evolve the model structure or parameters of such faulty DL models. In this paper, we present Plum, a novel hyperheuristic approach to fixing deep learning models. Plum generates a set of DL model candidates by applying low-level repair strategies. It then evaluates and prioritizes repair strategies based on their overall fixing effects exhibited by these model candidates and outputs a fixed DL model by applying the top-ranked repair

strategy. We also formulate a novel repair strategy to show the compatibility of Plum in incorporating new repair strategies. The experiment on five DL models showed that Plum achieved improvements in test accuracy by 2.49% and 3.11% on the CIFAR-10 and CIFAR-100 datasets over the baselines and outperformed Apricot and MODE, two previous state-of-the-art deep learning repair techniques. `https://ieeexplore.ieee.org/abstract/document/9623049`.

[168] Shuai Zhang, Yangbing Xu, and Wenyu Zhang. Multitask-oriented manufacturing service composition in an uncertain environment using a hyper-heuristic algorithm. *Journal of Manufacturing Systems*, 60:138–151, 2021. One of the most important issues in cloud manufacturing involves obtaining an optimal manufacturing service composition solution. However, traditional manufacturing service composition methods either focused on single-task-oriented service composition or optimized solutions under a deterministic environment. In the study, a multitask-oriented manufacturing service composition (MMSC) model with two stages in uncertain environment is proposed. It handles the problem of multitask scheduling and also deals with the inherent uncertainty and ambiguity in cloud manufacturing including the occurrence of urgent task requests and the delayed delivery time of raw materials. In order to solve the MMSC model, a new genetic based hyper-heuristic algorithm (GA-HH) with adjustable length of chromosome is proposed. The GA-HH contains a set of low-level heuristics that directly operate on the solution domain that are organized by the high-level heuristic (i.e., genetic algorithm). Finally, the proposed GA-HH is proved as an efficient, effective, and robust algorithm to solve the MMSC model with considerations of multitask and uncertainty, by comparing it with other well-known meta-heuristic algorithms such as the genetic algorithm and particle swarm optimization. `https://doi.org/10.1016/j.jmsy.2021.05.012`.

[169] Fuqing Zhao, Shilu Di, Jie Cao, Jianxin Tang, et al. A novel cooperative multi-stage hyper-heuristic for combination optimization problems. *Complex System Modeling and Simulation*, 1(2):91–108, 2021. A hyper-heuristic algorithm is a general solution framework that adaptively selects the optimizer to address complex problems. A classical hyper-heuristic framework consists of two levels, including the high-level heuristic and a set of low-level heuristics. The low-level heuristics to be used in the optimization process are chosen by the high-level tactics in the hyper-heuristic. In this study, a Cooperative Multi-Stage Hyper-Heuristic (CMS-HH) algorithm is proposed to address certain combinatorial optimization problems. In the CMS-HH, a genetic algorithm is introduced to perturb the initial solution to increase the diversity of the solution. In the search phase, an online learning mechanism based on the multi-armed bandits and relay hybridization technology are proposed to improve the quality of the solution. In addition, a multi-point search is introduced to cooperatively search with a single-point search when the state of the solution does not change in continuous time. The performance of the CMS-HH algorithm is assessed in six specific combinatorial optimiza-

tion problems, including Boolean satisfiability problems, one-dimensional packing problems, permutation flow-shop scheduling problems, personnel scheduling problems, traveling salesman problems, and vehicle routing problems. The experimental results demonstrate the efficiency and significance of the proposed CMS-HH algorithm. https://ieeexplore.ieee.org/abstract/document/9502053.

[170] Yanwei Zhao, Longlong Leng, and Chunmiao Zhang. A novel framework of hyper-heuristic approach and its application in location-routing problem with simultaneous pickup and delivery. *Operational Research*, 21(2):1299–1332, 2021. This paper addresses a new variant of location-routing problem (LRP), namely the LRP with simultaneous pickup and delivery (LRPSPD). A hyper-heuristic approach based on iterated local search (ILS-HH) is introduced to automatically optimize the LRPSPD. On basis of the novel proposed framework of hyper-heuristic, four selections mechanisms and five activation strategies are developed to examine the performance of the proposed framework. Three types computational evaluations were carried out and several conclusions can be drawn: (1) the proposed framework performs better than the classical one with performing several heavy-duty combinations of strategies in terms of solution quality and computing time; (2) different activated strategies have slight (not significant) effect on exploiting best solutions; (3) FRR-MAB-TS (fitness ratio rank based on multi-armed bandit with tabu search) works best among all selection methods. Moreover, the proposed approach could provide competitive, even better results compared to fine-tuned bespoke state-of-the-art approaches. https://link.springer.com/article/10.1007/s12351-019-00480-6.

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[178] Ashraf Elneima and Mohamed Salih. Optimisation of vehicle routing problem using hyper-heuristics. In *International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, pages 1–7. IEEE, 2020. The vehicle routing problem (VRP) is a computationally challenging combinatorial

problem. It has been intensively studied by many researchers in the last sixty years. Due to the significant economic benefit that can be achieved by optimizing the routing problems in practice, more and more attention has been given to several extensions of the VRPs that arise in real life. These extensions are called Rich Vehicle Routing Problems (RVRPs). In contrast to traditional VRP that focuses on the idealized models with unrealistic assumptions, the research of RVRPs considers those complex constraints faced in real-life planning. It provides solutions that are executable in practice. This work takes a rich VRP problem combining a capacitated vehicle routing problem with time windows (CVRPTW) and a service technician routing and scheduling problem (STRSP); for delivering various equipment based on customers' requests and the subsequent installation by several technicians. The main goal is to reduce the overall costs of used resources and the total transportation costs of trucks/technicians. The problem was the topic of the fourth edition of the VeRoLog Solver Challenge in cooperation with the ORTEC company. The problem was solved in C++ by implementing three different Hyper-heuristic methods: SR-IE, SR-SA and SS-SA. These methods are compared, and SS-SA is found to have the best performance. https://ieeexplore.ieee.org/abstract/document/9429682.

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[205] Leena Ahmed, Christine Mumford, and Ahmed Kheiri. Solving urban transit route design problem using selection hyper-heuristics. *European Journal of Operational Research*, 274(2):545–559, 2019. The urban transit routing problem (UTRP) focuses on finding efficient travelling routes for vehicles in a public transportation system. It is one of the most significant problems faced by transit planners and city authorities throughout the world. This problem belongs to the class of difficult combinatorial problems, whose optimal solution is hard to find with the complexity that arises from the large search space, and the number of constraints imposed in constructing the solution. Hyper-heuristics have emerged as general-purpose search techniques that explore the space of low level heuristics to improve a given solution under an iterative framework. In this work, we evaluate the performance of a set of selection hyper-heuristics on the route design problem of bus networks, with the goal of minimising the passengers' travel time, and the operators' costs. Each selection hyper-heuristic is empirically tested on a set of benchmark instances and statistically compared to the other selection hyper-heuristics to determine the best approach. A sequence-based selection method combined with the great deluge acceptance method achieved the best performance, succeeding in finding improved results in much faster run times over the current best known solutions. https://www.sciencedirect.com/science/article/abs/pii/S0377221718308750.

[206] Edmund K Burke, Matthew R Hyde, Graham Kendall, Gabriela Ochoa, Ender Özcan, and John R Woodward. A classification of hyper-heuristic approaches: Revisited. In *Handbook of Metaheuristics*, pages 453–477. Springer, 2019. Hyper-heuristics comprise a set of approaches that aim to automate the development of computational search methodologies. This chapter overviews previous categorisations of hyper-heuristics and provides a unified classification and

definition. We distinguish between two main hyper-heuristic categories: heuristic selection and heuristic generation. Some representative examples of each category are discussed in detail and recent research trends are highlighted. `https://link.springer.com/chapter/10.1007/978-3-319-91086-4_14`.

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[208] Sachchida Nand Chaurasia, Donghwi Jung, Ho Min Lee, and Joong Hoon Kim. An evolutionary algorithm based hyper-heuristic for the set packing problem. In *Harmony Search and Nature Inspired Optimization Algorithms*, pages 259–268. Springer, 2019. Utilizing knowledge of the problem of interest and lessons learned from solving similar problems would help to find the final optimal solution of better quality. A hyper-heuristic algorithm is to gain an advantage of such process. In this paper, we present an evolutionary algorithm based hyper-heuristic framework for solving the set packing problem (SPP). The SPP is a typical NPNP -hard problem. The hyper-heuristic is comprising of high level and low level. The higher level is mainly engaged in generating or constructing a heuristic. An evolutionary algorithm with guided mutation (EA/G) is employed at the high level. Whereas a set of problem-independent and problem-specific heuristics, called low level heuristics, are employed at the low level of hyper-heuristic. EA/G is recently added to the class of the evolutionary algorithms that try to utilize the complementary characteristics of genetic algorithms (GAs) and estimation of distribution algorithms (EDAs) to generate new offspring. In EA/G, the guided mutation operator generates an offspring by sampling the probability vector. The proposed

approach is compared with the state-of-the-art approaches reported in the literature. The computational results show the effectiveness of the proposed approach. https://link.springer.com/chapter/10.1007/978-981-13-0761-4_26.

[209] Sachchida Nand Chaurasia and Joong Hoon Kim. An artificial bee colony based hyper-heuristic for the single machine order acceptance and scheduling problem. In *Decision Science in Action*, pages 51–63. Springer, 2019. This paper presents an artificial bee colony based hyper-heuristic for solving the order acceptance and scheduling (OAS) problem in a single machine environment. The OAS problem gives the flexibility to accept or reject an order where the systems have limited production capacity and on-time delivery constraints. The OAS problem, which is a typical NPNP -hard problem, becomes more complex when a sequence-dependent setup time is incurred between two consecutive orders. Solving an NP-hard problem through exact approaches is computationally expensive and they fail to solve large-size instances. Therefore, we proposed hyper-heuristic in which artificial bee colony (ABC) algorithm is employed as a search methodology for the OAS problem. Hyper-heuristic works on the search space of heuristics, whereas ABC algorithm works on the solution space of the problem. A guided heuristic, which works on search space of heuristics, is developed to search the best heuristic from a set of heuristics residing at the lower level of hyper-heuristic. The proposed approach is compared with the state-of-the-art approaches. The computational results show that the integration of ABC algorithm into hyper-heuristic outperformed the other approaches in terms of average and minimum deviation from the upper bound. https://link.springer.com/chapter/10.1007/978-981-13-0860-4_5.

[210] Sachchida Nand Chaurasia and Joong Hoon Kim. An evolutionary algorithm based hyper-heuristic framework for the set packing problem. *Information Sciences*, 505:1–31, 2019. https://www.sciencedirect.com/science/article/pii/S002002551930684X.

[211] Sachchida Nand Chaurasia, Shyam Sundar, Donghwi Jung, Ho Min Lee, and Joong Hoon Kim. An evolutionary algorithm based hyper-heuristic for the job-shop scheduling problem with no-wait constraint. In *Harmony Search and Nature Inspired Optimization Algorithms*, pages 249–257. Springer, 2019. In this paper, we developed an evolutionary algorithm with guided mutation (EA/G) based hyper-heuristic for solving the job-shop scheduling problem with no-wait constraint (JSPNW). The JSPNW is an extension of well-known job-shop scheduling problem subject to the constraint that no waiting time is allowed between operations for a given job. This problem is a typical NP-hard problem. The hyper-heuristic algorithm comprises of two level frameworks. In the high-level, an evolutionary algorithm is employed to explore the search space. The low-level, which is comprised of generic as well as problem-specific heuristics such as guided mutation, multi-insert points and multi-swap. EA/G is a recent addition to the class of evolutionary algorithm that can be considered as a hy-

bridization of genetic algorithms (GAs) and estimation of distribution algorithms (EDAs), and which tries to overcome the shortcomings of both. In GAs, the location information of the solutions found so far is directly used to generate offspring. On the other hand, EDAs use global statistical information to generate new offspring. In EDAs the global statistical information is stored in the form probability vector, and a new offspring is generated by sampling this probability vector. We have compared our approach with the state-of-the-art approaches. The computational results show the effectiveness of our approach. https://link.springer.com/chapter/10.1007/978-981-13-0761-4_25.

[212] Shin Siang Choong, Li-Pei Wong, and Chee Peng Lim. An artificial bee colony algorithm with a modified choice function for the traveling salesman problem. *Swarm and Evolutionary Computation*, 44:622–635, 2019. The Artificial Bee Colony (ABC) algorithm is a swarm intelligence approach which has initially been proposed to solve optimisation of mathematical test functions with a unique neighbourhood search mechanism. This neighbourhood search mechanism could not be directly applied to combinatorial discrete optimisation problems. In order to tackle combinatorial discrete optimisation problems, the employed and onlooker bees need to be equipped with problem-specific perturbative heuristics. However, a large variety of problem-specific heuristics are available, and it is not an easy task to select an appropriate heuristic for a specific problem. In this paper, a hyper-heuristic method, namely a Modified Choice Function (MCF), is applied such that it can regulate the selection of the neighbourhood search heuristics adopted by the employed and onlooker bees automatically. The Lin-Kernighan (LK) local search strategy is integrated to improve the performance of the proposed model. To demonstrate the effectiveness of the proposed model, 64 Traveling Salesman Problem (TSP) instances available in TSPLIB are evaluated. On average, the proposed model solves the 64 instances to 0.055% from the known optimum within approximately 2.7 min. A performance comparison with other state-of-the-art algorithms further indicates the effectiveness of the proposed model. https://www.sciencedirect.com/science/article/pii/S2210650217309446.

[213] Kassem Danach, Shahin Gelareh, and Rahimeh Neamatian Monemi. The capacitated single-allocation p-hub location routing problem: a lagrangian relaxation and a hyper-heuristic approach. *EURO Journal on Transportation and Logistics*, 8(5):597–631, 2019. A variant of the hub location routing problem studied in this work, which is the problem of locating a set of hub nodes, is establishing the hub-level network and allocating the spoke nodes to the hub nodes. As a particular property of this problem, each cluster of spoke nodes allocated to a hub constitutes a directed route that starts from the hub, visits all the spokes in the same cluster, and terminates to the same hub. We propose a hybrid of hyper-heuristic and a relax-and-cut solution method, which includes cooperation among several low-level heuristics governed and controlled by a learning mechanism. This hybridiza-

tion provides a mechanism in which the obtained dual information through the Lagrangian relaxation (bundle) method being utilized to guide the local searches for constructing/improving feasible solutions. Several classes of valid inequalities as well as efficient separation routings are also proposed for being used within the relax-and-cut approach. Our extensive computational experiments confirm the efficiency of this solution method in terms of quality as well as computational time. `https://link.springer.com/article/10.1007/s13676-019-00141-w`.

[214] Daniel Domović, Tomislav Rolich, and Marin Golub. Evolutionary hyper-heuristic for solving the strip-packing problem. *The Journal of The Textile Institute*, pages 1–11, 2019. Strip-packing problem (marker making) is an optimization problem, where a set of cutting parts needs to be placed on a marker so that the items do not overlap, and do not exceed the boundaries of a marker. In this research a novel Grid algorithm is introduced, and improvement methods: Grid-BLP and Grid-Shaking. These algorithms were combined with genetic algorithm, and a novel placement order All equal first. An individual representation of a genetic algorithm has been developed that is consisted of placement sequence, rotation of a cutting part, the choice of a placement algorithm, and dynamic grid parameter. Experiments were conducted to determine the best placement algorithm for a dataset, and hyper-heuristic efficiency. The implementation has been developed and experiments were conducted in MATLAB using GEATbx toolbox on five datasets from textile industry: ALBANO, DAGLI, MAO, MARQUES and MAN SHIRT. The marker efficiency in percentage was recorded with best results: 85.17, 81.76, 78.67, 84.67 and 87.19% obtained for the datasets, respectively. `https://www.tandfonline.com/doi/abs/10.1080/00405000.2018.1550136`.

[215] Mohamed Abd Elaziz and Seyedali Mirjalili. A hyper-heuristic for improving the initial population of whale optimization algorithm. *Knowledge-Based Systems*, 172:42–63, 2019. This paper improves the performance of the recently-proposed Whale Optimization Algorithm (WOA). WOA is a meta-heuristic that simulates the foraging behavior of humpback whales. There are several improvements in the literature for this algorithm of which chaotic maps and Opposition-Based Learning (OBL) are proved to be the most effective. In the former method, however, there are many chaotic maps that make it difficult to choose the best one for a given optimization algorithm. In the latter method, OBL should be applied to a portion of solutions in the population, which is normally obtained manually, which is time-consuming. This work proposed a hyper-heuristic to alleviate these drawbacks by automatically choosing a chaotic map and a portion of the population using the Differential Evolution (DE) algorithm. The proposed algorithm, which called DEWCO, has high ability to improve the exploration and local optima avoidance of WOA. In order to investigate the performance of the proposed DEWCO algorithm, several experiments are conducted on 35 standard CEC2005 functions and using seven algorithms. The experimental results show the superior performance of the proposed DEWCO algo-

rithm to determine the optimal solutions of the test function problems. `https://www.sciencedirect.com/science/article/abs/pii/S0950705119300632`.

[216] Qinqin Fan, Ning Li, Yilian Zhang, and Xuefeng Yan. Zoning search using a hyper-heuristic algorithm. *Science China Information Sciences*, 62(9):199102, 2019. `http://scis.scichina.com/en/2019/199102.pdf`.

[217] Fernando Garza-Santisteban, Roberto Sánchez-Pámanes, Luis Antonio Puente-Rodríguez, Ivan Amaya, José Carlos Ortiz-Bayliss, Santiago Conant-Pablos, and Hugo Terashima-Marín. A simulated annealing hyper-heuristic for job shop scheduling problems. In *2019 IEEE Congress on Evolutionary Computation (CEC)*, pages 57–64. IEEE, 2019. Job Shop Scheduling problems (JSSPs) have become increasingly popular due to their application in supply chain systems. Several solution approaches have appeared in the literature. One of them is the use of low-level heuristics. These methods approximate a solution but only work well on some kind of problems. Hence, combining them may improve performance. In this paper, we use the classical stochastic local optimization algorithm Simulated Annealing to train a selection hyper-heuristic for solving JSSPs. To do so, we use an instance generator provided in literature to create training sets with a different number of instances: 20, 40, and 60. In addition, we select instances from the literature to create two test scenarios, one similar to the training instances, and another with bigger problems. Our results suggest that training with the highest number of instances lead to better and more stable hyper-heuristics. For example, in the first test scenario, we achieved a reduction in the data range of over 60% and an improvement in the median performance of almost 30%. Moreover, under these conditions about 75% of the generated hyper-heuristics were able to perform equal to or better than the best heuristic. Even so, less than 25% were able to outperform the synthetic Oracle. Because of the aforementioned, we strongly support the idea of using a selection hyper-heuristic model powered by Simulated Annealing for creating a high-level solver for Job Shop Scheduling problems. `https://ieeexplore.ieee.org/abstract/document/8790296`.

[218] Patricia González, Pablo Argüeso-Alejandro, David R Penas, Xoan C Pardo, Julio Saez-Rodriguez, Julio R Banga, and Ramón Doallo. Hybrid parallel multimethod hyperheuristic for mixed-integer dynamic optimization problems in computational systems biology. *The Journal of Supercomputing*, 75(7):3471–3498, 2019. `https://link.springer.com/article/10.1007/s11227-019-02871-0`.

[219] Akhilesh Jain and Arvind Upadhyay. Cloud scheduling using improved hyper heuristic framework. In *International Conference on Advanced Computing Networking and Informatics*, pages 127–133. Springer, 2019. Effective scheduling is a main anxiety for the execution of performance motivated applications. Cloud Computing has to work with the large number of tasks. The question arises, How to make appropriate decisions, while allocating hardware resources to the tasks and dispatching the computing tasks to resource pool that has become

the challenging problem on cloud. In cloud environment task scheduling refers to an allocation of best suitable resources for the task which are executing with the consideration of different characteristics like makespan, time, cost, scalability, reliability, availability, resource utilization and other factors. We had tried to find the right method or sequence of heuristic in a given situation rather than trying to solve the problem directly. To check the importance of proposed algorithm we had compared it with the existing algorithms which had provided the far better results. We have introduced the improved hyper heuristic scheduling algorithm with the help of some efficient meta-heuristic algorithms, to find out the better task scheduling solutions for cloud computing systems and reduced the makespan time, and enhanced the utilization of cloud resources. `https://link.springer.com/chapter/10.1007/978-981-13-2673-8_15`.

[220] Kuan Yik Junn, Joe Henry Obit, Rayner Alfred, and Jetol Bolongkikit. A formal model of multi-agent system for university course timetabling problems. In *Computational Science and Technology*, pages 215–225. Springer, 2019. This paper describes a general framework of Multi-agent system which incorporates the hyper-heuristics search methodology with both Great Deluge and Simulated Annealing acceptance criteria respectively. There are three types of agents introduce in the framework which involve the communication between heuristic agents, cooperative agents and mediator agent. The common goal for each agent is to improve the quality of course timetabling solutions until the best solution is found when the termination condition meets. A preliminary experiment have been conducted towards this approach in university course timetabling problem and the results shows the framework is able to increase the quality of existing solution compared with other meta-heuristics which have been studied in the previous researches. `https://link.springer.com/chapter/10.1007/978-981-13-2622-6_22`.

[221] Emmanuel Kieffer, Grégoire Danoy, Matthias R Brust, Pascal Bouvry, and Anass Nagih. Tackling large-scale and combinatorial bi-level problems with a genetic programming hyper-heuristic. *IEEE Transactions on Evolutionary Computation*, 2019. Combinatorial bi-level optimization remains a challenging topic, especially when the lower-level is an NP-hard problem. In this paper, we tackle large-scale and combinatorial bi-level problems using GP hyper-heuristics, i.e., an approach that permits to train heuristics like a machine learning model. Our contribution aims at targeting the intensive and complex lower-level optimizations that occur when solving a large-scale and combinatorial bi-level problem. For this purpose, we consider hyper-heuristics through heuristic generation. Using a GP hyper-heuristic approach, we train greedy heuristics in order to make them more reliable when encountering unseen lower-level instances that could be generated during bi-level optimization. To validate our approach referred to as GA+AGH, we tackle instances from the bi-level cloud pricing optimization problem (BCPOP) that model the trading interactions between a cloud service provider and cloud service customers. Numerical results demonstrate the abilities of the trained heuris-

tics to cope with the inherent nested structure that makes bi-level optimization problems so hard. Furthermore, it has been shown that training heuristics for lower-level optimization permits to outperform human-based heuristics and metaheuristics which constitute an excellent outcome for bi-level optimization. https://ieeexplore.ieee.org/abstract/document/8671761.

[222] Longlong Leng, Yanwei Zhao, Zheng Wang, Jingling Zhang, Wanliang Wang, and Chunmiao Zhang. A novel hyper-heuristic for the biobjective regional low-carbon location-routing problem with multiple constraints. *Sustainability*, 11(6):1596, 2019. With the aim of reducing cost, carbon emissions, and service periods and improving clients' satisfaction with the logistics network, this paper investigates the optimization of a variant of the location-routing problem (LRP), namely the regional low-carbon LRP (RLCLRP), considering simultaneous pickup and delivery, hard time windows, and a heterogeneous fleet. In order to solve this problem, we construct a biobjective model for the RLCLRP with minimum total cost consisting of depot, vehicle rental, fuel consumption, carbon emission costs, and vehicle waiting time. This paper further proposes a novel hyper-heuristic (HH) method to tackle the biobjective model. The presented method applies a quantum-based approach as a high-level selection strategy and the great deluge, late acceptance, and environmental selection as the acceptance criteria. We examine the superior efficiency of the proposed approach and model by conducting numerical experiments using different instances. Additionally, several managerial insights are provided for logistics enterprises to plan and design a distribution network by extensively analyzing the effects of various domain parameters such as depot cost and location, client distribution, and fleet composition on key performance indicators including fuel consumption, carbon emissions, logistics costs, and travel distance and time. https://www.mdpi.com/2071-1050/11/6/1596.

[223] Jian Lin. Backtracking search based hyper-heuristic for the flexible job-shop scheduling problem with fuzzy processing time. *Engineering Applications of Artificial Intelligence*, 77:186–196, 2019. Flexible job-shop scheduling problem (FJSP) is among the most investigated scheduling problems over the past decades. The uncertainty of the processing time is an important practical characteristic in manufacturing. By considering the processing time to be fuzzy variable, the FJSP with fuzzy processing time (FJSPF) is more close to the reality. This paper proposes an effective backtracking search based hyper-heuristic (BS-HH) approach to address the FJSPF. Firstly, six simple and efficient heuristics are incorporated into the BS-HH to construct a set of low-level heuristics. Secondly, a backtracking search algorithm is introduced as the high-level strategy to manage the low-level heuristics to operate on the solution domain. Additionally, a novel hybrid solution decoding scheme is proposed to find an optimal solution more efficiently. Finally, the performance of the BS-HH is evaluated on two typical benchmark sets. The results show that the proposed hyper-heuristic outperforms the state-of-the-art

algorithms in solving the FJSPF. https://www.sciencedirect.com/science/article/pii/S0952197618302203.

[224] Andrei Lissovoi, Pietro S Oliveto, and John Alasdair Warwicker. On the time complexity of algorithm selection hyper-heuristics for multimodal optimisation. In *the AAAI Conference on Artificial Intelligence*, 2019. Selection hyper-heuristics are automated algorithm selection methodologies that choose between different heuristics during the optimisation process. Recently selection hyperheuristics choosing between a collection of elitist randomised local search heuristics with different neighbourhood sizes have been shown to optimise a standard unimodal benchmark function from evolutionary computation in the optimal expected runtime achievable with the available low-level heuristics. In this paper we extend our understanding to the domain of multimodal optimisation by considering a hyper-heuristic from the literature that can switch between elitist and nonelitist heuristics during the run. We first identify the range of parameters that allow the hyper-heuristic to hillclimb efficiently and prove that it can optimise a standard hillclimbing benchmark function in the best expected asymptotic time achievable by unbiased mutation-based randomised search heuristics. Afterwards, we use standard multimodal benchmark functions to highlight function characteristics where the hyper-heuristic is efficient by swiftly escaping local optima and ones where it is not. For a function class called CLIFFd where a new gradient of increasing fitness can be identified after escaping local optima, the hyper-heuristic is extremely efficient while a wide range of established elitist and non-elitist algorithms are not, including the well-studied Metropolis algorithm. We complete the picture with an analysis of another standard benchmark function called JUMPd as an example to highlight problem characteristics where the hyper-heuristic is inefficient. Yet, it still outperforms the well-established non-elitist Metropolis algorithm. https://staffwww.dcs.shef.ac.uk/people/P.Oliveto/rig/papers/aaai19-low.pdf.

[225] Folarin B Oyebolu, Richard Allmendinger, Suzanne S Farid, and Jürgen Branke. Dynamic scheduling of multi-product continuous biopharmaceutical facilities: a hyper-heuristic framework. *Computers & Chemical Engineering*, 2019. The biopharmaceutical industry is increasingly interested in moving from batch to semi-continuous manufacturing processes. These continuous bioprocesses are more failure-prone and process failure is more consequential. In addition, the probability of failure is dependent on process run time which generally is determined independent of scheduling considerations. This work presents a discrete-event simulation of continuous bioprocesses in a scheduling environment. Dynamic scheduling policies are investigated to make operational decisions in a multi-product manufacturing facility and react to process failure events and uncertain demand. First, different scheduling policies are adapted from the stochastic lot sizing literature and a novel look-ahead scheduling policy is proposed. Then, policy parameters (including process run time) are tuned using evolu-

tionary algorithms. Our results demonstrate that the tuned policies perform much better than a policy that estimates policy parameters based on service level considerations and a policy based on a fixed cyclical sequence. https://www.sciencedirect.com/science/article/pii/S009813541831189X.

[226] Fehmi Burcin Ozsoydan. Artificial search agents with cognitive intelligence for binary optimization problems. *Computers & Industrial Engineering*, 136:18–30, 2019. Artificial intelligence techniques bring about new opportunities in problem solving. The notion such techniques have in common is learning mechanisms that are mostly problem and environment dependent. Although optimality is not guaranteed by these techniques, they draw attention due to being able to solve challenging optimization problems efficiently. Accordingly, the present study introduces a swarm-based optimization algorithm that is comprised of artificial search agents each with individual cognitive intelligence. In this technique, each agent is allowed to learn from problem space individually. Therefore, each of the search agents exhibits a different search characteristic. Nevertheless, they occasionally share information of the promising regions with each other. Thus, central swarm intelligence is also allowed to lead those independent search agents. Moreover, information-sharing techniques in the developed algorithm are designed as adaptive procedures so that search agents learn throughout generations by avoiding premature convergence and local optima problems as much as possible. The performance of the proposed algorithm is tested on a set of binary optimization problems including the set-union knapsack problem and the uncapacitated facility location problem, which have numerous real-life applications. All reported benchmarking problems are solved by the developed algorithm. As demonstrated by the comprehensive computational study and statistical tests, the proposed swarm-based algorithm significantly improves most of the published results. https://www.sciencedirect.com/science/article/pii/S0360835219303985.

[227] Diego A Rodriguez, Paola P Oteiza, and Nélida B Brignole. An urban transportation problem solved by parallel programming with hyper-heuristics. *Engineering Optimization*, pages 1–15, 2019. An innovative optimization strategy by means of hyper-heuristics is proposed. It consists of a parallel combination of three metaheuristics. In view of the need both to escape from local optima and to achieve high diversity, the algorithm cooperatively combines simulated annealing with genetic algorithms and ant colony optimization. A location routing problem (LRP), which aims at the design of transport networks, was adopted for the performance evaluation of the proposed algorithm. Information exchanges took place effectively between the metaheuristics and speeded up the search process. Moreover, the parallel implementation was useful since it allowed several metaheuristics to run simultaneously, thus achieving a significant reduction in the computational time. The algorithmic efficiency and effectiveness were ratified for a medium-sized city. The proposed optimization algorithm

not only accelerated computations, but also helped to improve solution quality. https://www.tandfonline.com/doi/abs/10.1080/0305215X.2018.1560435.

[228] Nasser R Sabar, Ayad Turky, Andy Song, and Abdul Sattar. An evolutionary hyper-heuristic to optimise deep belief networks for image reconstruction. *Applied Soft Computing*, page 105510, 2019. Deep Belief Networks (DBN) have become a powerful tools to deal with a wide range of applications. On complex tasks like image reconstruction, DBN's performance is highly sensitive to parameter settings. Manually trying out different parameters is tedious and time consuming however often required in practice as there are not many better options. This work proposes an evolutionary hyper-heuristic framework for automatic parameter optimisation of DBN. The hyper-heuristic framework introduced here is the first of its kind in this domain. It involves a high level strategy and a pool of evolutionary operators such as crossover and mutation to generates DBN parameter settings by perturbing or modifying the current setting of a DBN. Providing a large set of operators could be beneficial to form a more effective high level strategy, but in the same time would increase the search space hence make it more difficulty to form a good strategy. To address this issue, a non-parametric statistical test is introduced to identify a subset of effective operators for different phases of the hyper-heuristic search. Three well-known image reconstruction datasets were used to evaluate the performance of the proposed framework. The results reveal that the proposed hyper-heuristic framework is very competitive when compared to the state of art methods. https://www.sciencedirect.com/science/article/pii/S1568494619302807.

[229] Alan Toledo, María Cristina Riff, and Bertrand Neveu. A hyper-heuristic for the orienteering problem with hotel selection. *IEEE Access*, 2019. We present a hyper-heuristic approach to solve Orienteering Problem with Hotel Selection (OPHS). In practical applications, OPHS appears when a tourist is planning to visit various attractions and there is not enough time to reach all of them in a single day. Therefore, the tourist must build a tour within several days by selecting hotels, where each day has a different time budget. We propose a hyper-heuristic based on a Large Neighborhood Search, composed by a set of low-level heuristics that satisfy the different constraints associated with the problem. We put special emphasis on collaboration between low-level heuristics in order to guide the algorithm to more promising areas. We use 395 benchmark instances with known optimal solutions. This approach proves to be a more general method, with a simpler design compared to the literature, and is able to find 217 of the 395 known optimal solutions, in acceptable computational times. https://ieeexplore.ieee.org/abstract/document/8935153.

[230] Enrique Urra, Claudio Cubillos, Daniel Cabrera-Paniagua, and Rafael Mellado. hmod: A software framework for assembling highly detailed heuristics algorithms. *Journal of Software: Practice and Experience*, 2019. Software design and component reuse for heuristic algorithms have gained in relevance; however, further

innovation is needed. In this context, hMod is presented as a software framework suited for implementing heuristic algorithms, with a focus on intensive reuse of highly cohesive operator and data components within algorithmic structures, making it possible to dynamically (re)configure and manage such a structure. Rather than a fast-prototyping tool, hMod supports heuristic implementation in the long term, whereby complexity can escalate from simple operators to major hyperheuristic architectures. In its core resides a novel object-oriented representation of algorithms through a pattern-like implementation, namely, algorithm assembling (AA). Additionally, it incorporates component integration features, such as dependency injection mechanisms. hMod has been mentioned in previous research, in which hyperheuristic methods were implemented and evaluated from an optimization perspective. In this work, a description of the framework is presented from the software design perspective, including the AA model, its architecture, and a detailed presentation of the main features of the framework. Previous hMod applications have demonstrated that it supports not only the software design requirements of heuristic algorithms but performance standards as well. Available sources of the framework can be found in http://gitlab.com/eurra/hmod. `https://onlinelibrary.wiley.com/doi/full/10.1002/spe.2690`.

[231] Dunwen Wei, Feiran Wang, and Hongjiao Ma. Autonomous path planning of auv in large-scale complex marine environment based on swarm hyper-heuristic algorithm. *Applied Sciences*, 9(13):2654, 2019. Autonomous underwater vehicles (AUVs) as an efficient underwater exploration means have been used to perform various marine missions. However, limited by the technologies of underwater acoustic communications and intelligent autonomy, the most current and advanced AUVs only perform a limited number of tasks in the small-scale area and the known underwater environment. Therefore, in this paper, a one path planning model was proposed combining the global path planning and the local path planning for the large-scale complex marine environment. More specifically, the B-spline curve was used to represent the smooth path for the requirement of kinematic constraints of AUVs. After considering the various constraints, such as the energy/time consumption, the turning radius limitation, the marine environment, and the ocean current, the path planning was abstractly modeled as a multi-objective optimization model with the time cost, the curvature cost, the map cost, and the ocean current cost. The swarm hyper-heuristic algorithm (SHH) with the online learning ability was proposed to solve this model with real-time performance and stability. The results showed that the proposed online learning SHH algorithm had obvious advantages in terms of time efficiency, stability, and optimal performance compared with the results of two traditional heuristic algorithms, both particle swarm optimization (PSO) and firefly algorithm (FFA). The time efficiency of the online learning SHH algorithm improved at least 20% compared with PSO and FFA. `https://www.mdpi.com/2076-3417/9/13/2654`.

[232] Yanwei Zhao, Longlong Leng, and Chunmiao Zhang. A novel framework of

hyper-heuristic approach and its application in location-routing problem with simultaneous pickup and delivery. *Operational Research*, pages 1–34, 2019. https://link.springer.com/article/10.1007/s12351-019-00480-6.

[233] Yong Zhou, Jian-Jun Yang, and Lian-Yu Zheng. Hyper-heuristic coevolution of machine assignment and job sequencing rules for multi-objective dynamic flexible job shop scheduling. *IEEE Access*, 7:68–88, 2019. Nowadays, real-time scheduling is one of the key issues in cyber-physical system. In real production, dispatching rules are frequently used to react to disruptions. However, the man-made rules have strong problem relevance, and the quality of results depends on the problem itself. The motivation of this paper is to generate effective scheduling policies (SPs) through off-line learning and to implement the evolved SPs online for fast application. Thus, the dynamic scheduling effectiveness can be achieved, and it will save the cost of expertise and facilitate large-scale applications. Three types of hyper-heuristic methods were proposed in this paper for coevolution of the machine assignment rules and job sequencing rules to solve the multi-objective dynamic flexible job shop scheduling problem, including the multi-objective cooperative coevolution genetic programming with two sub-populations, the multi-objective genetic programming with two sub-trees, and the multi-objective genetic expression programming with two chromosomes. Both the training and testing results demonstrate that the CCGP-NSGAII method is more competitive than other evolutionary approaches. To investigate the generalization performance of the evolved SPs, the non-dominated SPs were applied to both the training and testing scenarios to compare with the 320 types of man-made SPs. The results reveal that the evolved SPs can discover more useful heuristics and behave more competitive than the man-made SPs in more complex scheduling scenarios. It also demonstrates that the evolved SPs have a strong generalization performance to be reused in new unobserved scheduling scenarios. https://ieeexplore.ieee.org/abstract/document/8550675/.

[234] Yong Zhou, Jian-Jun Yang, and Lian-Yu Zheng. Multi-agent based hyper-heuristics for multi-objective flexible job shop scheduling: A case study in an aero-engine blade manufacturing plant. *IEEE Access*, 7:21147–21176, 2019. In the paper, a case study focusing on multi-objective flexible job shop scheduling problem (MO-FJSP) in an aero-engine blade manufacturing plant is presented. The problem considered in this paper involves many attributes, including working calendar, due dates, and lot size. Moreover, dynamic events occur frequently in the shop-floor, making the problem more challenging and requiring real-time responses. Therefore, the priority-based methods are more suitable than the computationally intensive search-based methods for the online scheduling. However, developing an effective heuristic for online scheduling problem is a tedious work even for domain experts. Furthermore, the domain knowledge of the practical production scheduling needs to be integrated into the algorithm to guide the search direction, accelerate the convergence of the algorithm, and im-

prove the solution quality. To this end, three multi-agent-based hyper-heuristics (MAHH) integrated with the prior knowledge of the shop floor are proposed to evolve scheduling policies (SPs) for the online scheduling problem. To evaluate the performance of evolved SPs, a 5-fold cross-validation method which is frequently used in machine learning is adopted to avoid the overfitting problem. Both the training and test results demonstrate that the bottleneck-agent-based hyper-heuristic method produces the best result among the three MAHH methods. Furthermore, both the effectiveness and the efficiency of the evolved SPs are verified by comparison with the well-known heuristics and two multi-objective particle swarm optimization (MOPSO) algorithms on the practical case. The proposed method has been embedded in the manufacturing execution system that is built on JAVA and successfully applied in several manufacturing plants. `https://ieeexplore.ieee.org/abstract/document/8635479/`.

[235] Hiba Abdulaziz, Areeg Elnahas, Alaa Daffalla, Yossra Noureldien, Ahmed Kheiri, and Ender Özcan. Late acceptance selection hyper-heuristic for wind farm layout optimisation problem. In *International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, pages 1–5. IEEE, 2018. Wind is a promising source of renewable energy which can be harvested using wind turbines placed on farms. An efficient wind farm layout achieving various engineering and financial objectives is crucial to ensure the sustainability and continuity of energy production. In this study, a high-level search technique, namely late acceptance selection hyper-heuristic is applied to optimise the layout of wind farms. This approach aims to find the best placement of turbines at a given site, maximising the energy output while minimising the cost at the same time. The computational experiments indicate that the late acceptance selection hyper-heuristic improves upon the performance of a previously proposed genetic algorithm across all scenarios and an iterated local search over the majority of scenarios considering the best solutions obtained by each algorithm over the runs. `https://ieeexplore.ieee.org/abstract/document/8515808`.

[236] Eltayeb KE Ahmed, Amr MA Khalifa, and Ahmed Kheiri. Evolutionary computation for static traffic light cycle optimisation. In *International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, pages 1–6. IEEE, 2018. Cities have become congested with traffic and changes to road network infrastructure are usually not possible. Thus, researchers and practitioners are investigating the practice of traffic light signal optimisation methodologies upon already established road networks to improve the flow of vehicles through the cities. The flow of traffic can be described by multiple factors such as mean journey time, mean waiting time, average vehicle velocity, and time loss. Static timing means that each traffic phase is active for a pre-fixed duration during the cycle. We aim to optimise traffic signal timing plans to minimise the mean journey time, which is increased by improper signalling, for vehicles during their journey across the junctions. In this research, we propose and empirically analyse several

automatic intelligent decision support systems including genetic algorithms and selection hyper-heuristic methods for the optimisation of traffic light signalling problem. The empirical results indicate the success of the proposed algorithm techniques. `https://ieeexplore.ieee.org/abstract/document/8515802`.

[237] Yagub Alipouri, Mohammad Hassan Sebt, Abdollah Ardeshir, and Weng Tat Chan. Solving the fs-rcpsp with hyper-heuristics: A policy-driven approach. *Journal of the Operational Research Society*, pages 1–17, 2018. In this paper, a problem in the area of scheduling, namely Fuzzy Stochastic Resource-Constrained Project Scheduling Problem (FS-RCPSP), is addressed. Like the original Resource-Constrained Project Scheduling Problem (RCPSP), the objective is to minimise the expected makespan of the project subject to precedence and resource constraints. However, due to mixed uncertainty comprising fuzziness and randomness in the estimates of activity durations, the makespan is a fuzzy stochastic number. Recognising both fuzziness and randomness in activity durations results in more robust schedules but the scheduling problem is harder to solve. A hyper-heuristic, named Self-adaptive Differential Evolution to Scheduling Policy (SADESP) is proposed to address this issue. SADESP has two key modules: (1) a module (policyEvolver) which evolves scheduling policy and (2) a dynamic scheduling procedure (dScheduler) which makes scheduling decisions using a particular scheduling policy. The performance of SADESP is benchmarked against CPLEX across an extensive set of 960 problems created with ProGen a standardised problem generator for creating benchmark problems in scheduling. The results returned by SADESP for FS-RCPSP are very encouraging, both in terms of accuracy and computational performance. `https://orsociety.tandfonline.com/doi/abs/10.1080/01605682.2018.1441636`.

[238] Ehab Nabiel Alkhanak and Sai Peck Lee. A hyper-heuristic cost optimisation approach for scientific workflow scheduling in cloud computing. *Future Generation Computer Systems*, 2018. Effective management of Scientific Workflow Scheduling (SWFS) processes in a cloud environment remains a challenging task when dealing with large and complex Scientific Workflow Applications (SWFAs). Cost optimisation of SWFS benefits cloud service consumers and providers by reducing temporal and monetary costs in processing SWFAs. However, cost optimisation performance of SWFS approaches is affected by the inherent nature of the SWFA as well as various types of scenarios that depend on the number of available virtual machines and varied sizes of SWFA datasets. Cost optimisation performance of existing SWFS approaches is still not satisfactory for all considered scenarios. Thus, there is a need to propose a dynamic hyper-heuristic approach that can effectively optimise the cost of SWFS for all different scenarios. This can be done by employing different meta-heuristic algorithms in order to utilise their strengths for each scenario. Thus, the main objective of this paper is to propose a Completion Time Driven Hyper-Heuristic (CTDHH) approach for cost optimisation of SWFS in a cloud environment. The CTDHH approach employs four

well-known population-based meta-heuristic algorithms, which act as Low Level Heuristic (LLH) algorithms. In addition, the CTDHH approach enhances the native random selection way of existing hyper-heuristic approaches by incorporating the best computed workflow completion time to act as a high-level selector to dynamically pick a suitable algorithm from the pool of LLH algorithms after each run. A real-world cloud based experimentation environment has been considered to evaluate the performance of the proposed CTDHH approach by comparing it with five baseline approaches, i.e. four population-based approaches and an existing hyper-heuristic approach named Hyper-Heuristic Scheduling Algorithm (HHSA). Several different scenarios have also been considered to evaluate data-intensiveness and computation-intensive performance. Based on the results of the experimental comparison, the proposed approach has proven to yield the most effective performance results for all considered experimental scenarios. `https://www.sciencedirect.com/science/article/pii/S0167739X17328297`.

[239] Carolina Almeida, Richard Gonçalves, Sandra Venske, Ricardo Lüuders, and Myriam Delgado. Multi-armed bandit based hyper-heuristics for the permutation flow shop problem. In *2018 7th Brazilian Conference on Intelligent Systems (BRACIS)*, pages 139–144. IEEE, 2018. In this work, we propose MAB variants as selection mechanisms of a hyper-heuristic running on the multi-objective framework named MOEA/D-DRA to solve the Permutation Flow Shop Problem (PFSP). All the variants are designed to choose which of low-level heuristic components (for crossover and mutation operators) should be applied to each solution during execution. FRRMAB is the classical MAB, RMAB is restless and LinUCB is contextual (its context is based on side information). The proposed approaches are compared with each other and the best one, MOEA/D-LinUCB, is compared with MOEA/DDRA using the hypervolume indicator and nonparametric statistical tests. The results demonstrate the robustness of MAB-based approaches, especially the contextual-based one. `https://ieeexplore.ieee.org/abstract/document/8575603`.

[240] Ivan Amaya, Jose C Ortiz-Bayliss, Alejandro Rosales-Perez, Andres E Gutierrez-Rodriguez, Santiago E Conant-Pablos, Hugo Terashima-Marin, and Carlos A Coello Coello. Enhancing selection hyper-heuristics via feature transformations. *IEEE Computational Intelligence Magazine*, 13(2):30–41, 2018. Hyper-heuristics are a novel tool. They deal with complex optimization problems where standalone solvers exhibit varied performance. Among such a tool reside selection hyper-heuristics. By combining the strengths of each solver, this kind of hyper-heuristic offers a more robust tool. However, their effectiveness is highly dependent on the 'features' used to link them with the problem that is being solved. Aiming at enhancing selection hyper-heuristics, in this paper we propose two types of transformation: explicit and implicit. The first one directly changes the distribution of critical points within the feature domain while using a Euclidean distance to measure proximity. The second one operates indirectly by preserving the distribution

of critical points but changing the distance metric through a kernel function. We focus on analyzing the effect of each kind of transformation, and of their combinations. We test our ideas in the domain of constraint satisfaction problems because of their popularity and many practical applications. In this work, we compare the performance of our proposals against those of previously published data. Furthermore, we expand on previous research by increasing the number of analyzed features. We found that, by incorporating transformations into the model of selection hyper-heuristics, overall performance can be improved, yielding more stable results. However, combining implicit and explicit transformations was not as fruitful. Additionally, we ran some confirmatory tests on the domain of knapsack problems. Again, we observed improved stability, leading to the generation of hyper-heuristics whose profit had a standard deviation between 20% and 30% smaller. `https://ieeexplore.ieee.org/abstract/document/8335843`.

[241] Filipe Assuncao, David Sereno, Nuno Lourenco, Penousal Machado, and Bernardete Ribeiro. Automatic evolution of autoencoders for compressed representations. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 1–8. IEEE, 2018.

[242] Itay Azaria, Achiya Elyasaf, and Moshe Sipper. Evolving artificial general intelligence for video game controllers. In *Genetic Programming Theory and Practice XIV*, pages 53–63. Springer, 2018. The General Video Game Playing Competition (GVGAI) defines a challenge of creating controllers for general video game playing, a testbed as it were for examining the issue of artificial general intelligence. We develop herein a game controller that mimics human learning behavior, focusing on the ability to generalize from experience and diminish learning time as new games present themselves. We use genetic programming to evolve hyper-heuristic-based general players. Our results show the effectiveness of evolution in meeting the generality challenge. `https://link.springer.com/chapter/10.1007/978-3-319-97088-2_4`.

[243] Anja Babić, Nikola Mišković, and Zoran Vukić. Heuristics pool for hyper-heuristic selection during task allocation in a heterogeneous swarm of marine robots. *IFAC-PapersOnLine*, 51(29):412–417, 2018. For the purpose of enabling long-term autonomy of a heterogeneous swarm of marine robots, task allocation and sequencing are introduced into the system's energy management procedures. In a scenario where the system needs to autonomously go about its monitoring mission and survive long- term, the available maximum capacity of 5 USVs - aPad platforms which represent the charging hubs of the system - is usually outnumbered by the number of active charging requests, leading to a need for careful planning and optimisation of robot activities. A two-layered system of decision-making algorithms is developed: a low-level specific solution-focused set of algorithms based on various machine learning paradigms, and a high-level hyper-heuristic which selects between them. This paper focuses on the lower level of this decision-making system, and details some of the approaches to task sequencing to be offered for

selection, primarily based on differential evolution and k-means clustering, along with factoring in the effects of water currents and wind. Achieved simulation results are discussed and some directions for further work are suggested. https://www.sciencedirect.com/science/article/pii/S2405896318321414.

[244] Adil Baykasoğlu and Fehmi Burcin Ozsoydan. Dynamic optimization in binary search spaces via weighted superposition attraction algorithm. *Expert Systems with Applications*, 96:157–174, 2018. Optimization in dynamic environments is a fast developing research area. Several outstanding metaheuristic algorithms were proposed to solve dynamic optimization problems (DOPs) in the past decade. However, most of the effort is devoted to real-valued DOPs. Although, great majority of real-life problems has discrete and binary spaces, research in binary DOPs is still lacking. Accordingly, the present study introduces the first binary DOP application of Weighted Superposition Attraction Algorithm (WSA), which is a new generation swarm intelligence-based metaheuristic algorithm. As a distinctive feature from the existing literature, the introduced binary version of WSA (bWSA) does not require transfer functions for converting floating numbers to binary, whereas they are commonly employed in binary modifications of various metaheuristic algorithms. Additionally, some new extensions of bWSA are also developed in the present study. For comparative analysis, first, some state-of-the-art algorithms including Particle Swarm Optimization and Genetic Algorithm are adopted. As secondarily, another new-generation hot optimizer, namely, Firefly Algorithm (FA), which has already been shown to be quite promising in DOPs, is employed in the present work. Moreover, all algorithms implemented here are enhanced by using dualism-based search, triggered random immigrants and adaptive hill climbing strategies. Dynamic modifications of the well-known binary benchmarking problems such as One-Max, Plateau, Royal Road and Deceptive Functions are used in the computational study. Performances of the proposed algorithms are compared in detail. Finally, non-parametric statistical tests are employed to validate the results. Findings point out superiority of bWSA in binary DOPs. https://www.sciencedirect.com/science/article/pii/S0957417417308047.

[245] Yi Bian, Zheng Li, Junxia Guo, and Ruilian Zhao. Concrete hyperheuristic framework for test case prioritization. *Journal of Software: Evolution and Process*, 30(11):e1992, 2018. Test case prioritization (TCP), which aims to find the optimal test case execution sequences for specific testing objects, has been widely used in regression testing. A wide variety of search methodologies and algorithms have been proposed to optimize test case execution sequences, namely, search-based TCP. However, different algorithms perform differently and have different implementation costs and specific situations where an algorithm usually performs with high effectiveness and efficiency. When facing a new testing scenario, it is actually difficult to decide which algorithm is suitable. In this paper, to address the algorithm selection problem for dif-

ferent test scenarios, a more generally applicable algorithm based on a hyperheuristic strategy is proposed for search-based TCP. This includes a range of multiobjective algorithms with a variety of crossover strategies and a learning agent strategy to evaluate and select the appropriate algorithm execution sequence dynamically for different scenarios. The concrete hyperheuristic framework for multiobjective TCP is presented with an algorithm's repository in the low level and the learning agent strategy in the higher level. Experiments show that the proposed learning agent strategy can accurately evaluate algorithms in multiobjective problems and select the appropriate algorithm in each iteration. `https://onlinelibrary.wiley.com/doi/abs/10.1002/smr.1992`.

[246] Mohammad Babrdel Bonab, Yong Haur Tay, Siti Zaiton Mohd Hashim, and Khoo Thau Soon. An efficient robust hyper-heuristic algorithm to clustering problem. In *International Conference on Computational Intelligence in Information System*, pages 48–60. Springer, 2018. Designing and modeling an optimization algorithm with dedicated search is a costly process and it need a deep analysis of problem. In this regard, heuristic and hybrid of heuristic algorithms have been widely used to solve optimization problems because they have been provided efficient way to find an approximate solution but they are limited to use number of different heuristic algorithm and they are so problem-depend. Hyper-heuristic is a set of heuristics, meta- heuristics, and high-level search strategies that work on the heuristic search space instead of solution search space. Hyper-heuristics techniques have been employed to develop approaches that are more general than optimization search methods and traditional techniques. The aim of a hyperheuristic algorithms is to reduce the amount of domain knowledge by using the capabilities of high-level heuristics and the abilities of low-level heuristics simultaneously in the search strategies. In this study, an efficient robust hyperheuristic clustering algorithm is proposed to find the robust and optimum clustering results based on a set of easy-to-implement low-level heuristics. Several data sets are tested to appraise the performance of the suggested approach. Reported results illustrate that the suggested approach can provide acceptable results than the alternative methods. `https://link.springer.com/chapter/10.1007/978-3-030-03302-6_5`.

[247] Pei Cao and Jiong Tang. A reinforcement learning hyper-heuristic in multi-objective single point search with application to structural fault identification. *arXiv preprint arXiv:1812.07958*, 2018. Multi-objective optimizations are frequently encountered in engineering practices. The solution techniques and parametric selections however are usually problem-specific. In this study we formulate a reinforcement learning hyper-heuristic scheme, and propose four low-level heuristics which can work coherently with the single point search algorithm MOSA/R (Multi-Objective Simulated Annealing Algorithm based on Re-seed) towards multi-objective optimization problems of general applications. Making use of the domination amount, crowding distance and hypervolume calculations, the proposed hyper-heuristic scheme can meet various optimization re-

quirements adaptively and autonomously. The approach developed not only exhibits improved and more robust performance compared to AMOSA, NSGA-II and MOEA/D when applied to benchmark test cases, but also shows promising results when applied to a generic structural fault identification problem. The outcome of this research can be extended to a variety of design and manufacturing optimization applications. `https://arxiv.org/abs/1812.07958`.

[248] Olacir R Castro, Gian Mauricio Fritsche, and Aurora Pozo. Evaluating selection methods on hyper-heuristic multi-objective particle swarm optimization. *Journal of Heuristics*, pages 1–36, 2018. Multi-objective particle swarm optimization (MOPSO) is a promising meta-heuristic to solve multi-objective problems (MOPs). Previous works have shown that selecting a proper combination of leader and archiving methods, which is a challenging task, improves the search ability of the algorithm. A previous study has employed a simple hyper-heuristic to select these components, obtaining good results. In this research, an analysis is made to verify if using more advanced heuristic selection methods improves the search ability of the algorithm. Empirical studies are conducted to investigate this hypothesis. In these studies, first, four heuristic selection methods are compared: a choice function, a multi-armed bandit, a random one, and the previously proposed roulette wheel. A second study is made to identify if it is best to adapt only the leader method, the archiving method, or both simultaneously. Moreover, the influence of the interval used to replace the low-level heuristic is analyzed. At last, a final study compares the best variant to a hyper-heuristic framework that combines a Multi-Armed Bandit algorithm into the multi-objective optimization based on decomposition with dynamical resource allocation (MOEA/D-DRA) and a state-of-the-art MOPSO. Our results indicate that the resulting algorithm outperforms the hyper-heuristic framework in most of the problems investigated. Moreover, it achieves competitive results compared to a state-of-the-art MOPSO. `https://link.springer.com/article/10.1007%2Fs10732-018-9369-x`.

[249] José M Cecilia, José-Matías Cutillas-Lozano, Domingo Giménez, and Baldomero Imbernón. Landscape analysis for the improvement of hyperheuristics over parameterized metaheuristics. In *International Workshop on Optimization and Learning: Challenges and Applications*, 2018.

[250] Shelvin Chand, Quang Huynh, Hemant Singh, Tapabrata Ray, and Markus Wagner. On the use of genetic programming to evolve priority rules for resource constrained project scheduling problems. *Information Sciences*, 432:146–163, 2018. Resource constrained project scheduling is critical in logistic and planning operations across a range of industries. Most businesses rely on priority rules to determine the order in which the activities required for the project should be executed. However, the design of such rules is non-trivial. Even with significant knowledge and experience, human experts are understandably limited in terms of the possibilities they can consider. This paper introduces a genetic programming based hyper-heuristic (GPHH) for producing efficient priority

rules targeting the resource constrained project scheduling problem (RCPSP). For performance analysis of the proposed approach, a series of experiments are conducted on the standard PSPLib instances with up to 120 activities. The evolved priority rules are then compared against the existing state-of-the-art priority rules to demonstrate the efficacy of our approach. The experimental results indicate that our GPHH is capable of producing reusable priority rules which significantly out-perform the best human designed priority rules. https://www.sciencedirect.com/science/article/pii/S0020025517311350.

[251] Binhui Chen, Rong Qu, Ruibin Bai, and Wasakorn Laesanklang. A hyper-heuristic with two guidance indicators for bi-objective mixed-shift vehicle routing problem with time windows. *Applied Intelligence*, 48(12):4937–4959, 2018. In this paper, a Mixed-Shift Vehicle Routing Problem is proposed based on a real-life container transportation problem. In a long planning horizon of multiple shifts, transport tasks are completed satisfying the time constraints. Due to the different travel distances and time of tasks, there are two types of shifts (long shift and short shift) in this problem. The unit driver cost for long shifts is higher than that of short shifts. A mathematical model of this Mixed-Shift Vehicle Routing Problem with Time Windows (MS-VRPTW) is established in this paper, with two objectives of minimizing the total driver payment and the total travel distance. Due to the large scale and nonlinear constraints, the exact search showed is not suitable to MS-VRPTW. An initial solution construction heuristic (EBIH) and a selective perturbation Hyper-Heuristic (GIHH) are thus developed. In GIHH, five heuristics with different extents of perturbation at the low level are adaptively selected by a high level selection scheme with the Hill Climbing acceptance criterion. Two guidance indicators are devised at the high level to adaptively adjust the selection of the low level heuristics for this bi-objective problem. The two indicators estimate the objective value improvement and the improvement direction over the Pareto Front, respectively. To evaluate the generality of the proposed algorithms, a set of benchmark instances with various features is extracted from real-life historical datasets. The experiment results show that GIHH significantly improves the quality of the final Pareto Solution Set, outperforming the state-of-the-art algorithms for similar problems. Its application on VRPTW also obtains promising results. https://link.springer.com/article/10.1007/s10489-018-1250-y.

[252] Viorica Rozina Chifu, Cristina Bianca Pop, Adrian Birladeanu, Nicolae Dragoi, and Ioan Salomie. Choice function-based constructive hyper-heuristic for generating personalized healthy menu recommendations. In *the 14th International Conference on Intelligent Computer Communication and Processing (ICCP)*, pages 111–118. IEEE, 2018. This paper presents a Choice Function-based Constructive Hyper-Heuristic for generating personalized healthy menu recommendations based on a person's nutrition, price and delivery time constraints. We model the problem of generating personalized healthy menus as an optimization problem for which the search space consists of a set of food packages, the solution is

represented as a menu containing five food packages for each meal of the day, and the fitness function evaluates the degree to which a menu personalizes a person's profile. In each step of the proposed hyper-heuristic's iterative phase, a low level domain independent heuristic is chosen to be applied on the current menu, based on its affinity and competence. The hyper-heuristic has been evaluated on a set of persons' profiles and a set of food packages developed in-house. `https://ieeexplore.ieee.org/abstract/document/8516650`.

[253] Shin Siang Choong, Li-Pei Wong, and Chee Peng Lim. Automatic design of hyper-heuristic based on reinforcement learning. *Information Sciences*, 2018. Hyper-heuristic is a class of methodologies which automates the process of selecting or generating a set of heuristics to solve various optimization problems. A traditional hyper-heuristic model achieves this through a high-level heuristic that consists of two key components, namely a heuristic selection method and a move acceptance method. The effectiveness of the high-level heuristic is highly problem dependent due to the landscape properties of different problems. Most of the current hyper-heuristic models formulate a high-level heuristic by matching different combinations of components manually. This article proposes a method to automatically design the high-level heuristic of a hyper-heuristic model by utilizing a reinforcement learning technique. More specifically, Q-learning is applied to guide the hyper-heuristic model in selecting the proper components during different stages of the optimization process. The proposed method is evaluated comprehensively using benchmark instances from six problem domains in the Hyper-heuristic Flexible Framework. The experimental results show that the proposed method is comparable with most of the top-performing hyper-heuristic models in the current literature. `https://www.sciencedirect.com/science/article/pii/S0020025516315894`.

[254] Vinicius Renan de Carvalho and Jaime Simão Sichman. Evolutionary computation meets multiagent systems for better solving optimization problems. In *General Conference on Emerging Arts of Research on Management and Administration*, pages 27–41. Springer, 2018. In this work, we discuss the synergy between Evolutionary Computation (EC) and Multi-Agent Systems (MAS) when both are used together to enhance the process of solving optimization problems. Evolutionary algorithms are inspired by nature and follow Darwin theory of the fittest. They are usually applied where there is no specific algorithm which can solve optimization problems in a reasonable time. Multi-Agent Systems, in their turn, are collections of autonomous entities, named agents, that sense their environment and execute some actions in the environment to meet their individual or common goals. When these two techniques are applied together, one can create powerful approaches to better solve optimization problems. This paper presents an overview of this combined approach, considering both mono-objective and multi-objective approaches. In particular, we stress the importance of hyper-heuristic approaches,

i.e., heuristics that help to choose the best EC algorithm among a candidate set. https://link.springer.com/chapter/10.1007/978-981-13-6936-0_4.

[255] Vinicius Renan de Carvalho and JS Sichman. Solving real-world multi-objective engineering optimization problems with an election-based hyper-heuristic. In *International Workshop on Optimisation in Multi-agent Systems (OPTMAS)*, 2018. Hyper-heuristics are high-level methodologies responsible for automatically discover how to combine elements from a low-level heuristic set in order to solve optimization problems. Agents, in turn, are autonomous component responsible for sensing an environment and performing some actions according to their perceptions. Thus, agent-based techniques seem suitable for the design of hyper-heuristics. In a previous work we proposed MOABHH [5], an agent-based hyper-heuristic framework for choosing the best multi-objective evolutionary algorithm (MOEA). Our approach performs a cooperative voting procedure, considering a set of quality indicator voters, to define which MOEA should generate more new solutions during execution time. However, MOABHH was just applied to solve benchmark problems, without being tested in real-world problems. Thus, this paper evaluates MOABHH in four realworld multi-objective engineering problems. For this purpose, an additional MOEA and new quality indicators better adapted to real-world problems were used. The obtained results show that our strategy aways find solutions at least equals to the ones generated by the best algorithm, and sometimes even overcomes these results. http://www-personal.umich.edu/~fioretto/cfp/OPTMAS18/papers/paper_7.pdf.

[256] Alex GC de Sá, Adriano CM Pereira, and Gisele L Pappa. A customized classification algorithm for credit card fraud detection. *Engineering Applications of Artificial Intelligence*, 72:21–29, 2018. This paper presents Fraud-BNC, a customized Bayesian Network Classifier (BNC) algorithm for a real credit card fraud detection problem. The task of creating Fraud-BNC was automatically performed by a Hyper-Heuristic Evolutionary Algorithm (HHEA), which organizes the knowledge about the BNC algorithms into a taxonomy and searches for the best combination of these components for a given dataset. Fraud-BNC was automatically generated using a dataset from PagSeguro, the most popular Brazilian online payment service, and tested together with two strategies for dealing with cost-sensitive classification. Results obtained were compared to seven other algorithms, and analyzed considering the data classification problem and the economic efficiency of the method. Fraud-BNC presented itself as the best algorithm to provide a good trade-off between both perspectives, improving the current company's economic efficiency in up to 72.64%. https://www.sciencedirect.com/science/article/abs/pii/S0952197618300605.

[257] Fakhrud Din and Kamal Z Zamli. Hyper-heuristic based strategy for pairwise test case generation. *Advanced Science Letters*, 24(10):7333–7338, 2018.

[258] Benjamin Doerr, Andrei Lissovoi, Pietro S Oliveto, and John Alasdair Warwicker.

On the runtime analysis of selection hyper-heuristics with adaptive learning periods. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO)*, pages 1015–1022. ACM, 2018. Selection hyper-heuristics are randomised optimisation techniques that select from a set of low-level heuristics which one should be applied in the next step of the optimisation process. Recently it has been proven that a Random Gradient hyper-heuristic optimises the LeadingOnes benchmark function in the best runtime achievable with any combination of its low-level heuristics, up to lower order terms. To achieve this runtime, the learning period t, used to evaluate the performance of the currently chosen heuristic, should be set appropriately, i.e., super-linear in the problem size but not excessively larger. In this paper we automate the hyper-heuristic further by allowing it to self-adjust the learning period t during the run. To achieve this we equip the algorithm with a simple self-adjusting mechanism, called 1 - o(1) rule, inspired by the 1/5 rule traditionally used in continuous optimisation. We rigorously prove that the resulting hyper-heuristic solves LeadingOnes in optimal runtime by automatically adapting t and achieving a 1 - o(1) ratio of the desired behaviour. Complementary experiments for realistic problem sizes show the value of t adapting as desired and that the hyper-heuristic with adaptive learning period outperforms the hyper-heuristic with fixed learning periods. `https://dl.acm.org/citation.cfm?id=3205611`.

[259] Daniel Domović, Tomislav Rolich, and Marin Golub. Hyper-heuristic approach for improving marker efficiency. *Autex Research Journal*, 18(4):348–363, 2018. Marker planning is an optimization arrangement problem, where a set of cutting parts need to be placed on a thin paper without overlapping to create a marker an exact diagram of cutting parts that will be cut from a single spread. An optimal marker that utilizes the length of textile material has to be obtained. The aim of this research was to develop novel algorithms for obtaining an efficient marker that would achieve competitive results and optimize the garment production in terms of improving the utilization of textile material. In this research, a novel Grid heuristic was introduced for obtaining a marker, alongside its improvement methods: Grid-BLP and Grid-Shaking. These heuristics were hybridized with genetic algorithm that determined the placement order of cutting parts using the newly introduced All Equal First (AEF) placement order. A novel individual representation for genetic algorithm was designed that was composed of order sequence, rotation detection and the choice of placement algorithm (hyperheuristic). Experiments were conducted to determine the best marker making method, and hyper-heuristic efficiency. The implementation and experiments were conducted in MATLAB using GEATbx toolbox on five datasets from the garment industry: ALBANO, DAGLI, MAO, MARQUES and MAN SHIRT. Marker efficiency in percentage was recorded with best results: 84.50%, 80.13%, 79.54%, 84.67% and 86.02% obtained for the datasets respectively. The most efficient heuristic was Grid-Shaking. Hyper-heuristic applied Grid-Shaking in 88% of times. The created algorithm is independent of cutting

parts' shape. It can produce markers of arbitrary shape and is flexible in terms of expansion to new instances from the garment industry (leather nesting, avoiding damaged areas of material, marker making with materials with patterns). file:///E:/OneDrive/_Literature/domovic2018hyper-marker.pdf.

[260] Bronson Duhart, Fernando Camarena, José Carlos Ortiz-Bayliss, Ivan Amaya, and Hugo Terashima-Marín. An experimental study on ant colony optimization hyper-heuristics for solving the knapsack problem. In *Mexican Conference on Pattern Recognition*, pages 62–71. Springer, 2018. The knapsack problem is a fundamental problem that has been extensively studied in combinatorial optimization. The reason is that such a problem has many practical applications. Several solution techniques have been proposed in the past, but their performance is usually limited by the complexity of the problem. Hence, this paper studies a novel hyper-heuristic approach based on the ant colony optimization algorithm to solve the knapsack problem. The hyper-heuristic is used to produce rules that decide which heuristic to apply given the current problem state of the instance being solved. We test the hyper-heuristic model on sets with a variety of knapsack problem instances. Our resulting data seems promising. https://link.springer.com/chapter/10.1007/978-3-319-92198-3_7.

[261] A. Elhag and E. Ozcan. Data clustering using grouping hyper-heuristics. In *the 18th European Conference on Evolutionary Computation in Combinatorial Optimisation (EvoCOP)*, Parma, Italy, 2018. Grouping problems represent a class of computationally hard to solve problems requiring optimal partitioning of a given set of items with respect to multiple criteria varying dependent on the domain. A recent work proposed a general-purpose selection hyper-heuristic search framework with reusable components, designed for rapid development of grouping hyper-heuristics to solve grouping problems. The framework was tested only on the graph colouring problem domain. Extending the previous work, this study compares the performance of selection hyperheuristics implemented using the framework, pairing up various heuristic/operator selection and move acceptance methods for data clustering. The selection hyper-heuristic performs the search processing a single solution at any decision point and controls a fixed set of generic low level heuristics specifically designed for the grouping problems based on a biobjective formulation. An archive of high quality solutions, capturing the trade-off between the number of clusters and overall error of clustering, is maintained during the search process. The empirical results verify the effectiveness of a successful selection hyper-heuristic, winner of a recent hyper-heuristic challenge for data clustering on a set of benchmark problem instances. http://www.cs.nott.ac.uk/~pszeo/docs/publications/groupingDC.pdf.

[262] Michael G Epitropakis and Edmund K Burke. Hyper-heuristics. *Handbook of Heuristics*, pages 1–57, 2018. This chapter presents a literature review of the main advances in the field of hyper-heuristics, since the publication of a survey paper in 2013. The chapter demonstrates the most recent advances in hyper-

heuristic foundations, methodologies, theory, and application areas. In addition, a simple illustrative selection hyper-heuristic framework is developed as a case study. This is based on the well-known Iterated Local Search algorithm and is presented to provide a tutorial style introduction to some of the key basic issues. A brief discussion about the implementation process in addition to the decisions that had to be made during the implementation is presented. The framework implements an action selection model that operates on the perturbation stage of the Iterated Local Search algorithm to adaptively select among various low-level perturbation heuristics. The performance and efficiency of the developed framework is evaluated across six well-known real-world problem domains. `https://link.springer.com/referenceworkentry/10.1007%2F978-3-319-07153-4_32-1`.

[263] Iztok Fajfar, Árpád Bűrmen, and Janez Puhan. Grammatical evolution as a hyper-heuristic to evolve deterministic real-valued optimization algorithms. *Genetic Programming and Evolvable Machines*, pages 1–32, 2018. Hyper-heuristic methodologies have been extensively and successfully used to generate combinatorial optimization heuristics. On the other hand, there have been almost no attempts to build a hyper-heuristic to evolve an algorithm for solving real-valued optimization problems. In our previous research, we succeeded to evolve a Nelder-Mead-like real function minimization heuristic using genetic programming and the primitives extracted from the original Nelder-Mead algorithm. The resulting heuristic was better than the original Nelder-Mead method in the number of solved test problems but it was slower in that it needed considerably more cost function evaluations to solve the problems also solved by the original method. In this paper we exploit grammatical evolution as a hyper-heuristic to evolve heuristics that outperform the original Nelder-Mead method in all aspects. However, the main goal of the paper is not to build yet another real function optimization algorithm but to shed some light on the influence of different factors on the behavior of the evolution process as well as on the quality of the obtained heuristics. In particular, we investigate through extensive evolution runs the influence of the shape and dimensionality of the training function, and the impact of the size limit set to the evolving algorithms. At the end of this research we succeeded to evolve a number of heuristics that solved more test problems and in fewer cost function evaluations than the original Nelder-Mead method. Our solvers are also highly competitive with the improvements made to the original method based on rigorous mathematical convergence proofs found in the literature. Even more importantly, we identified some directions in which to continue the work in order to be able to construct a productive hyper-heuristic capable of evolving real function optimization heuristics that would outperform a human designer in all aspects. `https://link.springer.com/article/10.1007/s10710-018-9324-5`.

[264] Jesús Guillermo Falcón-Cardona and Carlos A Coello Coello. A multi-objective evolutionary hyper-heuristic based on multiple indicator-based density estimators. In *Proceedings of the Genetic and Evolutionary Computation Conference*,

pages 633–640. ACM, 2018. In recent years, Indicator-based Multi-Objective Evolutionary Algorithms (IB-MOEAs) have become a relatively popular alternative for solving multi-objective optimization problems. IB-MOEAs are normally based on the use of a single performance indicator. However, the effect of the combination of multiple performance indicators for selecting solutions is a topic that has rarely been explored. In this paper, we propose a hyper-heuristic which combines the strengths and compensates for the weaknesses of four density estimators based on R2, IGD+, ?+ and ?p. The selection of the indicator to be used at a particular moment during the search is done using online learning and a Markov chain. Additionally, we propose a novel framework that aims to reduce the computational cost involved in the calculation of the indicator contributions. Our experimental results indicate that our proposed approach can outperform state-of-the-art MOEAs based on decomposition (MOEA/D) reference points (NSGA-III) and the R2 indicator (R2-EMOA) for problems with both few and many objectives. `https://dl.acm.org/citation.cfm?id=3205463`.

[265] Thiago Nascimento Ferreira, Silvia Regina Vergilio, et al. Multiple objective test set selection for software product line testing: evaluating different preference-based algorithms. In *Proceedings of the XXXII Brazilian Symposium on Software Engineering*, pages 162–171. ACM, 2018. The selection of optimal test sets for Software Product Lines (SPLs) is a complex task impacted by many factors and that needs to consider the tester's preferences. To help in this task, Preference-based Evolutionary Multi-objective Algorithms (PEMOAs) have been explored. They use a Reference Point (RP), which represents the user preference and guides the search, resulting in a greater number of solutions in the ROI (Region of Interest). This region contains solutions that are more interesting from the tester's point of view. However, the explored PEMOAs have not been compared yet and the results reported in the literature do not consider many-objective formulations. Such an evaluation is important because in the presence of more than three objectives the performance of the algorithms may change and the number of solutions increases. Considering this fact, this work presents evaluation results of four PEMOAs for selection of products in the SPL testing considering cost, testing criteria coverage, products similarity, and the number of revealed faults, given by the mutation score. The PEMOAs present better performance than traditional algorithms, avoiding uninteresting solutions. We introduce a hyper-heuristic version of the PEMOA R-NSGA-II that presents the best results in a general case. `https://dl.acm.org/citation.cfm?id=3266275`.

[266] Gian Fritsche and Aurora Pozo. A hyper-heuristic collaborative multi-objective evolutionary algorithm. In *the 7th Brazilian Conference on Intelligent Systems (BRACIS)*, pages 354–359. IEEE, 2018. Many-objective optimization problems (MaOPs) are a great challenge for multi-objective evolutionary algorithms (MOEAs) and lately, several MOEAs have been proposed. Each MOEA uses different algorithmic components during the search process and performs differ-

ently. Therefore, there is no single algorithm able to achieve the best results in all problems. The collaboration of multiple MOEAs and the use of hyperheuristics can help to create a searchability able to achieve good results in a wide range of problem instances. In this context, this research proposes a model for collaboration of MOEAs guided by hyper-heuristic, called HHcMOEA. In HHcMOEA, the hyper-heuristic controls and mix MOEAs, automatically deciding which one to apply during the search process. On the other hand, HHcMOEA also incorporates exchange of information between the MOEAs. And, a fitness improvement rate metric, based on the R2 indicator to decide about the quality of the application of an MOEA. HHcMOEA is implemented using a set of MOEAs with diverse characteristics. An experiment is used to evaluate HHcMOEA in two versions: with and without information exchange. Although, the two versions of HHcMOEA are compared to the MOEAs applied alone. The empirical evaluation used a set of benchmark problems with different properties. The proposed model achieved the best result or equivalent to the best in almost all problems. Still, the results were deteriorated when the information exchange strategy was not used. `https://ieeexplore.ieee.org/abstract/document/8575639`.

[267] Richard Gonçalves, Carolina Almeida, Riccardo Lüders, and Myriam Delgado. A new hyper-heuristic based on a contextual multi-armed bandit for many-objective optimization. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 1–8. IEEE, 2018. Hyper-Heuristics are high-level methodologies which select or generate heuristics. Despite their success, there are only few hyper-heuristics developed for many-objective optimization. Our approach, namely MOEA/D-LinUCB, combines the MOEA/D framework with a new selection hyper-heuristic to solve many-objective problems. It uses an innovative Contextual Multi-Armed Bandit (MAB) to determine the low level heuristic (Differential Evolution mutation strategy) that should be applied to each individual during MOEA/D execution. The main advantage of using Contextual MAB is to include information about the current search state into the selection procedure. We tested MOEA/D-LinUCB on a well established set of 9 instances from the WFG benchmark for a number of objectives varying from 3 to 20. The IGD indicator and Kruskal-Wallis and Dunn-Sidak's statistical tests are applied to evaluate the algorithm performance. Four variants of the proposed algorithm are compared with each other to define a proper configuration. A properly configured MOEA/D-LinUCB is then compared with MOEA/D-FRRMAB and MOEAID-DRA-two well-known MOEA/D-based algorithms. Results show that MOEA/D-LinUCB performs well, particularly when the number of objectives is 10 or greater. Therefore, MOEA/D-LinUCB can be considered as a promising many-objective Hyper-Heuristic. `https://ieeexplore.ieee.org/abstract/document/8477930`.

[268] Suzanne S Habashi, Cherif Salama, Ahmed H Yousef, and Hossam MA Fahmy. Adaptive diversifying hyper-heuristic based approach for timetabling problems. In *IEEE 9th Annual Information Technology, Electronics and Mobile Communi-*

cation Conference (IEMCON), pages 259–266. IEEE, 2018. Combinatorial optimization is the search for an optimal configuration of a set of variables to accomplish certain goals. One of the well-known combinatorial optimization problems is the timetabling problem, with a lot of research conducted in the past few decades to investigate a variety of methodologies to solve it. One of the blossoming recent methodologies is hyper-heuristics, which attempts to automate the algorithm design process so that it would be able to work with different sets of problem domains. This paper focuses on the university course timetabling problem (UCTP) as the case of study, and proposes the use of a competitive iterated local search approach strengthened with an add-delete hyper-heuristic. The hyper-heuristic utilizes an adaptive heuristic generation mechanism through a variable-sized list of add and delete operations. The algorithm was enhanced with the use of a novel approach to construct a good feasible initial solution and strengthened with a diversifying mechanism to allow more exploration over large search spaces to find a global rather than local near optimal solution. The proposed work was tested with the ITC2007 benchmark datasets, and experiments show promising results and give better average performance when compared to recent approaches in the literature that work on similar timetabling problems. `https://ieeexplore.ieee.org/abstract/document/8615035`.

[269] Mona Hamid. New local search in the space of infeasible solutions framework for the routing of vehicles, 2018. Combinatorial optimisation problems (COPs) have been at the origin of the design of many optimal and heuristic solution frameworks such as branch-and-bound algorithms, branch-and-cut algorithms, classical local search methods, metaheuristics, and hyperheuristics. This thesis proposes a refined generic and parametrised infeasible local search (GPILS) algorithm for solving COPs and customises it to solve the traveling salesman problem (TSP), for illustration purposes. In addition, a rule-based heuristic is proposed to initialise infeasible local search, referred to as the parameterised infeasible heuristic (PIH), which allows the analyst to have some control over the features of the infeasible solution he/she might want to start the infeasible search with. A recursive infeasible neighbourhood search (RINS) as well as a generic patching procedure to search the infeasible space are also proposed. These procedures are designed in a generic manner, so they can be adapted to any choice of parameters of the GPILS, where the set of parameters, in fact for simplicity, refers to set of parameters, components, criteria and rules. Furthermore, a hyperheuristic framework is proposed for optimizing the parameters of GPILS referred to as HH-GPILS. Experiments have been run for both sequential (i.e. simulated annealing, variable neighbourhood search, and tabu search) and parallel hyperheuristics (i.e., genetic algorithms / GAs) to empirically assess the performance of the proposed HH-GPILS in solving TSP using instances from the TSPLIB. Empirical results suggest that HH-GPILS delivers an outstanding performance. Finally, an offline learning mechanism is proposed as a seeding technique to improve the performance and speed of the proposed parallel HH-GPILS. The proposed of-

fline learning mechanism makes use of a knowledge-base to keep track of the best performing chromosomes and their scores. Empirical results suggest that this learning mechanism is a promising technique to initialise the GA's population. `https://www.era.lib.ed.ac.uk/handle/1842/33177`.

[270] Libin Hong. Hyper-heuristic approaches to automatically designing heuristics as mutation operators for evolutionary programming on function classes, 2018. A hyper-heuristic is a search method or learning mechanism for selecting or generating heuristics to solve computational search problems. Researchers classify hyper-heuristics according to the source of feedback during learning: Online learning hyper-heuristics learn while solving a given instance of a problem; Offline learning hyper-heuristics learn from a set of training instances, a method that can generalise to unseen instances. Genetic programming (GP) can be considered a specialization of the more widely known genetic algorithms (GAs) where each individual is a computer program. GP automatically generates computer programs to solve specified tasks. It is a method of searching a space of computer programs. GP can be used as a kind of hyper-heuristic to be a learning algorithm when it uses some feedback from the search process. Our research mainly uses genetic programming as offline hyper-heuristic approach to automatically design various heuristics for evolutionary programming. `http://eprints.nottingham.ac.uk/52348/`.

[271] Libin Hong, John H Drake, John R Woodward, and Ender Özcan. A hyper-heuristic approach to automated generation of mutation operators for evolutionary programming. *Applied Soft Computing*, 62:162–175, 2018. Evolutionary programming can solve black-box function optimisation problems by evolving a population of numerical vectors. The variation component in the evolutionary process is supplied by a mutation operator, which is typically a Gaussian, Cauchy, or Levy probability distribution. In this paper, we use genetic programming to automatically generate mutation operators for an evolutionary programming system, testing the proposed approach over a set of function classes, which represent a source of functions. The empirical results over a set of benchmark function classes illustrate that genetic programming can evolve mutation operators which generalise well from the training set to the test set on each function class. The proposed method is able to outperform existing human designed mutation operators with statistical significance in most cases, with competitive results observed for the rest. `https://www.sciencedirect.com/science/article/pii/S1568494617306051`.

[272] Baldomero Imbernon, Jose M Cecilia, Jose-Matias Cutillas-Lozano, and Domingo Gimenez. Designing hyperdock: A parallel hyperheuristic method for virtual screening. In *Proceedings of the 47th International Conference on Parallel Processing Companion*, page 10. ACM, 2018. Virtual Screening (VS) methods aid clinical research by predicting the interaction of ligands with pharmacological targets, thus accelerating the process of finding new drugs. The computational requirements of VS models, along with the size of the databases, containing up

to millions of biological macromolecular structures, propitiates the use of High-Performance Computing. METADOCK is a tool for the application of metaheuristics to VS in heterogeneous clusters of computers based on CPU and GPU. It facilitates the efficient application of several metaheuristics in parallel computational systems. HYPERDOCK represents a step forward; the exploration for satisfactory metaheuristics is systematically approached by means of hyper-heuristics working on top of the metaheuristic schema of METADOCK. The parallelism of METADOCK is intrinsically exploited in HYPERDOCK, which also includes parallelism at its own level. HYPERDOCK helps to generate better ligand-receptor bindings. `https://dl.acm.org/citation.cfm?id=3229735`.

[273] Warren G Jackson, Ender Özcan, and Robert I John. Move acceptance in local search metaheuristics for cross-domain search. *Expert Systems with Applications*, 109:131–151, 2018. Metaheuristics provide high-level instructions for designing heuristic optimisation algorithms and have been successfully applied to a range of computationally hard real-world problems. Local search metaheuristics operate under a single-point based search framework with the goal of iteratively improving a solution in hand over time with respect to a single objective using certain solution perturbation strategies, known as move operators, and move acceptance methods starting from an initially generated solution. Performance of a local search method varies from one domain to another, even from one instance to another in the same domain. There is a growing number of studies on more general search methods referred to as cross-domain search methods, or hyper-heuristics, that operate at a high-level solving characteristically different problems, preferably without expert intervention. This paper provides a taxonomy and overview of existing local search metaheuristics along with an empirical study into the effects that move acceptance methods, as components of single-point based local search metaheuristics, have on the cross-domain performance of such algorithms for solving multiple combinatorial optimisation problems. The experimental results across a benchmark of nine different computationally hard problems highlight the shortcomings of existing and well-known methods for use as components of cross-domain search methods, despite being re-tuned for solving each domain. `https://www.sciencedirect.com/science/article/pii/S0957417418302835`.

[274] Helson Luiz Jakubovski Filho, Thiago Nascimento Ferreira, and Silvia Regina Vergilio. Incorporating user preferences in a software product line testing hyper-heuristic approach. In *2018 IEEE Congress on Evolutionary Computation (CEC)*, pages 1–8. IEEE, 2018. To perform the variability testing of Software Product Lines (SPLs) a set of products, represented in the Feature Model (FM), should be selected. Such selection is impacted by conflicting factors and has been efficiently solved by Evolutionary Multi-objective Algorithms in combination with hyper-heuristics. However, many times there is a cost budget or coverage level to be satisfied during the test, which are difficult to be incorporated as objective functions. Due to this, the choice of the best solution to be used in practice is not

always easy. To deal with this situation, this paper introduces a preference-based hyper-heuristic approach to solve this problem. The approach implements the preference-based algorithm r-NSGA-II working with the random and FRRMAB selection methods. This last one uses a reward function based on r-dominance concept that takes into consideration a Reference Point provided by the tester. Our approach outperforms existing approaches, as well as the traditional algorithm r-NSGA-II, generating a reduced number of non-interesting solutions from the tester's point of view, that is, considering the provided Region of Interest (ROI). https://ieeexplore.ieee.org/abstract/document/8477803/.

[275] Guozhang Jiang, Xiaowu Chen, Bingze Wu, Feng Xiang, and Gongfa Li. Hyper-heuristic for steelmaking casting rescheduling based on strong disturbance. *International Journal of Wireless and Mobile Computing*, 14(3):229–240, 2018. The stochastic disturbance in steelmaking casting often leads to failure of the original production plan. Rescheduling is necessary for the steel manufacturing system. In the background of the increasing scale of scheduling and the numerous kinds of disturbance, the different algorithms are designed for different rescheduling problems, which will greatly increase the workload of the scheduling. In this paper, the disturbances are classified as strong disturbance and weak disturbance, and a rescheduling driven rule of strong disturbance is designed. Especially, the various disturbances impact on the production plan could be reflected in a time change, so a rescheduling model under time strong disturbance is established. In this paper, a hyper-heuristic genetic algorithm (HHGA) is designed based on the heuristic rules and genetic algorithms. This combination is intended to reduce the generation time of rescheduling plan under the strong disturbance. In the end, the simulation results indicate the success with the HHGA. https://www.inderscienceonline.com/doi/abs/10.1504/IJWMC.2018.092365.

[276] Guozhang Jiang, Hushi Dong, Le Yang, Gongfa Li, and Feng Xiang. Hyper-heuristic genetic algorithm for steelmaking continuous casting rescheduling based on strong disturbance of task. *International Journal of Wireless and Mobile Computing*, 15(3):231–240, 2018. The problem of steelmaking and continuous casting rescheduling is the key problem in the steel production scheduling. Aiming at the problem of steelmaking and continuous casting rescheduling under strong disturbance of task in this paper, a fast and efficient hyperheuristic genetic algorithm is proposed to minimise the difference degree before and after the scheduling adjustment as the objective function. In the framework of the hyperheuristic algorithm, the high layer strategy is designed as a self-learning heuristic rule selection strategy, the low layer design is a series of genetic operators related to steelmaking and continuous casting scheduling, optimal solution of update iteration by searching for each other through high and low two layers of strategy in the effective threshold. Simulation experiments show that the effectiveness of the algorithm can meet the needs of real-time and stable production to the maximum extent. https://www.inderscienceonline.com/doi/abs/10.1504/IJWMC.2018.096006.

[277] Neeti Kashyap and A Charan Kumari. Hyper-heuristic approach for service composition in internet of things. *Electronic Government, an International Journal*, 14(4):321–339, 2018. The state-of-the-art on internet of things (IoT), deals with its definition, its architecture, ontology of its components, networking and middleware. IoT contains a large number of devices which are placed around the world. Every device provides an IoT service. As devices joining the IoT are increasing, the services are also rising proportionately. In order to meet the user requirements for the complex application, we need a collection of suitable services, also known as service composition. Identifying the optimal service composition in IoT is a challenging task. This paper presents a hyper-heuristic approach, a latest trend in the field of stochastic optimisation, for the solution of service composition problem in internet of things. The efficacy of the hyper-heuristic approach is tested on 25 test data instances and the results are compared with genetic algorithm, the most widely used global optimisation technique. `https://www.inderscienceonline.com/doi/abs/10.1504/EG.2018.095546`.

[278] D Rajesh Kumar and A Shanmugam. A hyper heuristic localization based cloned node detection technique using gsa based simulated annealing in sensor networks. In *Cognitive Computing for Big Data Systems Over IoT*, pages 307–335. Springer, 2018. Due to inadequate energy resources, data aggregation from multiple sensors in Wireless Sensor Networks (WSN) is typically accomplished by clustering. But such data aggregation is recognized to be highly susceptible to clone attacks owing to the unattended nature of the network. Thus, ascertaining trustiness of the sensor nodes is crucial for WSN. Though numerous methods for cloned attack node isolation are provided in recent years, energy efficiency is the most significant issues to be handled. In this work, a Residual Energy and GSA based Simulated Annealing (RE-GSASA) for detecting and isolating the cloned attack node in WSN is given. Residual Energy-based Data Aggregation in WSN initially uses residual energy because the basis to perform aggregation technique with the sensor node possessing the maximum residual energy as the Cluster Head (CH). Next, Location-based Cloned attack on cluster nodes is given to enhance the clone detection probability rate. Here, the location and residual energy is taken into account to identify the presence of cloned attack nodes within the network. Finally, Gravitational Search Algorithm with global search ability is investigated to identify the cloned attack nodes and performs isolation through local optimal simulated annealing model. Simulation results demonstrate that RE-GSASA provides optimized energy consumption and improves cloned attack detection probability by minimizing the cloned attack detection time. `https://link.springer.com/chapter/10.1007/978-3-319-70688-7_13`.

[279] Amina Lamghari and Roussos Dimitrakopoulos. Hyper-heuristic approaches for strategic mine planning under uncertainty. *Computers & Operations Research*, 2018. A hyper-heuristic refers to a search method or a learning mechanism for selecting or generating heuristics to solve computational search prob-

lems. Operating at a level of abstraction above that of a metaheuristic, it can be seen as an algorithm that tries to find an appropriate solution method at a given decision point rather than a solution. This paper introduces a new hyper-heuristic that combines elements from reinforcement learning and tabu search. It is applied to solve two complex stochastic scheduling problems arising in mining, namely the stochastic open-pit mine production scheduling problem with one processing stream (SMPS) and one of its generalizations, SMPS with multiple processing streams and stockpiles (SMPS+). The performance of the new hyper-heuristic is assessed by comparing it to several solution methods from the literature: problem-specific algorithms tailored for the two problems addressed in the paper and general hyper-heuristics, which use only limited problem-specific information. The computational results indicate that not only is the proposed new hyper-heuristic approach superior to the other hyper-heuristics, but it also provides results that are comparable to or improve on the results obtained by the state-of-the-art problem-specific methods. https://www.sciencedirect.com/science/article/pii/S0305054818302958.

[280] Longlong Leng, Yanwei Zhao, Zheng Wang, Hongwei Wang, and Jingling Zhang. Shared mechanism-based self-adaptive hyperheuristic for regional low-carbon location-routing problem with time windows. *Mathematical Problems in Engineering*, 2018, 2018. In this paper, we consider a variant of the location-routing problem (LRP), namely, the regional low-carbon LRP with reality constraint conditions (RLCLRPRCC), which is characterized by clients and depots that located in nested zones with different speed limits. The RLCLRPRCC aims at reducing the logistics total cost and carbon emission and improving clients satisfactory by replacing the travel distance/time with fuel consumption and carbon emission costs under considering heterogeneous fleet, simultaneous pickup and delivery, and hard time windows. Aiming at this project, a novel approach is proposed: hyperheuristic (HH), which manipulates the space, consisted of a fixed pool of simple operators such as "shift" and "swap" for directly modifying the space of solutions. In proposed framework of HH, a kind of shared mechanism-based self-adaptive selection strategy and self-adaptive acceptance criterion are developed to improve its performance, accelerate convergence, and improve algorithm accuracy. The results show that the proposed HH effectively solves LRP/LRPSPD/RLCLRPRCC within reasonable computing time and the proposed mathematical model can reduce 2.6% logistics total cost, 27.6% carbon emission/fuel consumption, and 13.6% travel distance. Additionally, several managerial insights are presented for logistics enterprises to plan and design the distribution network by extensively analyzing the effects of various problem parameters such as depot cost and location, clients' distribution, heterogeneous vehicles, and time windows allowance, on the key performance indicators, including fuel consumption, carbon emissions, operational costs, travel distance, and time. https://www.hindawi.com/journals/mpe/2018/8987402/abs/.

[281] W. Li, E. Ozcan, and R. John. A learning automata based multiobjective hyper-heuristic. *IEEE Transactions on Evolutionary Computation*, 2018. Metaheuristics, being tailored to each particular domain by experts, have been successfully applied to many computationally hard optimisation problems. However, once implemented, their application to a new problem domain or a slight change in the problem description would often require additional expert intervention. There is a growing number of studies on reusable cross-domain search methodologies, such as, selection hyper-heuristics, which are applicable to problem instances from various domains, requiring minimal expert intervention or even none. This study introduces a new learning automata based selection hyper-heuristic controlling a set of multiobjective metaheuristics. The approach operates above three well-known multiobjective evolutionary algorithms and mixes them, exploiting the strengths of each algorithm. The performance and behaviour of two variants of the proposed selection hyper-heuristic, each utilising a different initialisation scheme are investigated across a range of unconstrained multiobjective mathematical benchmark functions from two different sets and the real-world problem of vehicle crashworthiness. The empirical results illustrate the effectiveness of our approach for cross-domain search, regardless of the initialisation scheme, on those problems when compared to each individual multiobjective algorithm. Moreover, both variants perform signicantly better than some previously proposed selection hyper-heuristics for multiobjective optimisation, thus signicantly enhancing the opportunities for improved multiobjective optimisation. `http://ieeexplore.ieee.org/document/8231198/`.

[282] Andrei Lissovoi, Pietro S Oliveto, and John Alasdair Warwicker. Hyper-heuristics can achieve optimal performance for pseudo-boolean optimisation. *arXiv preprint arXiv:1801.07546*, 2018. Selection hyper-heuristics are randomised search methodologies which choose and execute heuristics from a set of low-level heuristics. Recent research for the LeadingOnes benchmark function has shown that the standard Simple Random, Permutation, Random Gradient, Greedy and Reinforcement Learning selection mechanisms show no effects of learning. The idea behind the learning mechanisms is to continue to exploit the currently selected heuristic as long as it is successful. However, the probability that a promising heuristic is successful in the next step is relatively low when perturbing a reasonable solution to a combinatorial optimisation problem. In this paper we generalise the simple selection-perturbation mechanisms so success can be measured over some fixed period of time tau, rather than in a single iteration. We present a benchmark function where it is necessary to learn to exploit a particular low-level heuristic, rigorously proving that it makes the difference between an efficient and an inefficient algorithm. For LeadingOnes we prove that the Generalised Random Gradient, and the Generalised Greedy Gradient hyper-heuristics achieve optimal performance, while Generalised Greedy, although not as fast, still outperforms Random Local Search. The performance of the former two hyper-heuristics improves as the number of operators to choose from increases, while that of

the Generalised Greedy hyper-heuristic does not. Experimental analyses confirm these results for realistic problem sizes and shed some light on the best choices of the parameter tau in various situations. https://arxiv.org/abs/1801.07546.

[283] Mariana Macedo, Carlos Henrique Macedo dos Santos, Eronita Maria Luizines Van Leijden, Joao Fausto Lorenzato de Oliveira, Fernando Buarque de Lima Neto, and Hugo Siqueira. Hyper-heuristics using genetic programming to time series forecasting. In *2018 IEEE Latin American Conference on Computational Intelligence (LA-CCI)*, pages 1–6. IEEE, 2018. Time series forecasting methods allow companies and researchers to analyze and predict data that change over time, such as stock exchange and climate change. However, because of their complexity and dynamic nature, each type of time series ideally should be modeled using ad-hoc algorithms. To create a more general methodology, we proposed a combination of meta-heuristics, led by Genetic Programming (GP), to enhance the overall prediction ability. GP may not be as popular as the Box & Jenkins methodology for forecasting tasks, but the literature shows appealing outcomes. Swarm intelligence is also a powerful mechanism for searching patterns in large data spaces. Thus, we investigated and proposed a hybrid method using GP together with the Fish School Search (FSS) algorithm, where the latter is used to select optimal parameters for the former. We also used local search techniques for preventing the Genetic Programming to get stuck in local minima, by refining the coefficients on the GP expression. Our proposal was compared to standard autoregressive integrated moving average (ARIMA) model, exponential smoothing (ETS) and standard GP. The proposed method achieved promising results in one-step-ahead predictions and was applied to a well-known time series data library. https://ieeexplore.ieee.org/abstract/document/8625240.

[284] Jordan MacLachlan, Yi Mei, Juergen Branke, and Mengjie Zhang. An improved genetic programming hyper-heuristic for the uncertain capacitated arc routing problem. In *Australasian Joint Conference on Artificial Intelligence*, pages 432–444. Springer, 2018. This paper uses a Genetic Programming Hyper-Heuristic (GPHH) to evolve routing policies for the Uncertain Capacitated Arc Routing Problem (UCARP). Given a UCARP instance, the GPHH evolves feasible solutions in the form of decision making policies which decide the next task to serve whenever a vehicle completes its current service. Existing GPHH approaches have two drawbacks. First, they tend to generate small routes by routing through the depot and refilling prior to the vehicle being fully loaded. This usually increases the total cost of the solution. Second, existing GPHH approaches cannot control the extra repair cost incurred by a route failure, which may result in higher total cost. To address these issues, this paper proposes a new GPHH algorithm with a new No-Early-Refill filter to prevent generating small routes, and a novel Flood Fill terminal to better handle route failures. Experimental studies show that the newly proposed GPHH algorithm significantly outperforms the existing GPHH approaches on the Ugdb and Uval benchmark datasets. Fur-

ther analysis has verified the effectiveness of both the new filter and terminal. https://link.springer.com/chapter/10.1007/978-3-030-03991-2_40.

[285] Jiachen Mao, Yangyang Fu, Afshin Afshari, Peter R Armstrong, and Leslie K Norford. Optimization-aided calibration of an urban microclimate model under uncertainty. *Building and Environment*, 143:390–403, 2018. Simulation models play an important role in the design, analysis, and optimization of modern energy and environmental systems at building or urban scale. However, due to the extreme complexity of built environments and the sheer number of interacting parameters, it is difficult to obtain an accurate representation of real-world systems. Thus, model calibration and uncertainty analysis hold a particular interest, and it is necessary to evaluate to what degree simulation models are imperfect before implementing them during the decision-making process. In contrast to the extensive literature on the calibration of building performance models, little has been reported on how to automatically calibrate physics-based urban microclimate models. This paper illustrates a general methodology for automatic model calibration and applies it to an urban microclimate system. The Urban Weather Generator (UWG) is selected as the underlying simulation engine for an optimization-aided calibration based on the urban outdoor air temperature in an existing district area located in downtown Abu Dhabi (UAE) during 2017. In particular, given the time-constrained nature of engineering applications, an online hyper-heuristic evolutionary algorithm (EA) is proposed and developed in order to accelerate the calibration process. The validation results show that, in single-objective optimization, the online hyper-heuristics could robustly help EA produce quality solutions with smaller uncertainties at much less computational cost. In addition, the resulting calibrated solutions are able to capture weekly-average and hourly diurnal profiles of the urban outdoor air temperature similar to the measurements for certain periods of the year. https://www.sciencedirect.com/science/article/pii/S0360132318304426.

[286] Aritz Martinez, Eneko Osaba, Miren Nekane Bilbao, and Javier Del Ser. Let nature decide its nature: On the design of collaborative hyperheuristics for decentralized ephemeral environments. *Future Generation Computer Systems*, 2018. The research community has traditionally aimed at the derivation and development of metaheuristic solvers, suited to deal with problems of very diverse characteristics. Unfortunately, it is often the case that new metaheuristic techniques are presented and assessed in a reduced set of cases, mostly due to the lack of computational resources to undertake extensive performance studies over a sufficiently diverse set of optimization benchmarks. This manuscript explores how ephemeral environments could be exploited to efficiently construct metaheuristic algorithms by virtue of a collaborative, distributed nature-inspired hyperheuristic framework specifically designed to be deployed over unreliable, uncoordinated computation nodes. To this end, the designed framework defines two types of nodes (trackers and peers, similarly to peer-to-peer networks), both reacting resiliently to unex-

pected disconnections of nodes disregarding their type. Peer nodes exchange their populations (i.e. constructed algorithms) asynchronously, so that local optima are avoided at every peer thanks to the contribution by other nodes. Furthermore, the overall platform is fully scalable, allowing its users to implement and share newly derived operators and fitness functions so as to enrich the diversity and universality of the heuristic algorithms found by the framework. Results obtained from in-lab experiments with a reduced number of nodes are discussed to shed light on the evolution of the best solution of the framework with the number of connected peers and the tolerance of the network to node disconnections. `https://www.sciencedirect.com/science/article/pii/S0167739X17323555`.

[287] A. Masood, G. Chen, Y. Mei, and M. Zhang. Reference point adaption method for genetic programming hyper-heuristic in many-objective job shop scheduling. In *the 18th European Conference on Evolutionary Computation in Combinatorial Optimisation (EvoCOP)*, Parma, Italy, 2018. Job Shop Scheduling (JSS) is considered to be one of the most significant combinatorial optimization problems in practice. It is widely evidenced in the literature that JSS usually contains many (four or more) potentially conflicting objectives. One of the promising and successful approaches to solve the JSS problem is Genetic Programming Hyper-Heuristic (GP-HH). This approach automatically evolves dispatching rules for solving JSS problems. This paper aims to evolve a set of effective dispatching rules for many-objective JSS with genetic programming and NSGA-III. NSGA-III originally defines uniformly distributed reference points in the objective space. Thus, there will be few reference points with no Pareto optimal solutions associated with them; especially, in the cases with discrete and non-uniform Pareto front, resulting in many useless reference points during evolution. In other words, these useless reference points adversely affect the performance of NSGA-III and genetic programming. To address the above issue, in this paper a new reference point adaptation mechanism is proposed based on the distribution of the candidate solutions. We evaluated the performance of the proposed mechanism on many-objective benchmark JSS instances. Our results clearly show that the proposed strategy is promising in adapting reference points and outperforms the existing state-of-the-art algorithms for many-objective JSSP. `http://www.evostar.org/2018/cfp_evocop.php#abstracts`.

[288] Yi Mei and Mengjie Zhang. Genetic programming hyper-heuristic for multi-vehicle uncertain capacitated arc routing problem. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO) Companion*, pages 141–142. ACM, 2018. This paper investigates evolving routing policy for general Uncertain Capacitated Arc Routing Problems (UCARP) with any number of vehicles, and for the first time, designs a novel model for online decision making (i.e. meta-algorithm) for multiple vehicles in service simultaneously. Then, we develop a GPHH based on the meta-algorithm. The experimental studies show the GPHH can evolve much better policies than the state-of-the-art man-

ually designed policy. In addition, the reusability of the evolved policies dramatically decreases when the number of vehicles changes, which suggests a retraining process when a new vehicle is brought or an existing vehicle breaks down. `https://dl.acm.org/citation.cfm?id=3205651.3205661`.

[289] Yi Mei and Mengjie Zhang. Genetic programming hyper-heuristic for stochastic team orienteering problem with time windows. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 1–8. IEEE, 2018. This paper investigates the stochastic team orienteering problem with time windows, which is a well known problem to model personalised tourist trip design. Specifically, we consider the stochastic visit duration, which may make preplanned trip infeasible. Existing studies focus on optimising robust solutions in advance, which is not effective in adjusting the subsequent trip in real time. Decision making policies, on the other hand, are effective heuristics to this end. However, it is very challenging to manually design effective policies. In this paper, we investigate automatically evolving policies for the stochastic team orienteering problem with time windows by genetic programming hyper-heuristics. We designed novel problem-specific features for the terminal set, and a meta-algorithm for fitness evaluation. Furthermore, we developed two look-ahead features that can provide more fruitful information than the basic features for real-time decision making. The experimental studies showed that the proposed genetic programming hyper-heuristic can evolve policies that are much better than the manually designed policies. In addition, it seems that the look-ahead features are not so effective when directly included in the terminals. This suggests the requirement of more intelligent ways of incorporating lookahead information. `https://ieeexplore.ieee.org/abstract/document/8477983`.

[290] Ahmad Muklason, Putri C Bwananesia, Sasmi Hidayatul YT, Nisa D Angresti, and Vicha Azthanty Supoyo. Automated examination timetabling optimization using greedy-late acceptance-hyperheuristic algorithm. In *International Conference on Electrical Engineering and Computer Science (ICECOS)*, pages 201–206. IEEE, 2018. Due to its non-deterministic polinomial (NP)-hard nature, exam timetabling problem is one of challenging combinatorial optimisation problems. Therefore, it attracts researchers especially in operation research and artificial intelligence fields for decades. Since the problem is very complex, exam timetable in many universities is developed manually which is very time consuming. This paper presents a new hybrid algorithm, i.e. greedy-late acceptance within hyper-heuristic framework to generate and optimise exam timetable automatically. Greedy algorithm is used to generate initial solution, whereas late acceptance is used as move acceptance strategy. The algorithm is simple but proven powerfull. The algorithm is tested over two datasets from real-world exam timetabling problem from Information Systems Department, Institut Teknologi Sepuluh Nopember (ITS). Over 11 different scenarios, the experimental results show that in addition to its ability to generate feasible solution, the algorithm

also could produce more optimal solutions compared to the timetables generated manually. https://ieeexplore.ieee.org/abstract/document/8605194.

[291] Bahareh Nikpour and Hossein Nezamabadi-pour. HTSS: a hyper-heuristic training set selection method for imbalanced data sets. *Iran Journal of Computer Science*, pages 1–20, 2018. Imbalanced data sets are those in which data samples have uneven distribution amongst the classes. When classifying such data, classical classifiers encounter problem; hence, this problem has become a challenging issue in the field of machine learning. To weaken this problem, we propose a novel hyper-heuristic algorithm, called HTSS, to select the best training samples in this paper. In other words, the best training sample subset is chosen with the goal of enhancing the performance of classifier when confronting imbalanced data. To do so, some local search algorithms and a choice function are incorporated with a global search algorithm to improve its effectiveness. The global search used in this paper is binary quantum inspired gravitational search algorithm (BQIGSA) which is a recently proposed metaheuristic search for optimization of binary encoded problems. Experiments are performed on 75 imbalanced data sets, and G-mean and AUC measures are employed for evaluation. The results of comparing the proposed method with other state of the art algorithms show the superiority of the proposed HTSS method. https://link.springer.com/article/10.1007/s42044-018-0009-2.

[292] Thambo Nyathi and Nelishia Pillay. Comparison of a genetic algorithm to grammatical evolution for automated design of genetic programming classification algorithms. *Expert Systems with Applications*, 104:213–234, 2018.

[293] Paola P Oteiza, Diego A Rodríguez, and Nélida B Brignole. Parallel cooperative optimization through hyperheuristics. In *Computer Aided Chemical Engineering*, volume 44, pages 805–810. Elsevier, 2018. A hyperheuristics that coordinates the interaction between various metaheuristic techniques is presented. The proposed algorithm, which we called Parallel Optimizer With Hyperheuristics (POWH), includes a Genetic Algorithm, Simulated Annealing, and Ant Colony Optimization. In view of the need to escape from local optima, information exchanges take place between these metaheuristics. In this way, it is possible to take advantage of each metaheuristics' particular strengths during the search process. Testing related to the hyperheuristic approach was carried out by using the following real-life case studies: I. the optimal design of a subsea pipeline network and II. the urban bus-transit optimal planning. In both cases, a satisfactory reduction of the computational time was achieved due to the parallel implementation that allowed several metaheuristics to run simultaneously. Moreover, better results were also obtained thanks to the parallel cooperative combination of metaheuristics compared with serial executions. https://www.sciencedirect.com/science/article/pii/B9780444642417501294.

[294] Paola P Oteiza, Diego A Rodríguez, and Nélida B Brignole. Parallel hyper-

heuristic algorithm for the design of pipeline networks. *Industrial & Engineering Chemistry Research*, 57(42):14307–14314, 2018. A hyperheuristic optimization technique to reduce computational times for the design of pipeline networks is presented. The proposed strategy is an A-team approach comprising the guided execution of three metaheuristics: a genetic algorithm, simulated annealing, and an ant colony optimization. Besides, a specialized learning mechanism for information exchange was defined in order to speed up the search process. Moreover, the algorithm was implemented in parallel so as to allow several metaheuristics to run simultaneously, thus achieving a significant reduction of time overhead. In the algorithmic design, realistic scenarios were employed so as to appraise the impact of each agent on optimization efficiency. The cases correspond to real-world offshore infrastructures to be located in the Argentinian marine platform. They were also analyzed to illustrate the validity and suitability of the proposed approach. This optimization technique proved to be competitive since it is able to explore a wide search space fast, yielding satisfactory solutions. `https://pubs.acs.org/doi/abs/10.1021/acs.iecr.8b02818`.

[295] Arunkumar Panneerselvam and Bhuvaneswari Subbaraman. Hyper heuristic mapreduce workflow scheduling in cloud. In *Proceedings of the 2nd International conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC 2018)*, pages 691–693. IEEE, 2018. The Advancement in the field of computing requires new technologies and algorithms for efficient processing of large scale data such as Big Data. Distributed environments such as Cloud are prominent in storing and processing Big Data. Hadoop is a framework for processing Big Data. Hadoop follows MapReduce technique to process data in parallel. Today MapReduce workflows are extensively used in large scale scientific applications which are executed in cloud. Cloud offers rented resources for scheduling MapReduce workflows. Hyper Heuristic technique can be efficiently used for efficient scheduling of MapReduce task to the cloud resources. This paper explores the basis of MapReduce workflow execution in IaaS cloud and application of Hyper Heuristic technique in resource provisioning. `https://ieeexplore.ieee.org/abstract/document/8653677`.

[296] John Park, Yi Mei, Su Nguyen, Gang Chen, and Mengjie Zhang. An investigation of ensemble combination schemes for genetic programming based hyper-heuristic approaches to dynamic job shop scheduling. *Applied Soft Computing*, 63:72–86, 2018. Genetic programming based hyper-heuristic (GP-HH) approaches that evolve ensembles of dispatching rules have been effectively applied to dynamic job shop scheduling (JSS) problems. Ensemble GP-HH approaches have been shown to be more robust than existing GP-HH approaches that evolve single dispatching rules for dynamic JSS problems. For ensemble learning in classification, the design of how the members of the ensembles interact with each other, e.g., through various combination schemes, is important for developing effective ensembles for specific problems. In this paper, we investigate and carry out systematic analysis

for four popular combination schemes. They are majority voting, which has been applied to dynamic JSS, followed by linear combination, weighted majority voting and weighted linear combination, which have not been applied to dynamic JSS. In addition, we propose several measures for analysing the decision making process in the ensembles evolved by GP. The results show that linear combination is generally better for the dynamic JSS problem than the other combination schemes investigated. In addition, the different combination schemes result in significantly different interactions between the members of the ensembles. Finally, the analysis based on the measures shows that the behaviours of the evolved ensembles are significantly affected by the combination schemes. Weighted majority voting has bias towards single members of the ensembles. `https://www.sciencedirect.com/science/article/pii/S156849461730683X`.

[297] Nelishia Pillay and Rong Qu. *Hyper-Heuristics: Theory and Applications*, chapter Advances in Hyper-Heuristics, pages 91–97. Springer, 2018. The previous chapters have introduced the four types of hyper-heuristics, presented the theoretical foundations and examined various applications of hyper-heuristics. This chapter provides an overview of some advanced topics and recent trends in hyper-heuristics, namely, hybrid hyper-heuristics, hyper-heuristics for automated design, automated design of hyper-heuristics and hyper-heuristics for continuous optimization. `https://link.springer.com/chapter/10.1007/978-3-319-96514-7_12`.

[298] Nelishia Pillay and Rong Qu. *Hyper-Heuristics: Theory and Applications*. Natural Computing Series, Springer, 2018. This introduction to the field of hyper-heuristics presents the required foundations and tools and illustrates some of their applications. The authors organized the 13 chapters into three parts. The first, hyper-heuristic fundamentals and theory, provides an overview of selection constructive, selection perturbative, generation constructive and generation perturbative hyper-heuristics, and then a formal definition of hyper-heuristics. The chapters in the second part of the book examine applications of hyper-heuristics in vehicle routing, nurse rostering, packing and examination timetabling. The third part of the book presents advanced topics and then a summary of the field and future research directions. Finally the appendices offer details of the HyFlex framework and the EvoHyp toolkit, and then the definition, problem model and constraints for the most tested combinatorial optimization problems. `https://link.springer.com/book/10.1007/978-3-319-96514-7`.

[299] Nelishia Pillay and Rong Qu. *Hyper-Heuristics: Theory and Applications*, chapter Theoretical Aspect – A Formal Definition, pages 37–48. Springer, 2018. Along with the continuous developments in hyper-heuristic (HH), various descriptive definitions for HH have emerged, leading to classifications of HH. Initially, hyper-heuristics have been defined as a search technique "to decide (select) at a higher abstraction level which low-level heuristics to apply", "to combine simple heuristics", or recently as a search method or learning mecha-

nism for selecting or generating heuristics to solve computational search problems. HH is thus categorized into four classifications, namely, selection perturbative / constructive, generation perturbative / constructive (see Chapters 3, 2, 5 and 4). Some attempts have also been made to generalize these classifications of HH, to allow both selection / generation and offline / online learning to interoperate within a repository. It has also been proposed that the "domain barrier" in the HH definition should be moved so more knowledge can be easily incorporated in a more expressive HH for inexperienced practitioners. https://link.springer.com/chapter/10.1007/978-3-319-96514-7_6.

[300] Lucas Prestes, Myriam R Delgado, Ricardo Lüders, Richard Gonçalves, and Carolina P Almeida. Boosting the performance of moea/d-dra with a multi-objective hyper-heuristic based on irace and ucb method for heuristic selection. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 1–8. IEEE, 2018. Multi-Objective Evolutionary Algorithm based on Decomposition with Dynamical Resource Allocation (MOEA/D-DRA) is one of the most successful decomposition based multiobjective algorithm. Its main feature is a mechanism to allocate different computational effort proportional to the difficult of each subproblem. Despite its success, MOEA/D-DRA has a large set of parameters and operators, whose selection could be a difficult task. This paper aims at improving the performance of MOEA/D-DRA by means of a hyper-heuristic using two parameter/operator selection phases: one off-line strongly based on Iterated Race Automatic Algorithm Configuration (Irace) and another one (online) based on the Upper Confidence Bound (UCB) technique. The proposed approach is compared with the original MOEA/D-DRA, NSGAII and IBEA over 51 instances of 7 well known benchmarks (CEC 2009, GLT, LZ09, MOP, DTLZ, ZDT and WFG). Results show that Irace and UCB are interesting methods to support the hyper-heuristic functioning when selecting parameters/operators of MOEA/D-DRA in the addressed problems. https://ieeexplore.ieee.org/abstract/document/8477661.

[301] Zhenyu Qian, Yanwei Zhao, Shun Wang, Longlong Leng, and Wanliang Wang. A hyper heuristic algorithm for low carbon location routing problem. In *International Symposium on Neural Networks*, pages 173–182. Springer, 2018. In this paper, the carbon emission factor is taken into account in the Location Routing Problem (LRP), and a multi-objective LRP model combining carbon emission with total cost is established. Due to the complexity of the proposed problem, a generality-oriented and emerging Multi-Objective Hyper Heuristic algorithm (MOHH) is proposed. In the framework of MOHH, the LRP related operates are constructed as the low level heuristics, and the different high level strategies are designed. Compared with the NSGA-II algorithm, the MOHH can better solve the multi-objective problem of LRP, and can quickly find the better solution, and achieve higher search efficiency and stability of the algorithm. https://link.springer.com/chapter/10.1007/978-3-319-92537-0_21.

[302] Nasser R Sabar, Xun Yi, and Andy Song. A bi-objective hyper-heuristic support

vector machines for big data cyber-security. *IEEE Access*, 2018. Cyber security in the context of big data is known to be a critical problem and presents a great challenge to the research community. Machine learning algorithms have been suggested as candidates for handling big data security problems. Among these algorithms, support vector machines (SVMs) have achieved remarkable success on various classification problems. However, to establish an effective SVM, the user needs to define the proper SVM configuration in advance, which is a challenging task that requires expert knowledge and a large amount of manual effort for trial and error. In this paper, we formulate the SVM configuration process as a bi-objective optimization problem in which accuracy and model complexity are considered as two conflicting objectives. We propose a novel hyper-heuristic framework for bi-objective optimization that is independent of the problem domain. This is the first time that a hyper-heuristic has been developed for this problem. The proposed hyper-heuristic framework consists of a high-level strategy and low-level heuristics. The high-level strategy uses the search performance to control the selection of which low-level heuristic should be used to generate a new SVM configuration. The low-level heuristics each use different rules to effectively explore the SVM configuration search space. To address bi-objective optimization, the proposed framework adaptively integrates the strengths of decomposition- and Pareto based approaches to approximate the Pareto set of SVM configurations. The effectiveness of the proposed framework has been evaluated on two cyber security problems: Microsoft malware big data classification and anomaly intrusion detection. The obtained results demonstrate that the proposed framework is very effective, if not superior, compared with its counterparts and other algorithms. `http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8307061`.

[303] EB Schlünz, PM Bokov, and JH van Vuuren. Multiobjective in-core nuclear fuel management optimisation by means of a hyperheuristic. *Swarm and Evolutionary Computation*, 2018. This paper is concerned with the problem of constrained multiobjective in-core fuel management optimisation (MICFMO) using, for the first time, a hyperheuristic technique as solution approach. A multiobjective hyperheuristic called the AMALGAM method (an evolutionary-based technique incorporating multiple sub-algorithms simultaneously) is compared to three previously-studied metaheuristics, namely the nondominated sorting genetic algorithm II, the Pareto ant colony optimisation algorithm and the multiobjective optimisation using cross-entropy method, in an attempt to improve upon the level of generality at which MICFMO may be conducted. This solution approach was motivated by a lack of consistent performance by the aforementioned metaheuristics when applied in isolation. Comparisons are conducted in the context of a test suite of several problem instances based on the SAFARI-1 nuclear research reactor. Nonparametric statistical analyses in respect of the optimisation results reveal that the AMALGAM method significantly outperforms the three metaheuristics in the majority of problem instances within the test suite. Additional comparisons are also performed between the proposed AMALGAM

method and a randomised (or no-learning) version thereof, as well as a selection choice function-based multiobjective hyperheuristic available in the literature. It is found that the proposed method is superior to the choice function-based algorithm within the context of the MICFMO test suite, and yields results of similar quality when compared to its randomised version. The practical relevance of the hyperheuristic results is further demonstrated by comparing the solutions thus obtained to a reload configuration designed according to the current fuel assembly reload design approach followed at the SAFARI-1 reactor. `https://www.sciencedirect.com/science/article/abs/pii/S221065021630503X`.

[304] Ram Sharma, A Charan Kumari, Mona Aggarwal, and Swaran Ahuja. Hyperheuristic-based analysis and optimization of a mobile indoor visible light communication system. *Transactions on Emerging Telecommunications Technologies*, 2018. In this paper, we study a mobile indoor visible light communication system that can be used for the creation of the indoor network infrastructure for sending information besides serving its main purpose of illumination. It uses visible light communication technology where the light-emitting diodes (LEDs) are deployed on the ceiling of the room and the receiver is kept mobile at a certain height from the ground level. This paper focuses on the optimal deployment of the LEDs with an objective to achieve the requisite level of communication performance without any transmission error while maintaining ubiquitous receiver mobility. The hyperheuristic evolutionary algorithm (HypEA) has been implemented to analyze and optimize the energy consumption through optimal placement of LEDs under variation of semiangle values. Furthermore, the implemented optimization algorithm investigates the other system related parameters including average outage area ratio, signal-to-noise ratio, and root mean square delay for a given threshold average bit error ratio. Finally, The obtained results are illustrated through numerical plots, which reveal that the HypEA is efficient in optimizing the system to minimize the overall power consumption under maximum receiver mobility. `http://onlinelibrary.wiley.com/doi/10.1002/ett.3274/full`.

[305] Ram Sharma, A Charan Kumari, Mona Aggarwal, and Swaran Ahuja. Improved rms delay and optimal system design of led based indoor mobile visible light communication system. *Physical Communication*, 28:89–96, 2018. The light emitting diode (LED) based lighting systems can be used for creation of the indoor communication network for sending information besides serving its main purpose of illumination. However, there are a number of impediments which are still under resolution in order to realize the full potential of such a system. In particular, the visible light communication (VLC) systems suffer due to high inter symbol interference (ISI) mainly on account of multi path propagation which impacts the spectral efficiency of the system. Besides ensuring ubiquitous coverage, it is also important to improve the system's bandwidth within the indoor scenario. The optimal deployment of such systems may result in optimum resource utilization (LEDs and driver circuits etc.) to minimize the energy consumption and to achieve

improved operational efficiency. In this paper, we propose two types of LED deployment strategies centralized and distributed and compare their performances on the basis of average outage area ratio, effect of semi-angle, root mean square delay and data transmission rate. The hyper heuristic evolutionary algorithm (HypEA) has been implemented to optimize the performance of the systems to achieve full receiver mobility in the indoor environment. The experimental results show that the distributed deployment strategy is able to optimize the system performance significantly in comparison to centralized deployment strategy. `https://www.sciencedirect.com/science/article/pii/S1874490717303075`.

[306] Ram Sharma, A Charan Kumari, Mona Aggarwal, and Swaran Ahuja. Optimal led deployment for mobile indoor visible light communication system: Performance analysis. *AEU-International Journal of Electronics and Communications*, 83:427–432, 2018. The maximization of the system performance in a typical indoor visible light communication system is a major challenge while minimizing the overall resources for the deployment. The intelligent smart lighting systems can be optimized to reduce the requirement of various resources without compromising on the system performance. In this paper, we investigate the optimization of the light emitting diode (LED) resources within an indoor room scenario using a most efficient stochastic optimization technique-Hyper-heuristics evolutionary algorithm (HypEA). The performance of the communication system has been measured in terms of average area outage ratio, computational efficiency and mobility area analysis. The performance of the HypEA has been compared against the most experimented algorithm-Particle swarm optimization (PSO). The detailed investigation and analysis shows that HypEA is computationally more efficient and is able to achieve full mobility with almost 12.5 percent fewer resources as compared to PSO. `https://www.sciencedirect.com/science/article/pii/S1434841117316370`.

[307] Maria Amélia Lopes Silva, Sergio Ricardo de Souza, Marcone Jamilson Freitas Souza, and Moacir Felizardo de Franca Filho. Hybrid metaheuristics and multi-agent systems for solving optimization problems: A review of frameworks and a comparative analysis. *Applied Soft Computing*, 2018. This article presents a review and a comparative analysis between frameworks for solving optimization problems using metaheuristics. The aim is to identify both the desirable characteristics as the existing gaps in the current state of the art, with a special focus on the use of multi-agent structures in the development of hybrid metaheuristics. A literature review of existing frameworks is introduced, with emphasis on their characteristics of hybridization, cooperation, and parallelism, particularly focusing on issues related to the use of multi-agents. For the comparative analysis, a set of twenty-two characteristics was listed, according to four categories: basics, advanced, multi-agent approach and support to the optimization process. Strategies used in hybridization, such as parallelism, cooperation, decomposition of the search space, hyper-heuristic and multi-agent systems are assessed in respect to

their use in the various analyzed frameworks. Specific features of multi-agent systems, such as learning and interaction between agents, are also analyzed. The comparative analysis shows that the hybridization is not a strong feature in existing frameworks. On the other hand, proposals using multi-agent systems stand out in the implementation of hybrid methods, as they allow the interaction between metaheuristics. It also notes that the concept of hyper-heuristic is little explored by the analyzed frameworks, as well as there is a lack of tools that offer support to the optimization process, such as statistical analysis, self-tuning of parameters and graphical interfaces. Based on the presented analysis, it can be said that there are important gaps to be filled in the development of Frameworks for Optimization using metaheuristics, which open important possibilities for future works, particularly by implementing the approach of multi-agent systems. `https://www.sciencedirect.com/science/article/pii/S1568494618303867`.

[308] Christopher Stone, Emma Hart, and Ben Paechter. Automatic generation of constructive heuristics for multiple types of combinatorial optimisation problems with grammatical evolution and geometric graphs. In *International Conference on the Applications of Evolutionary Computation*, pages 578–593. Springer, 2018. In many industrial problem domains, when faced with a combinatorial optimisation problem, a "good enough, quick enough" solution to a problem is often required. Simple heuristics often suffice in this case. However, for many domains, a simple heuristic may not be available, and designing one can require considerable expertise. Noting that a wide variety of problems can be represented as graphs, we describe a system for the automatic generation of constructive heuristics in the form of Python programs by mean of grammatical evolution. The system can be applied seamlessly to different graph-based problem domains, only requiring modification of the fitness function. We demonstrate its effectiveness by generating heuristics for the Travelling Salesman and Multi-Dimensional Knapsack problems. The system is shown to be better or comparable to human-designed heuristics in each domain. The generated heuristics can be used out-of-the-box to provide a solution, or to augment existing hyper-heuristic algorithms with new low-level heuristics. `https://link.springer.com/chapter/10.1007/978-3-319-77538-8_40`.

[309] Christopher Stone, Emma Hart, and Ben Paechter. On the synthesis of perturbative heuristics for multiple combinatorial optimisation domains. In *International Conference on Parallel Problem Solving from Nature*, pages 170–182. Springer, 2018. Hyper-heuristic frameworks, although intended to be cross-domain at the highest level, rely on a set of domain-specific low-level heuristics at lower levels. For some domains, there is a lack of available heuristics, while for novel problems, no heuristics might exist. We address this issue by introducing a novel method, applicable in multiple domains, that constructs new low-level heuristics for a domain. The method uses grammatical evolution to construct iterated local search heuristics: it can be considered cross-domain in that the same grammar can evolve heuristics in multiple domains

without requiring any modification, assuming that solutions are represented in the same form. We evaluate the method using benchmarks from the travelling-salesman (TSP) and multi-dimensional knapsack (MKP) domain. Comparison to existing methods demonstrates that the approach generates low-level heuristics that outperform heuristic methods for TSP and are competitive for MKP. https://link.springer.com/chapter/10.1007/978-3-319-99253-2_14.

[310] Jerry Swan, Patrick De Causmaecker, Simon Martin, and Ender Ozcan. A re-characterization of hyper-heuristics. In L. Amodeo, E-G. Talbi, and F. Yalaoui, editors, *Recent Developments of Metaheuristics*, pages 75–89. Springer, 2018. Hyper-heuristics are an optimization methodology which 'search the space of heuristics' rather than directly searching the space of the underlying candidate-solution representation. Hyper-heuristic search has traditionally been divided into two layers: a lower problem-domain layer (where domain-specific heuristics are applied) and an upper hyper-heuristic layer, where heuristics are selected or generated. The interface between the two layers is commonly termed the "domain barrier". Historically this interface has been defined to be highly restrictive, in the belief that this is required for generality. We argue that this prevailing conception of domain barrier is so limiting as to defeat the original motivation for hyper-heuristics. We show how it is possible to make use of domain knowledge without loss of generality and describe generalized hyper-heuristics which can incorporate arbitrary domain knowledge. https://link.springer.com/chapter/10.1007/978-3-319-58253-5_5.

[311] Boxiong Tan, Hui Ma, and Yi Mei. A genetic programming hyper-heuristic approach for online resource allocation in container-based clouds. In *Australasian Joint Conference on Artificial Intelligence*, pages 146–152. Springer, 2018. The popularity of container-based clouds is its ability to deploy and run applications without launching an entire virtual machine (VM) for each application. Container-based clouds support flexible deployment of applications and therefore brings the potential to reduce the energy consumption of data centers. With the goal of energy reduction, it is more difficult to optimize the allocation of containers than traditional VM-based clouds because of the finer granularity of resources. Little research has been conducted for applying human-design heuristics on balanced and unbalanced resources. In this paper, we first compare three human-design heuristics and show they cannot handle balanced and unbalanced resources scenarios well. We propose a learning-based algorithm: genetic programming hyper-heuristic (GPHH) to automatically generate a suitable heuristic for allocating containers in an online fashion. The results show that the proposed GPHH managed to evolve better heuristics than the human-designed ones in terms of energy consumption in a range of cloud scenarios. https://link.springer.com/chapter/10.1007/978-3-030-03991-2_15.

[312] Fei Tao, Luning Bi, Ying Zuo, and AYC Nee. Partial/parallel disassembly sequence planning for complex products. *Journal of Manufacturing Science and*

Engineering, 140(1):011016, 2018. Disassembly is a very important step in recycling and maintenance, particularly for energy saving. However, disassembly sequence planning (DSP) is a challenging combinatorial optimization problem due to complex constraints of many products. This paper considers partial and parallel disassembly sequence planning for solving the degrees-of-freedom in modular product design, considering disassembly time, cost, and energy consumption. An automatic self-decomposed disassembly precedence matrix (DPM) is designed to generate partial/parallel disassembly sequence for reducing complexity and improving efficiency. A Tabu search-based hyper heuristic algorithm with exponentially decreasing diversity management strategy is proposed. Compared with the low-level heuristics, the proposed algorithm is more efficient in terms of exploration ability and improving energy benefits (EBs). The comparison results of three different disassembly strategies prove that the partial/parallel disassembly has a great advantage in reducing disassembly time, and improving EBs and disassembly profit (DP). `http://manufacturingscience.asmedigitalcollection.asme.org/article.aspx?articleid=2649369`.

[313] Aydin Teymourifar, Gurkan Ozturk, Zehra Kamisli Ozturk, and Ozan Bahadir. Extracting new dispatching rules for multi-objective dynamic flexible job shop scheduling with limited buffer spaces. *Cognitive Computation*, pages 1–11, 2018.

[314] Surafel Luleseged Tilahun and Mohamed A Tawhid. Swarm hyperheuristic framework. *Journal of Heuristics*, pages 1–28, 2018. Swarm intelligence is one of the central focus areas in the study of metaheuristic algorithms. The effectiveness of these algorithms towards solving difficult problems has attracted researchers and practitioners. As a result, numerous type of this algorithm have been proposed. However, there is a heavy critics that some of these algorithms lack novelty. In fact, some of these algorithms are the same in terms of the updating operators but with different mimicking scenarios and names. The performance of a metaheuristic algorithm depends on how it balance the degree of the two basic search mechanisms, namely intensification and diversification. Hence, introducing novel algorithms which contributes to a new way of search mechanism is welcome but not for a mere repetition of the same algorithm with the same or perturbed operators but different metaphor. With this regard, it is ideal to have a framework where different custom made operators are used along with existing or new operators. Hence, this paper presents a swarm hyperheuristic framework, where updating operators are taken as low level heuristics and guided by a high level hyperheuristic. Different learning approaches are also proposed to guide the intensification and diversification search behaviour of the algorithm. Hence, a swarm hyperheuristic without learning (SSH1), with offline learning (SSH2) and with an online learning (SSH3) is proposed and discussed. A simulation based comparison and discussion is also presented using a set of nine updating operators with selected metaheuristic algorithms based on twenty benchmark problems. The problems are selected from both unconstrained and constrained optimiza-

tion problems with their dimension ranging from two to fifty. The simulation results show that the proposed approach with learning has a better performance in general.

[315] Ayad Turky, Nasser R Sabar, Simon Dunstall, and Andy Song. Hyper-heuristic based local search for combinatorial optimisation problems. In *Australasian Joint Conference on Artificial Intelligence*, pages 312–317. Springer, 2018. Combinatorial optimisation is often needed for solving real-world problems, which are often NP-hard so exact methods are not suitable. Instead local search methods are often effective to find near-optimal solutions quickly. However, it is difficult to determine which local search with what parameter setting should be optimal for a given problem. In this study two complex combinatorial optimisation are used, Multi-capacity Bin Packing Problems (MCBPP) and Google Machine Reassignment Problem (GMRP). Our experiments show that no single local search method could consistently achieve the best. They are sensitive to problem search space and parameters. Therefore we propose a hyper heuristic based method, which automatically selects the most appropriate local search during the search and tune the parameters accordingly. The results show that our proposed hyper-heuristic approach is effective and can achieve the overall best on multiple instances of both MCBPP and GMRP. `https://link.springer.com/chapter/10.1007/978-3-030-03991-2_30`.

[316] Muneeb ul Hassan, Nasser R Sabar, and Andy Song. Optimising deep learning by hyper-heuristic approach for classifying good quality images. In *International Conference on Computational Science*, pages 528–539. Springer, 2018. Deep Convolutional Neural Network (CNN), which is one of the prominent deep learning methods, has shown a remarkable success in a variety of computer vision tasks, especially image classification. However, tuning CNN hyper-parameters requires expert knowledge and a large amount of manual effort of trial and error. In this work, we present the use of CNN on classifying good quality images versus bad quality images without understanding the image content. The well known data-sets were used for performance evaluation. More importantly we propose a hyper-heuristic approach for tuning CNN hyper-parameters. The proposed hyper-heuristic encompasses of a high level strategy and various low level heuristics. The high level strategy utilises search performance to determine how to apply low level heuristics to automatically find an appropriate set of CNN hyper-parameters. Our experiments show the effectiveness of this hyper-heuristic approach which can achieve high accuracy even when the training size is significantly reduced and conventional CNNs can no longer perform well. In short the proposed hyper-heuristic approach does enhance CNN deep learning. `https://link.springer.com/chapter/10.1007/978-3-319-93701-4_41`.

[317] Stefan AG van der Stockt and Andries P Engelbrecht. Analysis of selection hyper-heuristics for population-based meta-heuristics in real-valued dynamic optimization. *Swarm and evolutionary computation*, 43:127–146, 2018. Dynamic

optimization problems provide a challenge in that optima have to be tracked as the environment changes. The complexity of a dynamic optimization problem is determined by the severity and frequency of changes, as well as the behavior of the values and trajectory of optima. While many efficient algorithms have been developed to solve these types of problems, the choice of the best algorithm is highly dependent on the type of change present in the environment. This paper analyses the ability of popular selection operators used in a hyper-heuristic framework to continuously select the most appropriate optimization method over time. Empirical studies examine the behavioral differences between various hyper-heuristic selection operators to better understand their mode of operation. The results show that these hyper-heuristic approaches can yield higher performance more consistently across difference types of environments. `https://www.sciencedirect.com/science/article/abs/pii/S2210650217303796`.

[318] Pandiri Venkatesh and Alok Singh. A hyper-heuristic based artificial bee colony algorithm for k-interconnected multi-depot multi-traveling salesman problem. *Information Sciences*, 2018. This paper addresses a newly introduced variant of traveling salesman problem, viz. k-Interconnected Multi-Depot Multi-Traveling Salesman Problem (k-IMDMTSP). This problem has the potential to address a variety of problems as it is a general problem that can change its characteristics according to the combination of parameter values. In fact, k-IMDMTSP can become an altogether different problem depending on the choice of its parameter values. According to the No Free Lunch Theorem, it is not possible to have a general algorithm that can outperform all algorithms across all problems emanating from k-IMDMTSP due to various parameter values. However, an appropriate combination of different algorithms can successfully deal with all such problems emanating from k-IMDMTSP. Here, we have made an attempt in this direction with the help of hyper-heuristics. A hyper-heuristic based artificial bee colony algorithm is proposed for k-IMDMTSP. A new solution encoding scheme is proposed for representing a k-IMDMTSP solution within the proposed approach, and its associated search space is analyzed theoretically. It has been proved that our encoding scheme yields a search space that is considerably smaller in comparison to encoding schemes used previously. Experimental results on standard benchmark instances show that the proposed approach outperforms other state-of-the-art approaches available in literature in terms of both solution quality and running time. `https://www.sciencedirect.com/science/article/pii/S0020025518304675`.

[319] Dennis Wilson, Silvio Rodrigues, Carlos Segura, Ilya Loshchilov, Frank Hutter, Guillermo López Buenfil, Ahmed Kheiri, Ed Keedwell, Mario Ocampo-Pineda, Ender Özcan, et al. Evolutionary computation for wind farm layout optimization. *Renewable energy*, 126:681–691, 2018. This paper presents the results of the second edition of the Wind Farm Layout Optimization Competition, which was held at the 22nd Genetic and Evolutionary Computation COn-

ference (GECCO) in 2015. During this competition, competitors were tasked with optimizing the layouts of five generated wind farms based on a simplified cost of energy evaluation function of the wind farm layouts. Online and offline APIs were implemented in C++, Java, Matlab and Python for this competition to offer a common framework for the competitors. The top four approaches out of eight participating teams are presented in this paper and their results are compared. All of the competitors' algorithms use evolutionary computation, the research field of the conference at which the competition was held. Competitors were able to downscale the optimization problem size (number of parameters) by casting the wind farm layout problem as a geometric optimization problem. This strongly reduces the number of evaluations (limited in the scope of this competition) with extremely promising results. `https://www.sciencedirect.com/science/article/pii/S096014811830363X`.

[320] Changqing Xu, Peng Li, et al. Unified multi-objective mapping for network-on-chip using genetic based hyper-heuristic algorithms. *IET Computers & Digital Techniques*, 2018. In this study, a flexible energy- and delay-aware mapping approach is proposed for the co-optimisation of energy consumption and communication latency for network-on-chips (NoCs). A novel genetic-based hyper-heuristic algorithm (GHA) is proposed as the core algorithm. This algorithm consists of bottom-level optimisation which includes a variety of operators and top-level optimisation which selects suitable operators through a reward mechanism. As this algorithm can select suitable operators automatically during the mapping process, it noticeably improves convergence speed and demonstrates excellent stability. Compared to the random algorithm, GHA can achieve on average 23.28% delay reduction and 11.81% power reduction. Compared to state-of-the-art mapping algorithms, GHA produces improved mapping results with less time, especially when the size of NoC is large. `http://digital-library.theiet.org/content/journals/10.1049/iet-cdt.2017.0156`.

[321] Xiong Xu, Li Jiao, and Ziming Zhu. Boosting search based software testing by using ensemble methods. In *2018 IEEE Congress on Evolutionary Computation (CEC)*, pages 1–10. IEEE, 2018. Search Based Software Testing (SBST) formulates testing as an optimization problem, hence some search algorithms (e.g., Genetic Algorithms) can be used to tackle it. There are different types of coverage criteria, and the goal of SBST is to improve various test adequacy criteria. However, the major limitation of SBST is the insufficiently informed fitness functions and the inefficient search algorithms. Besides, although there are various fitness functions and search algorithms for SBST, there is little guidance on when to use one fitness function (resp., search algorithm) over another. To address these problems, we propose an ensemble strategy to boost the performance of SBST. In this paper, we deal with path coverage. Concretely, by combining multiple weak fitness functions, the heuristic information of the problem instances can be expressed more sufficiently, and therefore, a stronger fitness function can

be obtained. On the other hand, by combining multiple complementary search algorithms, a hyper-heuristic search algorithm is generated and the search performance can be improved. The empirical study reveals the promising results of our proposal. Especially, for the paths that are very difficult to be covered, our ensemble method proposed in this paper outperforms other approaches significantly. `https://ieeexplore.ieee.org/abstract/document/8477734`.

[322] Yuan Yao, Zhe Peng, and Bin Xiao. Parallel hyper-heuristic algorithm for multi-objective route planning in a smart city. *IEEE Transactions on Vehicular Technology*, 67(11):10307–10318, 2018. Most of the commercial navigation products provide route planning service for users. However, they only consider a single metric such as distance, time, or other costs, while ignoring a critical criterion: safety. In a smart city, people may prefer to find a safe walking route to avoid the potential crime risk as well as obtain a short distance. This problem can be specified as a multi-objective optimization problem (MOOP). Many methods were proposed in the past to solve the multi-objective route planning, the multi-objective evolutionary approach (MOEA) is considered as the most popular one. However, MOEA is non-optimized when used in a large-scale road network and becomes computationally expensive when handling a large population size. In this paper, we propose a multi-objective hyper-heuristic (MOHH) framework for walking route planning in a smart city. In the search framework, we design a set of low level heuristics to generate new routes. Moreover, we adopt reinforcement learning mechanism to select good low-level heuristics to accelerate searching speed. We further improve the reinforcement learning-based multi-objective hyper-heuristic (RL-MOHH) algorithm and implement a parallel version (RL-PMOHH) on general purpose graphic process unit. Extensive experiments are conducted on the safety-index map constructed from the historical urban data of the New York city. Comprehensive experimental results show that the proposed RL-PMOHH is almost 173, 5.3, and 3.1 times faster than the exact multi-objective optimization algorithm, the RL-MOHH algorithm, and the parallel NSGA-II algorithm, respectively. Moreover, both RL-MOHH and RL-PMOHH can obtain more than 80% Pareto optimal solutions in a large-scale road network. `https://ieeexplore.ieee.org/abstract/document/8456612/`.

[323] WB Yates and EC Keedwell. An analysis of heuristic subsequences for offline hyper-heuristic learning. *Journal of Heuristics*, pages 1–32, 2018. A selection hyper-heuristic is used to minimise the objective functions of a well-known set of benchmark problems. The resulting sequences of low level heuristic selections and objective function values are used to generate a database of heuristic selections. The sequences in the database are broken down into subsequences and the mathematical concept of a logarithmic return is used to discriminate between "effective" subsequences, which tend to decrease the objective value, and "disruptive" subsequences, which tend to increase the objective value. These subsequences are then employed in a sequenced based hyper-heuristic and evalu-

ated on an unseen set of benchmark problems. Empirical results demonstrate that the "effective" subsequences perform significantly better than the "disruptive" subsequences across a number of problem domains with 99% confidence. The identification of subsequences of heuristic selections that can be shown to be effective across a number of problems or problem domains could have important implications for the design of future sequence based hyper-heuristics. `https://link.springer.com/article/10.1007/s10732-018-09404-7`.

[324] Peng-Yeng Yin and Geng-Shi Li. A hyper-heuristic of artificial bee colony and simulated annealing for optimal wind turbine placement. In *International Conference on Swarm Intelligence*, pages 145–152. Springer, 2018. The ascending of quantity of CO2 emissions is the main factor contributing the global warming which results in extremely abnormal weather and causes disaster damages. Due to intensive CO2 pollutants produced by classic energy sources such as fossil fuels, practitioners and researchers pay increasing attentions on the renewable energy production such as wind power. Optimal wind turbine placement problem is to find the optimal number and placement location of wind turbines in a wind farm against the wake effect. The efficiency of wind power production does not necessarily grows with an increasing number of installed wind turbines. This paper presents a hyper-heuristic framework combining several lower-level heuristics with an artificial bee colony algorithm and a simulated annealing technique to construct an optimal wind turbine placement considering wake effect influence. Finally, we compare our approach with existing works in the literature. The experimental results show that our approach produces the wind power with a lower cost of energy. `https://link.springer.com/chapter/10.1007/978-3-319-93815-8_15`.

[325] Daniel Yska, Yi Mei, and Mengjie Zhang. Feature construction in genetic programming hyper-heuristic for dynamic flexible job shop scheduling. In *Annual Conference on Genetic and Evolutionary Computation (GECCO) Companion*. ACM, 2018.

[326] Daniel Yska, Yi Mei, and Mengjie Zhang. Genetic programming hyper-heuristic with cooperative coevolution for dynamic flexible job shop scheduling. In *European Conference on Genetic Programming (EuroGP)*, pages 306–321. Springer, 2018.

[327] Shuang Yu, Aldeida Aleti, Jan Carlo Barca, and Andy Song. Hyper-heuristic online learning for self-assembling swarm robots. In *International Conference on Computational Science*, pages 167–180. Springer, 2018. A robot swarm is a solution for difficult and large scale tasks. However, controlling and coordinating a swarm of robots is challenging, because of the complexity and uncertainty of the environment where manual programming of robot behaviours is often impractical. In this study we propose a hyper-heuristic methodology for swarm robots. It allows robots to create suitable actions based on a set of low-level heuris-

tics, where each heuristic is a behavioural element. With online learning, the robot behaviours can be improved during execution by autonomous heuristic adjustment. The proposed hyper-heuristic framework is applied to surface cleaning tasks on buildings where multiple separate surfaces exist and complete surface information is difficult to obtain. Under this scenario, the robot swarm not only needs to clean the surfaces efficiently by distributing the robots, but also to move across surfaces by self-assembling into a bridge structure. Experimental results showed the effectiveness of the hyper-heuristic framework; the same group of robots was able to autonomously deal with multiple surfaces of different layouts. Their behaviours can improve over time because of the online learning mechanism. `https://link.springer.com/chapter/10.1007/978-3-319-93698-7_13`.

[328] Shuang Yu, Andy Song, and Aldeida Aleti. Collective hyper-heuristics for self-assembling robot behaviours. In *Pacific Rim International Conference on Artificial Intelligence*, pages 499–507. Springer, 2018. Swarm robots are highly desirable in dealing with complex tasks. However, manual coding of individual robot behaviours and robot collaboration is not trivial especially under unknown and dynamic environments. This study introduced a hyper-heuristic methodology for this challenge, so robots can learn suitable behaviours during the process. The hyper-heuristic method creates actions based on a set of low-level heuristics and improves these actions through autonomous heuristic adjustment. A collective negotiation and updating mechanism is proposed so the robot swarm performance can be improved. We evaluate this method on the problem of building surface cleaning. Experiments show the effectiveness of the hyper-heuristic method and the collective learning mechanism. `https://link.springer.com/chapter/10.1007/978-3-319-97310-4_57`.

[329] Kamal Z Zamli. Enhancing generality of meta-heuristic algorithms through adaptive selection and hybridization. In *International Conference on Information and Communications Technology (ICOIACT)*, pages 67–71. IEEE, 2018. Solving complex optimization problems can be painstakingly difficult endeavor considering multiple and conflicting design goals. A growing trend in utilizing meta-heuristic algorithms to solve these problems has been observed as they have shown considerable success in dealing with tradeoffs between conflicting design goals. Many meta-heuristic algorithms have been developed to date (e.g. Simulated Annealing (SA), Particle Swarm Optimization (PSO), Teaching Learning based Optimization (TLBO), Grey Wolf Optimizer(GWO) to name a few). Much of these algorithms have adopted elegant metaphors (e.g. heating and cooling of metals in the case of SA and swarming of flocking birds in the case of PSO) from nature in order to derive the mathematical models for generating the solution as well as provides control over their exploration (i.e. sufficient roaming of the search space) and exploitation (i.e. using known knowledge of the surroundings). In line with the no free lunch theorem (), this paper argues that rather than focusing on designing new algorithm, new research

should focus on adaptive hybridization of meta-heuristics algorithms in order to compensate the limitation of one with the strengths of another. In this paper, we review the meta-heuristic and hyper-heuristic algorithms in order to highlight the current-state-of-the-arts and suggest areas for future research. https://ieeexplore.ieee.org/abstract/document/8350825.

[330] Yuanyuan Zhang, Mark Harman, Gabriela Ochoa, Guenther Ruhe, and Sjaak Brinkkemper. An empirical study of meta-and hyper-heuristic search for multi-objective release planning. *ACM Transactions on Software Engineering and Methodology (TOSEM)*, 27(1):3, 2018. A variety of meta-heuristic search algorithms have been introduced for optimising software release planning. However, there has been no comprehensive empirical study of different search algorithms across multiple different real-world datasets. In this article, we present an empirical study of global, local, and hybrid meta- and hyper-heuristic search-based algorithms on 10 real-world datasets. We find that the hyper-heuristics are particularly effective. For example, the hyper-heuristic genetic algorithm significantly outperformed the other six approaches (and with high effect size) for solution quality 85% of the time, and was also faster than all others 70% of the time. Furthermore, correlation analysis reveals that it scales well as the number of requirements increases. https://dl.acm.org/citation.cfm?id=3196831.

[331] Fawaz Alanazi. Reinforcement learning hyper-heuristics for optimisation, 2017. Hyper-heuristics are search algorithms which operate on a set of heuristics with the goal of solving a wide range of optimisation problems. It has been observed that different heuristics perform differently between different optimisation problems. A hyper-heuristic combines a set of predefined heuristics, and applies a machine learning technique to predict which heuristic is the most suitable to apply at a given point in time while solving a given problem. A variety of machine learning techniques have been proposed in the literature. Most of the existing machine learning techniques are reinforcement learning mechanisms interacting with the search environment with the goal of adapting the selection of heuristics during the search process. The literature on the theoretical foundation of reinforcement learning hyper-heuristics is almost nonexisting. This work provides theoretical analyses of reinforcement learning hyper-heuristics. The goal is to shed light on the learning capabilities and limitations of reinforcement learning hyper-heuristics. This improves our understanding of these hyper-heuristics, and aid the design of better reinforcement learning hyper-heuristics. It is revealed that the commonly used additive reinforcement learning mechanism, under a mild assumption, chooses asymptotically heuristics uniformly at random. This thesis also proposes the problem of identifying the most suitable heuristic with a given error probability. We show a general lower bound on the time that "every" reinforcement learning hyper-heuristic needs to identify the most suitable heuristic with a given error probability. The results reveal a general limitation to learning achieved by this computational approach. Following our the-

oretical analysis, different reusable and easyto-implement reinforcement learning hyper-heuristics are proposed in this thesis. The proposed hyper-heuristics are evaluated on well-known combinatorial optimisation problems. One of the proposed reinforcement learning hyper-heuristics outperformed a state-of-the-art algorithm on several benchmark problems of the well-known CHeSC 2011. `http://eprints.nottingham.ac.uk/42204/`.

[332] Ivan Amaya, José Carlos Ortiz-Bayliss, Andrés Eduardo Gutiérrez-Rodriguez, Hugo Terashima-Marin, and Carlos A Coello Coello. Improving hyper-heuristic performance through feature transformation. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 2614–2621. IEEE, 2017. Hyper-heuristics are powerful search methodologies that can adapt to different kinds of problems. One element of paramount importance, however, is the selection module that they incorporate. Traditional approaches define a set of features for characterizing a problem and, thus, define how to best solve it. However, some features may vary nonlinearly as the solver progresses, requiring higher resolution in specific areas of the feature domain. This work focuses on assessing the advantage of using feature transformations to improve the given resolution and, as a consequence, to improve the overall performance of a hyper-heuristic. We provide evidence that using feature transformations may result in a better discrimination of the problem instance and, as consequence, a better performance of the hyper-heuristics. The feature transformation strategy was applied to an evolutionary-based hyper-heuristic model taken from the literature and tested on constraint satisfaction problems The proposed strategy increased the median success rate of hyper-heuristics by more than 13% and reduced its standard deviation in about 7%, while reducing the median number of adjusted consistency checks by almost 30%. `http://ieeexplore.ieee.org/abstract/document/7969623/`.

[333] Filipe Assunçao, Nuno Lourenço, Penousal Machado, and Bernardete Ribeiro. Automatic generation of neural networks with structured grammatical evolution. In *IEEE Congress on Evolutionary Computation (CEC)*, San Sebastian, Spain, 2017. The effectiveness of Artificial Neural Networks (ANNs) depends on a non-trivial manual crafting of their topology and parameters. Typically, practitioners resort to a time consuming methodology of trial-and-error to find and/or adjust the models to solve specific tasks. To minimise this burden one might resort to algorithms for the automatic selection of the most appropriate properties of a given ANN. A remarkable example of such methodologies is Grammar-based Genetic Programming. This work analyses and compares the use of two grammar-based methods, Grammatical Evolution (GE) and Structured Grammatical Evolution (SGE), to automatically design and configure ANNs. The evolved networks are used to tackle several classification datasets. Experimental results show that SGE is able to automatically build better models than GE, and that are competitive with the state of the art, outperforming hand-designed ANNs

in all the used benchmarks. https://cdv.dei.uc.pt/wp-content/uploads/2017/03/assuncao2017nnsge.pdf.

[334] Yilmaz Atay, Ismail Koc, Ismail Babaoglu, and Halife Kodaz. Community detection from biological and social networks: A comparative analysis of metaheuristic algorithms. *Applied Soft Computing*, 50:194–211, 2017. In order to analyze complex networks to find significant communities, several methods have been proposed in the literature. Modularity optimization is an interesting and valuable approach for detection of network communities in complex networks. Due to characteristics of the problem dealt with in this study, the exact solution methods consume much more time. Therefore, we propose six metaheuristic optimization algorithms, which each contain a modularity optimization approach. These algorithms are the original Bat Algorithm (BA), Gravitational Search Algorithm (GSA), modified Big Bang-Big Crunch algorithm (BB-BC), improved Bat Algorithm based on the Differential Evolutionary algorithm (BADE), effective Hyperheuristic Differential Search Algorithm (HDSA) and Scatter Search algorithm based on the Genetic Algorithm (SSGA). Four of these algorithms (HDSA, BADE, SSGA, BB-BC) contain new methods, whereas the remaining two algorithms (BA and GSA) use original methods. To clearly demonstrate the performance of the proposed algorithms when solving the problems, experimental studies were conducted using nine real-world complex networks - five of which are social networks and the rest of which are biological networks. The algorithms were compared in terms of statistical significance. According to the obtained test results, the HDSA proposed in this study is more efficient and competitive than the other algorithms that were tested. http://www.sciencedirect.com/science/article/pii/S1568494616305944.

[335] Adil Baykasoglu and Fehmi B. Ozsoydan. Evolutionary and population-based methods versus constructive search strategies in dynamic combinatorial optimization. *Information Sciences*, 420:159–183, 2017. Optimization in dynamic environments is a hot research area that has attracted a notable attention in the past decade. It is clear from the dynamic optimization literature that most of the effort is devoted to continuous dynamic optimization problems although majority of the real-life problems are combinatorial. Additionally, in comparison to evolutionary or population-based approaches, constructive search strategy, which is shown to be successful in stationary combinatorial optimization problems, is commonly ignored by the dynamic optimization community. In the present work, a constructive and multi-start search strategy is proposed to solve dynamic multi-dimensional knapsack problem, which has numerous applications in real world. Making use of constructive and multi-start features, the aim here is to test the performance of such a strategy and to observe its behavior in dynamically changing environments. In this regard, this strategy is compared to the well-known evolutionary and population-based approaches, including a Genetic Algorithm-based memetic algorithm, Differential Evolution algorithm,

Firefly Algorithm and a hyper-heuristic, which employs these population-based algorithms as low-level heuristics in accordance with their individual contributions. Furthermore, in order to improve their performances in dynamic environments, the mentioned evolutionary algorithms are enhanced by using triggered random immigrants and adaptive hill climbing strategies. As one can see from the comprehensive experimental analysis, while the proposed approach outperforms most of the evolutionary-based approaches, it is outperformed by firefly and hyper-heuristic algorithms in some of the instances. This points out competiveness of the proposed approaches. Finally, according to the statistical results of non-parametric tests, one can conclude that the proposed approach can be considered as a promising and a competitive algorithm in dynamic environments. `http://www.sciencedirect.com/science/article/pii/S0020025517309064`.

[336] Pei Cao, Zhaoyan Fan, Robert Gao, and Jiong Tang. A manufacturing oriented single point search hyper-heuristic scheme for multi-objective optimization. In *ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, pages V02BT03A031–V02BT03A031. American Society of Mechanical Engineers, 2017.

[337] Jose M Cecilia, Jose-Matias Cutillas-Lozano, Domingo Gimenez, and Baldomero Imbernon. Exploiting multilevel parallelism on a many-core system for the application of to a molecular docking problem. *The Journal of Supercomputing*, pages 1–12, 2017. The solution of Protein-Ligand Docking Problems can be approached through metaheuristics, and satisfactory metaheuristics can be obtained with hyperheuristics searching in the space of metaheuristics implemented inside a parameterized schema. These hyperheuristics apply several metaheuristics, resulting in high computational costs. To reduce execution times, a shared-memory schema of hyperheuristics is used with four levels of parallelism, two for the hyperheuristic and two for the metaheuristics. The parallel schema is executed in a many-core system in "native mode" and the four-level parallelism allows us to take full advantage of the massive parallelism offered by this architecture and obtain satisfactory fitness and an important reduction in the execution time. `https://link.springer.com/article/10.1007/s11227-017-1989-7`.

[338] Yujie Chen. Optimisation for large-scale maintenance, scheduling and vehicle routing problems, 2017. Solving real-world combinatorial problems is involved in many industry fields to minimise operational cost or to maximise profit, or both. Along with continuous growth in computing power, many asset management decision-making processes that were originally solved by hand now tend to be based on big data analysis. Larger scale problem can be solved and more detailed operation instructions can be delivered. In this thesis, we investigate models and algorithms to solve large scale Geographically Distributed asset Maintenance Problems (GDMP). Our study of the problem was motivated by our business partner, Gaist solutions Ltd., to optimise scheduling of maintenance actions for a drainage system in an urban area. The models and solution methods proposed in

the thesis can be applied to many similar issues arising in other industry fields. The thesis contains three parts. We firstly built a risk driven model considering vehicle routing problems and the asset degradation information. A hyperheuristic method embedded with customised low-level heuristics is employed to solve our real-world drainage maintenance problem in Blackpool. Computational results show that our hyperheuristic approach can, within reasonable CPU time, produce much higher quality solutions than the scheduling strategy currently implemented by Blackpool council. We then attempt to develop more efficient solution approaches to tackle our GDMP. We study various hyperheuristics and propose efficient local search strategies in part II. We present computational results on standard periodic vehicle routing problem instances and our GDMP instances. Based on manifold experimental evidences, we summarise the principles of designing heuristic based solution approaches to solve combinatorial problems. Last bu not least, we investigate a related decision making problem from highway maintenance, that is again of interest to Gaist solutions Ltd. We aim to make a strategical decision to choose a cost effective method of delivering the road inspection at a national scale. We build the analysis based on the Chinese Postman Problem and theoretically proof the modelling feasibility in real-world road inspection situations. We also propose a novel graph reduction process to allow effective computation over very large data sets. `http://etheses.whiterose.ac.uk/16107/`.

[339] Yujie Chen, Peter Cowling, Fiona Polack, Stephen Remde, and Philip Mourdjis. Dynamic optimisation of preventative and corrective maintenance schedules for a large scale urban drainage system. *European Journal of Operational Research*, 257(2):494–510, 2017. Gully pots or storm drains are located at the side of roads to provide drainage for surface water. We consider gully pot maintenance as a risk-driven maintenance problem. We explore policies for preventative and corrective maintenance actions, and build optimised routes for maintenance vehicles. Our solutions take the risk impact of gully pot failure and its failure behaviour into account, in the presence of factors such as location, season and current status. The aim is to determine a maintenance policy that can automatically adjust its scheduling strategy in line with changes in the local environment, to minimise the surface flooding risk due to clogged gully pots. We introduce a rolling planning strategy, solved by a hyper-heuristic method. Results show the behaviour and strength of the automated adjustment in a range of real-world scenarios. `http://www.sciencedirect.com/science/article/pii/S0377221716305641`.

[340] Shin Siang Choong, Li-Pei Wong, and Chee Peng Lim. An artificial bee colony algorithm with a modified choice function for the traveling salesman problem. In *IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. IEEE, 2017. The Artificial Bee Colony (ABC) algorithm is a swarm intelligence approach which has initially been proposed to solve optimization of mathematical test functions with a unique neighbourhood search mechanism. However, this neighbourhood search mechanism could not be directly applied to

combinatorial discrete optimization problems. The employed and onlooker bees need to be equipped with problem-specific perturbative heuristics in order to tackle combinatorial discrete optimization problems. However, there is a large variety of available problem-specific heuristics. In this paper, a hyper-heuristic method, namely a Modified Choice Function (MCF), is applied such that it can regulate the selection of the neighbourhood search heuristics adopted by the employed and onlooker bees automatically. The proposed MCF-based ABC model is implemented using the Hyper-heuristic Flexible Framework (HyFlex). To demonstrate the effectiveness of the proposed model, ten Traveling Salesman Problem (TSP) instances available in HyFlex have been evaluated. The empirical results show that the proposed model is able to statistically outperform four out of five ABC variants throughout the optimization process. `http://www.smc2017.org/SMC2017_Papers/media/files/0602.pdf`.

[341] Chung-Yao Chuang and Stephen F Smith. A study of agnostic hyper-heuristics based on sampling solution chains. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 271–278. IEEE, 2017. In this paper, we study a simple hyper-heuristic that functions by sampling solution chains. A solution chain in this algorithm is formed by successively applying a randomly chosen heuristic to the previous solution to generate the next solution. Operating in this way, the algorithm can benefit from the accumulated effect of applying multiple heuristics. A key factor in this algorithm is the strategy for choosing the sampling length. We discuss a balanced strategy in a setting that contains two agnostic assumptions: First, we do not have detailed knowledge about the problem domain being solved except that we have access to the objective function and a set of predefined heuristics. Secondly, we have no information about the amount of time allocated for running our algorithm. We present a theoretical guarantee on using this strategy to choose the sampling lengths and derive some variants based on this strategy. Empirical results also confirm that these strategies deliver desired behavior. Finally, we briefly discuss the extension of incorporating a learning mechanism into the algorithm. `http://ieeexplore.ieee.org/abstract/document/7969323/`.

[342] Robertas Damaševičius and Marcin Woźniak. State flipping based hyper-heuristic for hybridization of nature inspired algorithms. In *International Conference on Artificial Intelligence and Soft Computing*, pages 337–346. Springer, 2017. The paper presents a novel hyper-heuristic strategy for hybridization of nature inspired algorithms. The strategy is based on switching the state of agents using a logistic probability function, which depends upon the fitness rank of an agent. A case study using two nature inspired algorithms (Artificial Bee Colony (ABC) and Krill Herding (KH)) and eight optimization problems (Ackley Function, Bukin Function N.6, Griewank Function, Holder Table Function, Levy Function, Schaffer Function N.2, Schwefel Function, Shubert Function) is presented. The results show a superiority of the proposed hyper-heuristic (mean

end-rank for hybrid algorithm is 1.435 vs. 2.157 for KH and 2.408 for ABC). https://link.springer.com/chapter/10.1007/978-3-319-59063-9_30.

[343] Vinicius Renan de Carvalho and Jaime Simao Sichman. Applying copeland voting to design an agent-based hyper-heuristic. In *Proceedings of the 16th Conference on Autonomous Agents and MultiAgent Systems*, pages 972–980. International Foundation for Autonomous Agents and Multiagent Systems, 2017. Metaheuristics are algorithms which are applied to solve problems when conventional algorithms can not find good solutions in reasonable time; evolutionary algorithms are perhaps the most well-known examples of meta-heuristics. As there are many possible meta-heuristics, finding the most suitable meta-heuristic for a given problem is not a trivial task. In order to make this choice, one can design hyper-heuristics. In the literature, one can find some agent-based research whose focus is to propose a framework where meta-heuristics are considered as agents, that solve a given problem in a collaborative or competitive way. Most of these works focus on mono-objective meta-heuristics. Other works focus on how to select multi-objective meta-heuristics, but not using an agent-based approach. We present in this work an agent-based hyper-heuristic for choosing the most suitable evolutionary meta-heuristic for a given problem. Our approach performs a cooperative Copeland voting procedure, considering five different metrics, to define which one of three competitive evolutionary meta-heuristics should execute during a certain processing time. We use the Walking Fish Problem (WFG) suite with two and three objectives to analyse the proposed approach performance. The obtained results showed that in all cases our strategy found the most indicated evolutionary algorithm and gets competitive results against the state of art. http://dl.acm.org/citation.cfm?id=3091263.

[344] Vinicius Veloso de Melo and Wolfgang Banzhaf. Drone squadron optimization: a novel self-adaptive algorithm for global numerical optimization. *Neural Computing and Applications*, pages 1–28, 2017. This paper proposes Drone Squadron Optimization (DSO), a new self-adaptive metaheuristic for global numerical optimization which is updated online by a hyper-heuristic. DSO is an artifact-inspired technique, as opposed to many nature-inspired algorithms used today. DSO is very flexible because it is not related to natural behaviors or phenomena. DSO has two core parts: the semiautonomous drones that fly over a landscape to explore, and the command center that processes the retrieved data and updates the drones' firmware whenever necessary. The self-adaptive aspect of DSO in this work is the perturbation/movement scheme, which is the procedure used to generate target coordinates. This procedure is evolved by the command center during the global optimization process in order to adapt DSO to the search landscape. We evaluated DSO on a set of widely employed single-objective benchmark functions. The statistical analysis of the results shows that the proposed method is competitive with the other methods,

but we plan several future improvements to make it more powerful and robust. https://link.springer.com/article/10.1007/s00521-017-2881-3.

[345] Gang Chen Deepak Karunakaran, Yi Mei and Mengjie Zhang. Toward evolving dispatching rules for dynamic job shop scheduling under uncertainty. In *the 18th Annual Conference on Genetic and Evolutionary Computation (GECCO)*, Berlin, Germany, 2017. Dynamic job shop scheduling (DJSS) is a complex problem which is an important aspect of manufacturing systems. Even though the manufacturing environment is uncertain, most of the existing research works consider merely deterministic problems where the time required for processing any job is known in advance and never changes. However many DJSS problems in practice involve high level of uncertainty that must be explicitly addressed. In this work, we consider DJSS problems with varied uncertainty configurations of machines in terms of processing times. We find that with the varying levels of uncertainty, more and more machines cannot fulfill their duties as scheduled and will become bottlenecks of the job shop. To cope with uncertainties, it is therefore essential to identify these bottleneck machines and schedule the jobs to be performed by them carefully. Driven by this idea, we develop a new effective method to evolve pairs of dispatching rules each for a different bottleneck level on the machines. A clustering approach to classify the bottleneck level of the machines arising in the system due to uncertain processing times is proposed. Then, a cooperative co-evolution technique to evolve pairs of dispatching rules which generalizes well across different uncertainty configurations is presented. We perform empirical analysis to show its generalization characteristic over the different uncertainty configurations and show that the proposed method outperforms the current approaches. http://homepages.ecs.vuw.ac.nz/~yimei/papers/GECCO17-Deepak.pdf.

[346] Fakhrud Din, Abdul Rahman A Alsewari, and Kamal Z Zamli. A parameter free choice function based hyper-heuristic strategy for pairwise test generation. In *IEEE International Conference on Software Quality, Reliability and Security Companion (QRS-C)*, pages 85–91. IEEE, 2017. Hyper-heuristics are advanced high-level search methodologies that solve hard computational problems indirectly via low-level heuristics. Choice function based hyper-heuristics are selection and acceptance hyper-heuristics that use statistical information to rank low-level heuristics for selection. In this paper, we describe a choice function based hyper-heuristic called Pairwise Choice Function based Hyper-heuristic (PCFHH) for the pairwise test generation problem. PCFHH uses a combination of three measures to select and apply an effective low-level heuristic from a set of four low-level heuristics at any stage of the search. Our experimental results have been encouraging as PCFHH outperforms most of pairwise test generation strategies on many of the problem instances. http://ieeexplore.ieee.org/abstract/document/8004298/.

[347] John H Drake, Jerry Swan, Geoff Neumann, and Ender Özcan. Sparse, continuous policy representations for uniform online bin packing via regression of

interpolants. In *European Conference on Evolutionary Computation in Combinatorial Optimization*, pages 189–200. Springer, 2017. Online bin packing is a classic optimisation problem, widely tackled by heuristic methods. In addition to human-designed heuristic packing policies (e.g. first- or best- fit), there has been interest over the last decade in the automatic generation of policies. One of the main limitations of some previously-used policy representations is the trade-off between locality and granularity in the associated search space. In this article, we adopt an interpolation-based representation which has the jointly-desirable properties of being sparse and continuous (i.e. exhibits good genotype-to-phenotype locality). In contrast to previous approaches, the policy space is searchable via real-valued optimization methods. Packing policies using five different interpolation methods are comprehensively compared against a range of existing methods from the literature, and it is determined that the proposed method scales to larger instances than those in the literature. `https://link.springer.com/chapter/10.1007/978-3-319-55453-2_13`.

[348] Mohamed El Yafrani, Marcella Martins, Markus Wagner, Belaid Ahiod, Myriam Delgado, and Ricardo Lüders. A hyperheuristic approach based on low-level heuristics for the travelling thief problem. *Genetic Programming and Evolvable Machines*, pages 1–30, 2017. In this paper, we investigate the use of hyper-heuristics for the travelling thief problem (TTP). TTP is a multi-component problem, which means it has a composite structure. The problem is a combination between the travelling salesman problem and the knapsack problem. Many heuristics were proposed to deal with the two components of the problem separately. In this work, we investigate the use of automatic online heuristic selection in order to find the best combination of the different known heuristics. In order to achieve this, we propose a genetic programming based hyper-heuristic called GPHS*, and compare it to state-of-the-art algorithms. The experimental results show that the approach is competitive with those algorithms on small and mid-sized TTP instances. `https://link.springer.com/article/10.1007/s10710-017-9308-x`.

[349] Islam Elnabarawy, Daniel R Tauritz, and Donald C Wunsch. Evolutionary computation for the automated design of category functions for fuzzy art: an initial exploration. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO) Companion*, pages 1133–1140. ACM, 2017. Fuzzy Adaptive Resonance Theory (ART) is a classic unsupervised learning algorithm. Its performance on a particular clustering problem is sensitive to the suitability of the category function for said problem. However, classic Fuzzy ART employs a fixed category function and thus is unable to benefit from the potential to adjust its category function. This paper presents an exploration into employing evolutionary computation for the automated design of category functions to obtain significantly enhanced Fuzzy ART performance through tailoring to specific problem classes. We employ a genetic programming powered hyper-heuristic approach where the category functions are constructed from a set of primitives constituting those

of the original Fuzzy ART category function as well as additional hand-selected primitives. Results are presented for a set of experiments on benchmark classification tasks from the UCI Machine Learning Repository demonstrating that tailoring Fuzzy ART's category function can achieve statistically significant superior performance on the testing datasets in stratified 10-fold cross-validation procedures. We conclude with discussing the results and placing them in the context of being a first step towards automating the design of entirely new forms of ART. `http://dl.acm.org/citation.cfm?id=3082056`.

[350] Alexandre Silvestre Ferreira, Richard Aderbal Gonçalves, and Aurora Pozo. A multi-armed bandit selection strategy for hyper-heuristics. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 525–532. IEEE, 2017. Meta-heuristics have emerged as an efficient way to solve NP-hard problems even without the guaranteed of optimal values. The main issue of meta-heuristics is that they are built using domain-specific knowledge. Therefore, they require a great effort to be adapted to a new domain. The concept of Hyper-heuristic was proposed to solve this problem. Hyper-heuristics are search methods that aim to solve optimization problems by selecting or generating heuristics. Selection hyper-heuristics choose from a pool of heuristics a good one to be applied at the current stage of the optimization process. Although there are several works focused on selection hyper-heuristics, there is no consensus about which is the best way to define a selection strategy. In this work, a deterministic selection strategy based on the concepts of the Multi-Armed Bandit (MAB) problem is proposed for combinatorial optimization. Multi-armed bandit approaches define a selection function with two components; the first is based on the performance of an operator and the second based on the number of times that the operator was used. In this work, three MAB algorithms were implemented using the HyFlex framework. An empirical parameter configuration was performed to each algorithm, and the best setup was compared to the top ten CHeSC 2011 algorithms using the same methodology adopted during the competition. The results obtained were comparable to those attained by the literature. Moreover, it was concluded that the behavior of MAB selection is heavily affected by its parameters. As this is not a desirable behavior for hyper-heuristics, future research will investigate ways to better deal with the parameter setting. `http://ieeexplore.ieee.org/abstract/document/7969356/`.

[351] Thiago N Ferreira, Jackson A Prado Lima, Andrei Strickler, Josiel N Kuk, Silvia R Vergilio, and Aurora Pozo. Hyper-heuristic based product selection for software product line testing. *IEEE Computational Intelligence Magazine*, 12(2):34–45, 2017. A Software Product Line (SPL) is defined as a set of software systems that share a common and managed set of features satisfying specific needs of a particular market segment or domain [1]. The SPL offers a number of common artifacts for building products, including mandatory and variable elements. SPL approaches have been adopted by many software companies1 to ease reuse and reduce time and production costs. A feature represents

a functionality that is visible to the user and can be designed as a variability, which represents a variable functionality that may or may not be present in a product. On the other hand, mandatory features are common to all SPL products. To facilitate feature management, most SPL methodologies use the Feature Model (FM) to represent all the SPL variabilities and commonalities. http://ieeexplore.ieee.org/abstract/document/7895294/.

[352] Vidal D Fontoura, Aurora TR Pozo, and Roberto Santana. Automated design of hyper-heuristics components to solve the psp problem with hp model. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 1848–1855. IEEE, 2017. The Protein Structure Prediction (PSP) problem is one of the modern most challenging problems from science. Simplified protein models are usually applied to simulate and study some characteristics of the protein folding process. Hence, many heuristic strategies have been applied in order to find simplified protein structures in which the protein configuration has the minimal energy. However, these strategies have difficulties in finding the optimal solutions to the longer sequences of amino-acids, due to the complexity of the problem and the huge amount of local optima. Hyper heuristics have proved to be useful in this type of context since they try to combine different heuristics strengths into a single framework. However, there is lack of work addressing the automated design of hyper-heuristics components. This paper proposes GEHyPSP, an approach which aims to achieve generation, through grammatical evolution, of selection mechanisms and acceptance criteria for a hyper-heuristic framework applied to PSP problem. We investigate the strengths and weaknesses of our approach on a benchmark of simplified protein models. GEHyPSP was able to reach the best known results for 7 instances from 11 that composed the benchmark set used to evaluate the approach. http://ieeexplore.ieee.org/abstract/document/7969526/.

[353] Mahmut Ali Gokce, Berkay Beygo, and Turgut Emekci. A hyperheuristic approach for dynamic multilevel capacitated lot sizing with linked lot sizes for aps implementations. *Journal of Yasar University*, 12(45):14–31, 2017. This study is concerned with solving real-life sized APS problems practically. Specifically, the problem of Multilevel Capacitated Lot Sizing Problem with linked lot sizes (MLCLSP-L) is considered. The problem is a classical, practical and notoriously hard problem. We propose a new modeling technique for MLCLSP-L based on a GA-driven hyperheuristic, which enables modeling of some issues previously not modeled. Proposed model uses an indirect representation by allowing GA search through a space of low level heuristics. Each one of the low level heuristics is simple and determines the detailed production plan of a machine in a period. The solution is constructed through combination of these low level heuristics. New model is demonstrated by solving moderate size test problem along with software developed. http://dergipark.ulakbim.gov.tr/jyasar/article/view/5000168850.

[354] Juan Carlos Gomez and Hugo Terashima-Marin. Evolutionary hyper-heuristics for tackling bi-objective 2d bin packing problems. *Genetic Programming and Evolvable Machines*, pages 1–31, 2017. In this article, a multi-objective evolutionary framework to build selection hyper-heuristics for solving instances of the 2D bin packing problem is presented. The approach consists of a multi-objective evolutionary learning process, using specific tailored genetic operators, to produce sets of variable length rules representing hyper-heuristics. Each hyper-heuristic builds a solution to a given problem instance by sensing the state of the instance, and deciding which single heuristic to apply at each decision point. The hyper-heuristics consider the minimization of two conflicting objectives when building a solution: the number of bins used to accommodate the pieces and the total time required to do the job. The proposed framework integrates three well-studied multi-objective evolutionary algorithms to produce sets of Pareto-approximated hyper-heuristics: the Non-dominated Sorting Genetic Algorithm-II, the Strength Pareto Evolutionary Algorithm 2, and the Generalized Differential Evolution Algorithm 3. We conduct an extensive experimental analysis using a large set of 2D bin packing problem instances containing convex and non-convex irregular pieces, under many conditions, settings and using several performance metrics. The analysis assesses the robustness and flexibility of the proposed approach, providing encouraging results when compared against a set of well-known baseline single heuristics. `https://link.springer.com/article/10.1007/s10710-017-9301-4`.

[355] Raquel Hernández Gómez and Carlos A Coello Coello. A hyper-heuristic of scalarizing functions. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO)*, pages 577–584. ACM, 2017. Scalarizing functions have been successfully used by Multi-Objective Evolutionary Algorithms (MOEAs) for the fitness assignment process. Their popularity has to do with their low computational cost, their capability to generate (weakly) Pareto optimal solutions, and their effectiveness in solving many-objective optimization problems. Nevertheless, recent studies indicate that the search behavior of MOEAs strongly depends on the choice of the scalarizing function. Besides, this specification varies according to the Pareto-front geometry of the problem at hand. In this work, we present a novel hyper-heuristic for continuous search spaces, which combines the strengths and compensates for the weaknesses of different scalarizing functions. These heuristics have been proposed within the evolutionary multi-objective optimization and mathematical programming communities. Furthermore, the selection of heuristics is conducted through the s-energy, which measures the even distribution of a set of points in k-dimensional manifolds. Experimental results indicate that our proposed approach outperforms the use of a single heuristic as well as other state-of-the-art algorithms in the majority of the ZDT, DTLZ and WFG test problems. `http://dl.acm.org/citation.cfm?id=3071178.3071220`.

[356] Martin González, Jose J López-Espin, Juan Aparicio, Domingo Giménez, and

El-Ghazali Talbi. A parameterized scheme of metaheuristics with exact methods for determining the principle of least action in data envelopment analysis. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 588–595. IEEE, 2017. Data Envelopment Analysis (DEA) is a nonparametric methodology for estimating technical efficiency of a set of Decision Making Units (DMUs) from a dataset of inputs and outputs. This paper is devoted to computational aspects of DEA models under the application of the Principle of Least Action. This principle guarantees that the efficient closest targets are determined as benchmarks for each assessed unit. Usually, these models have been addressed in the literature by applying unsatisfactory techniques, based fundamentally on combinatorial NP-hard problems. Recently, some heuristics have been developed to partially solve these DEA models. This paper improves the heuristic methods used in previous works by applying a combination of metaheuristics and an exact method. Also, a parameterized scheme of metaheuristics is developed in order to implement metaheuristics and hybridations/combinations, adapting them to the particular problem proposed here. In this scheme, some parameters are used to study several types of metaheuristics, like Greedy Random Adaptative Search Procedure, Genetic Algorithms or Scatter Search. The exact method is included inside the metaheuristic to solve the particular model presented in this paper. A hyperheuristic is used on top of the parameterized scheme in order to search, in the space of metaheuristics, for metaheuristics that provide solutions close to the optimum. The method is competitive with exact methods, obtaining fitness close to the optimum with low computational time. `http://ieeexplore.ieee.org/abstract/document/7969364/`.

[357] Rosa G. Gonzalez-Ramirez, Neale R. Smith, Ronald G. Askin, Jose-Fernando Camacho-Vallejo, and Jose Luis Gonzalez-Velarde. A grasp-tabu heuristic approach to territory design for pickup and delivery operations for large scale instances. *Mathematical Problems in Engineering*, 2017. In this article, we address a logistics districting problem faced by a parcel company whose operations consists of picking up and delivering packages over a service region. The districting process aims to find a partition of the service region into delivery and collection zones that may be served by a single vehicle that departs from a central depot. Criteria to be optimized are to balance workload content among the districts and to create districts of compact shape. A solution approach based on a hybrid procedure that combines elements of GRASP and Tabu Search (TS) is proposed to solve large scale instances. Numerical experimentation is performed considering different instance sizes and types. Results show that the proposed solution approach is able to solve large scale instances in reasonable computational times with good quality of the solutions obtained. To determine the quality of the solutions, results are compared with CPLEX solutions and with the current real solution to highlight the benefits of the proposed approach. Conclusions and recommendations for further research are provided. `https://www.hindawi.com/journals/mpe/aip/4708135/`.

[358] Kevin Graham and Leslie Smith. Comparing hyper-heuristics with blackboard systems. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, pages 1141–1145. ACM, 2017. This paper aims to draw a comparison between the traditional view of hyper-heuristics and a lesser known type of multi-agent system known as a blackboard system. Both approaches share many similarities in both implementation and philosophy but also have several important differences in terms of characteristics and approach, such as a difference in control scheme. To investigate the consequences of the perceived differences, both approaches are decomposed into their constituent parts and compared with a focus on the perceived strengths and weaknesses of adopting one methodology over the other. `http://dl.acm.org/citation.cfm?id=3082055`.

[359] Angeliki Gretsista and Edmund K Burke. An iterated local search framework with adaptive operator selection for nurse rostering. In *International Conference on Learning and Intelligent Optimization*, pages 93–108. Springer, 2017. Considerable attention has been paid to selective hyper-heuristic frameworks for addressing computationally hard scheduling problems. By using selective hyper-heuristics, we can derive benefits from the strength of low level heuristics and their components at different stages of the heuristic search. In this paper, a simple, general and effective selective hyper heuristic is presented. We introduce an iterated local search based hyper-heuristic framework that incorporates the adaptive operator selection scheme to learn through the search process. The considered iterative approach employs an action selection model to decide the perturbation strategy to apply in each step and a credit assignment module to score its performance. The designed framework allows us to employ any action selection model and credit assignment mechanism used in the literature. Empirical results and an analysis of six different action selection models against state-of-the-art approaches, across 39 problem instances, highlight the significant potential of the proposed selection hyper-heuristics. Further analysis on the adaptive behavior of the model suggests that two of the six models are able to learn the best performing perturbation strategy, resulting in significant performance gains. `https://link.springer.com/chapter/10.1007/978-3-319-69404-7_7`.

[360] Giovani Guizzo, Mosab Bazargani, Matheus Paixao, and John H Drake. A hyper-heuristic for multi-objective integration and test ordering in google guava. In *International Symposium on Search Based Software Engineering*, pages 168–174. Springer, 2017. `http://dl.acm.org/citation.cfm?id=3131152`.

[361] Giovani Guizzo, Silvia R Vergilio, Aurora TR Pozo, and Gian M Fritsche. A multi-objective and evolutionary hyper-heuristic applied to the integration and test order problem. *Applied Soft Computing*, 56:331–344, 2017. The field of Search-Based Software Engineering (SBSE) has widely utilized Multi-Objective Evolutionary Algorithms (MOEAs) to solve complex software engineering problems. However, the use of such algorithms can be a hard task for the software engineer, mainly due to the significant range of parameter and algorithm choices.

To help in this task, the use of Hyper-heuristics is recommended. Hyper-heuristics can select or generate low-level heuristics while optimization algorithms are executed, and thus can be generically applied. Despite their benefits, we find only a few works using hyper-heuristics in the SBSE field. Considering this fact, we describe HITO, a Hyper-heuristic for the Integration and Test Order Problem, to adaptively select search operators while MOEAs are executed using one of the selection methods: Choice Function and Multi-Armed Bandit. The experimental results show that HITO can outperform the traditional MOEAs NSGA-II and MOEA/DD. HITO is also a generic algorithm, since the user does not need to select crossover and mutation operators, nor adjust their parameters. http://www.sciencedirect.com/science/article/pii/S1568494617301357.

[362] Andres E Gutierrez-Rodriguez, José C Ortiz-Bayliss, Alejandro Rosales-Pérez, Ivan M Amaya-Contreras, Santiago E Conant-Pablos, Hugo Terashima-Marin, and Carlos A Coello Coello. Applying automatic heuristic-filtering to improve hyper-heuristic performance. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 2638–2644. IEEE, 2017. Hyper-heuristics have emerged as an important strategy for combining the strengths of different heuristics into a single method. Although hyper-heuristics have been found to be successful in many scenarios, little attention has been paid to the subsets of heuristics that these methods manage and apply. In several cases, heuristics can interfere with each other and can be harmful for the search. Thus, obtaining information about the differences among heuristics, and how they contribute to the search process is very important. The main contribution of this paper is an automatic heuristic-filtering process that allows hyper-heuristics to exclude heuristics that do not contribute to improving the solution. Based on some previous works in feature selection, two methods are proposed that rank heuristics and sequentially select only suitable heuristics in a hyper-heuristic framework. Our experiments over a set of Constraint Satisfaction Problem instances show that a hyper-heuristic with only selected heuristics obtains significantly better results than a hyper-heuristic containing all heuristics, in terms of running times. In addition, the success rate of solving such instances is better for the hyper-heuristic with the suitable heuristics than for the hyper-heuristic without our proposed filtering process. http://ieeexplore.ieee.org/abstract/document/7969626/.

[363] Helga Ingimundardottir and Thomas Philip Runarsson. Discovering dispatching rules from data using imitation learning: A case study for the job-shop problem. *Journal of Scheduling*, pages 1–16, 2017. Dispatching rules can be automatically generated from scheduling data. This paper will demonstrate that the key to learning an effective dispatching rule is through the careful construction of the training data, (i) features of partially constructed schedules xixi should necessarily reflect the induced data distribution DD for when the rule is applied. This is achieved by updating the learned model in an active imitation learning fashion; (ii) yiyi is labelled optimally using a MIP solver; and (iii) data

need to be balanced, as the set is unbalanced with respect to the dispatching step k. Using the guidelines set by our framework the design of custom dispatching rules, for a particular scheduling application, will become more effective. In the study presented three different distributions of the job-shop will be considered. The machine learning approach considered is based on preference learning, i.e. which dispatch (post-decision state) is preferable to another. `https://link.springer.com/article/10.1007/s10951-017-0534-0`.

[364] Gang Chen Mengjie Zhang Josiah Jacobsen-Grocott, Yi Mei. Evolving heuristics for dynamic vehicle routing with time windows using genetic programming. In *IEEE Congress on Evolutionary Computation (CEC)*, San Sebastian, Spain, 2017. Dynamic vehicle routing problem with time windows is an important combinatorial optimisation problem in many real-world applications. The most challenging part of the problem is to make real-time decisions (i.e. whether to accept the newly arrived service requests or not) during the execution of the routes. It is hardly applicable to use the optimisation methods such as mathematical programming and evolutionary algorithms that are competitive for static problems, since they are usually time consuming, and cannot give real-time responses. In this paper, we consider solving this problem using heuristics. A heuristic gradually builds a solution by adding the requests to the end of the route one by one. This way, it can take advantage of the latest information when making the next decision, and give immediate response. In this paper, we propose a meta-algorithm to generate a solution given any heuristic. The meta-algorithm maintains a set of routes throughout the scheduling horizon. Whenever a new request arrives, it tries to re-generate new routes to include the new request by the heuristic. It accepts the new request if successful, and reject otherwise. Then we manually designed several heuristics, and proposed a genetic programming-based hyper-heuristic to automatically evolve heuristics. The results showed that the heuristics evolved by genetic programming significantly outperformed the manually designed heuristics. `http://homepages.ecs.vuw.ac.nz/~yimei/papers/CEC17-Josiah.pdf`.

[365] Daniel Karapetyan, Abraham P Punnen, and Andrew J Parkes. Markov chain methods for the bipartite boolean quadratic programming problem. *European Journal of Operational Research*, 2017. We study the Bipartite Boolean Quadratic Programming Problem (BBQP) which is an extension of the well known Boolean Quadratic Programming Problem (BQP). Applications of the BBQP include mining discrete patterns from binary data, approximating matrices by rank-one binary matrices, computing the cut-norm of a matrix, and solving optimisation problems such as maximum weight biclique, bipartite maximum weight cut, maximum weight induced sub-graph of a bipartite graph, etc. For the BBQP, we first present several algorithmic components, specifically, hill climbers and mutations, and then show how to combine them in a high-performance metaheuristic. Instead of hand-tuning a standard metaheuristic to test the efficiency of the hybrid of the components, we chose to use an automated generation of a multi-component

metaheuristic to save human time, and also improve objectivity in the analysis and comparisons of components. For this we designed a new metaheuristic schema which we call Conditional Markov Chain Search (CMCS). We show that CMCS is flexible enough to model several standard metaheuristics; this flexibility is controlled by multiple numeric parameters, and so is convenient for automated generation. We study the configurations revealed by our approach and show that the best of them outperforms the previous state-of-the-art BBQP algorithm by several orders of magnitude. In our experiments we use benchmark instances introduced in the preliminary version of this paper and described here, which have already become the de facto standard in the BBQP literature.

[366] Deepak Karunakaran, Yi Mei, Gang Chen, and Mengjie Zhang. Dynamic job shop scheduling under uncertainty using genetic programming. In *the 20th Asia Pacific Symposium on Intelligent and Evolutionary Systems (IES)*, pages 195–210, Canberra, Australia, 2017. Springer. Job shop scheduling (JSS) is a hard problem with most of the research focused on scenarios with the assumption that the shop parameters such as processing times, due dates are constant. But in the real world uncertainty in such parameters is a major issue. In this work, we investigate a genetic programming based hyper-heuristic approach to evolving dispatching rules suitable for dynamic job shop scheduling under uncertainty. We consider uncertainty in processing times and consider multiple job types pertaining to different levels of uncertainty. In particular, we propose an approach to use exponential moving average of the deviations of the processing times in the dispatching rules. We test the performance of the proposed approach under different uncertain scenarios. Our results show that the proposed method performs significantly better for a wide range of uncertain scenarios. `http://link.springer.com/chapter/10.1007/978-3-319-49049-6_14`.

[367] Deepak Karunakaran, Yi Mei, Gang Chen, and Mengjie Zhang. Evolving dispatching rules for dynamic job shop scheduling with uncertain processing times. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 364–371. IEEE, 2017.

[368] Ahmed Kheiri and Ed Keedwell. A hidden markov model approach to the problem of heuristic selection in hyper-heuristics with a case study in high school timetabling problems. *Evolutionary Computation*, 25(3):473–501, 2017. Operations research is a well established field that uses computational systems to support decisions in business and public life. Good solutions to operations research problems can make a large difference to the efficient running of businesses and organisations and so the field often searches for new methods to improve these solutions. The high school timetabling problem is an example of an operations research problem and is a challenging task which requires assigning events and resources to time slots subject to a set of constraints. In this paper a new sequence-based selection hyper-heuristic is presented that produces excellent results on a suite of high school timetabling problems. In this study, we present

an easy-to-implement, easy-to-maintain and effective sequence-based selection hyper-heuristic to solve high school timetabling problems using a benchmark of unified real-world instances collected from different countries. We show that with sequence-based methods, it is possible to discover new best known solutions for a number of the problems in the timetabling domain. Through this investigation, the usefulness of sequence-based selection hyper-heuristics has been demonstrated and the capability of these methods has been shown to exceed the state-of-the-art. http://www.mitpressjournals.org/doi/abs/10.1162/EVCO_a_00186.

[369] K Raja Kumari, P Sengottuvelan, and J Shanthini. A hybrid approach of genetic algorithm and multi objective pso task scheduling in cloud computing. *Asian Journal of Research in Social Sciences and Humanities*, 7(3):1260–1271, 2017. The genetic algorithm is an evolutionary optimization algorithm based upon Initial population, crossover, mutation and Evaluation. On the other side, Multi Objective particle swarm optimization (MOPSO) is a swarm intelligence algorithm functioning by means of inertia weight, learning factors and the mutation probability. In high-performance hyper-heuristic algorithm is used to find better scheduling solutions in cloud computing. To improve the scheduling results in terms of makespan, throughput, cost. Hyper-heuristic algorithm finds better scheduling solutions for cloud computing systems and to further improve the scheduling results in terms of make span. A novel Multi objective particle swarm optimization and Genetic Algorithm based hyper-heuristic resource scheduling algorithm has been designed as the hybrid algorithm. Performance of the proposed algorithm has also been evaluated through the Cloud Sim toolkit. We have compared our hybrid scheduling algorithm with existing common heuristic-based scheduling algorithms. The results thus obtained have shown a better performance by our algorithm than the existing algorithms, in terms of giving reduce cost and improve makespan. The proposed model shows the improved resource utilization, makespan, throughput. http://www.indianjournals.com/ijor.aspx?target=ijor:ajrssh&volume=7&issue=3&article=088.

[370] Mourad Lassouaoui, Dalila Boughaci, and Belaid Benhamou. A multilevel hyper-heuristic for solving max-sat. *International Journal of Metaheuristics*, 6(3):133–159, 2017. A hyper-heuristic is a high-level method that manages a set of low-level heuristics to solve various problems in a problem-independent manner. In this paper, we propose a new selection hyper-heuristic with the multilevel paradigm. The multilevel paradigm refers to the process of dividing large problems into sub-problems. Each sub-problem is being solved to reach an optimal solution by using the resulting solution from a previous level as a starting solution at the next level. The selection strategy chooses the adequate low-level heuristic at any iteration during the search. For analysis purposes, several variants of hyper-heuristics are implemented and Max-SAT is used as the test bed. The experimental results revealed that the multilevel paradigm together with a new hybrid-heuristic selection mechanism provides a substantial performance improve-

ment. A comparison with two known state of the art algorithms that are GSAT and WALKSAT is given to further show the efficiency of our method. `http://www.inderscienceonline.com/doi/abs/10.1504/IJMHEUR.2017.085123`.

[371] Seongmin Lee and Shin Yoo. Hyperheuristic observation based slicing of guava. In *Proceeedings of the 9th Symposium on Search-Based Software Engineering (SSBSE)*, LNCS. Springer, 2017.

[372] W. Li, E. Ozcan, and R. John. Multi-objective evolutionary algorithms and hyper-heuristics for wind farm layout optimisation. *Renewable Energy*, 105:473–482, 2017. Wind farm layout optimisation is a challenging real-world problem which requires the discovery of trade-off solutions considering a variety of conflicting criteria, such as minimisation of the land area usage and maximisation of energy production. However, due to the complexity of handling multiple objectives simultaneously, many approaches proposed in the literature often focus on the optimisation of a single objective when deciding the locations for a set of wind turbines spread across a given region. In this study, we tackle a multi-objective wind farm layout optimisation problem. Different from the previously proposed approaches, we are applying a high-level search method, known as selection hyper-heuristic to solve this problem. Selection hyper-heuristics mix and control a predefined set of low-level (meta)heuristics which operate on solutions. We test nine different selection hyper-heuristics including an online learning hyper-heuristic on a multi-objective wind farm layout optimisation problem. Our hyper-heuristic approaches manage three well-known multi-objective evolutionary algorithms as low-level metaheuristics. The empirical results indicate the success and potential of selection hyper-heuristics for solving this computationally difficult problem. We additionally explore other objectives in wind farm layout optimisation problems to gain a better understanding of the conflicting nature of those objectives. `http://www.sciencedirect.com/science/article/pii/S0960148116310709`.

[373] Jackson A Prado Lima and Silvia R Vergilio. A multi-objective optimization approach for selection of second order mutant generation strategies. In *Proceedings of the 2nd Brazilian Symposium on Systematic and Automated Software Testing*, page 6. ACM, 2017. The use of Higher-Order Mutants (HOMs) presents some advantages concerning the traditional use of First-Order Mutants (FOMs). HOMs can better simulate real and subtle faults, reduce the number of generated mutants and test cases, and so on. However, the HOM space is potentially huge, and an efficient strategy to generate the best HOMs is fundamental. In the literature different strategies were proposed and evaluated, mainly to generate Second-Order Mutants (SOMs), but none has been proved to perform better in different situations. Due to this, the selection of the best strategy is an important task. Most times a lot of experiments need to be conducted. To help the tester in this task and to allow the use of HOMs in practice, this paper proposes a hyper-heuristic approach. Such approach is based on NSGA-II and uses the selection method Choice Function to automatically choose among different Low-Level

Heuristics (LLHs), which, in this case, are search-operators related to existing SOM generation strategies. The performance of each LLH is related to some objectives such as the number of SOMs generated, the capacity to capture subtler faults and replace the constituent FOMs. In comparison with existing strategies, our approach obtained better results considering the used objectives, and statistically equivalent results considering mutation score with respect to the FOMs. `https://dl.acm.org/citation.cfm?id=3128479`.

[374] Jackson A Prado Lima, Silvia R Vergilio, et al. Automatic generation of search-based algorithms applied to the feature testing of software product lines. In *Proceedings of the 31st Brazilian Symposium on Software Engineering*, pages 114–123. ACM, 2017. The selection of products for the variability testing of Feature Models (FMs) is a complex task impacted by many factors. To solve this problem, Multi-Objective Evolutionary Algorithms (MOEAs) have been successfully used in the field known as Search-Based Software Engineering (SBSE). However, the design of a search-based approach is not an easy task for the software engineer, who can find some difficulties such as: the choice and configuration of the best MOEAs, the choice of the best search operators to be implemented, and so on. In addition to this, existing approaches are dependent on the problem domain and do not allow reuse. In this way the use of Hyper-Heuristic (HH) can help to obtain more generic and reusable search-based approaches, and because of this is considered a trend in the SBSE field. Following this trend and to contribute to reduce the software engineer's efforts, this work explores the use of a hyper-heuristic for automatic generation of MOEAs to select test products from the FM, considering three factors: pairwise coverage, mutation score and cost, given by the number of products. The HH is based on a grammar that represents the elements, parameters and components of existing MOEAs and implements evolutionary operators, such as crossover and mutation, suitable for selection problems. In this way, it can be reused for other similar software engineering problems. Evaluation results show that the proposed approach obtains results that are better or statistically equivalent than similar approaches found in the literature. `https://dl.acm.org/citation.cfm?id=3131152`.

[375] Jian Lin, Dike Luo, Xiaodong Li, Kaizhou Gao, and Yanan Liu. Differential evolution based hyper-heuristic for the flexible job-shop scheduling problem with fuzzy processing time. In *Asia-Pacific Conference on Simulated Evolution and Learning*, pages 75–86. Springer, 2017. In this paper, a differential evolution based hyper-heuristic (DEHH) algorithm is proposed to solve the flexible job-shop scheduling problem with fuzzy processing time (FJSPF). In the DEHH scheme, five simple and effective heuristic rules are designed to construct a set of low-level heuristics, and differential evolution is employed as the high-level strategy to manipulate the low-level heuristics to operate on the solution domain. Additionally, an efficient hybrid machine assignment scheme is proposed to decode a solution to a feasible schedule. The effectiveness of the DEHH is evaluated on

two typical benchmark sets and the computational results indicate the superiority of the proposed hyper-heuristic scheme over the state-of-the-art algorithms. https://link.springer.com/chapter/10.1007/978-3-319-68759-9_7.

[376] Jian Lin, Zhou-Jing Wang, and Xiaodong Li. A backtracking search hyper-heuristic for the distributed assembly flow-shop scheduling problem. *Swarm and Evolutionary Computation*, 36:124–135, 2017. Distributed assembly permutation flow-shop scheduling problem (DAPFSP) is recognized as an important class of problems in modern supply chains and manufacturing systems. In this paper, a backtracking search hyper-heuristic (BS-HH) algorithm is proposed to solve the DAPFSP. In the BS-HH scheme, ten simple and effective heuristic rules are designed to construct a set of low-level heuristics (LLHs), and the backtracking search algorithm is employed as the high-level strategy to manipulate the LLHs to operate on the solution space. Additionally, an efficient solution encoding and decoding scheme is proposed to generate a feasible schedule. The effectiveness of the BS-HH is evaluated on two typical benchmark sets and the computational results indicate the superiority of the proposed BS-HH scheme over the state-of-the-art algorithms. http://www.sciencedirect.com/science/article/pii/S2210650216305028.

[377] Andrei Lissovoi, Pietro S Oliveto, and John Alasdair Warwicker. On the runtime analysis of generalised selection hyper-heuristics for pseudo-boolean optimisation. In *Proceedings of the Genetic and Evolutionary Computation Conference*, pages 849–856. ACM, 2017. Selection hyper-heuristics are randomised search methodologies which choose and execute heuristics from a set of low-level heuristics. Recent time complexity analyses for the LeadingOnes benchmark function have shown that the standard simple random, permutation, random gradient, greedy and reinforcement learning selection mechanisms show no effects of learning. The idea behind the learning mechanisms is to continue to exploit the currently selected heuristic as long as it is successful. However, the probability that a promising heuristic is successful in the next step is relatively low when perturbing a reasonable solution to a combinatorial optimisation problem. In this paper we generalise the classical selection-perturbation mechanisms so success can be measured over some fixed period of length r, rather than in a single iteration. We present a benchmark function where it is necessary to learn to exploit a particular low-level heuristic, rigorously proving that it makes the difference between an efficient and an inefficient algorithm. For LeadingOnes we prove that the generalised random gradient mechanism approaches optimal performance while generalised greedy, although not as fast, still outperforms random local search. An experimental analysis shows that combining the two generalised mechanisms leads to even better performance. https://dl.acm.org/citation.cfm?id=3071288.

[378] Yuxin Liu, Yi Mei, Mengjie Zhang, and Zili Zhang. Automated heuristic design using genetic programming hyper-heuristic for uncertain capacitated arc routing problem. In *the 18th Annual Conference on Genetic and Evolutionary*

Computation (GECCO), Berlin, Germany, 2017. Uncertain Capacitated Arc Routing Problem (UCARP) is a variant of the well-known CARP. It considers a variety of stochastic factors to reeect the reality where the exact information such as the actual task demand and accessibilities of edges are unknown in advance. Existing works focus on obtaining a robust solution beforehand. However, it is also important to design eeective heuris-tics to adjust the solution in real time. In this paper, we develop a new Genetic Programming-based Hyper-Heuristic (GPHH) for automated heuristic design for UCARP. A novel eeective meta-algorithm is designed carefully to address the failures caused by the environment change. In addition, it employs domain knowledge to lter some infeasible candidate tasks for the heuristic function. e experimental results show that the proposed GPHH signiicantly outperforms the existing GPHH methods and manually designed heuristics. Moreover, we nd that eliminating the infeasible and distant tasks in advance can reduce much noise and improve the eecacy of the evolved heuristics. In addition, it is found that simply adding a slack factor to the expected task demand may not improve the performance of the GPHH. https://www.researchgate.net/publication/315497953_Automated_Heuristic_Design_Using_Genetic_Programming_Hyper-Heuristic_for_Uncertain_Capacitated_Arc_Routing_Problem.

[379] Mashael Suliaman Maashi. Multi-objective hyper-heuristics. In *Heuristics and Hyper-Heuristics-Principles and Applications*. InTech, 2017. Multi-objective hyper-heuristics is a search method or learning mechanism that operates over a fixed set of low-level heuristics to solve multi-objective optimization problems by controlling and combining the strengths of those heuristics. Although numerous papers on hyper-heuristics have been published and several studies are still underway, most research has focused on single-objective optimization. Work on hyper-heuristics for multi-objective optimization remains limited. This chapter draws attention to this area of research to help researchers and PhD students understand and reuse these methods. It also provides the basic concepts of multi-objective optimization and hyper-heuristics to facilitate a better understanding of the related research areas, in addition to exploring hyper-heuristic methodologies that address multi-objective optimization. Some design issues related to the development of hyper-heuristic framework for multi-objective optimization are discussed. The chapter concludes with a case study of multi-objective selection hyper-heuristics and its application on a real-world problem. https://www.intechopen.com/books/heuristics-and-hyper-heuristics-principles-and-applications/multi-objective-hyper-heuristics.

[380] Hammad Majeed and Samina Naz. Deja vu: a hyper heuristic framework with record and recall (2r) modules. *Cluster Computing*, pages 1–15, 2017. Despite the success of heuristic methods in solving real-world problems, there are still some difficulties in terms of easily applying them to newly encountered problems, or

even new instances of similar problems. In addition, the little or no understanding of why different heuristics work effectively (or not) in certain situations does not facilitate simple choices of which approach to use in which situation. This paper proposes a new hyper heuristic framework named Deja Vu to address these issues. As the names suggests, it retrieves the stored solution of already solved problems for the new but similar problems. This makes the our system efficient and knowledge rich. The performance of Deja Vu is tested on the data sets with varying difficulty. Deja Vu has shown promising results on almost all the occasions. `https://link.springer.com/article/10.1007/s10586-017-1095-x`.

[381] E Mamatha, S Sasritha, CS Reddy, et al. Expert system and heuristics algorithm for cloud resource scheduling. *Romanian Statistical Review*, 65(1):3–18, 2017. Rule-based scheduling algorithms have been widely used on cloud computing systems and there is still plenty of room to improve their performance. This paper proposes to develop an expert system to allocate resources in cloud by using Rule based Algorithm, thereby measuring the performance of the system by letting the system adapt new rules based on the feedback. Here performance of the action helps to make better allocation of the resources to improve quality of services, scalability and flexibility. The performance measure is based on how the allocation of the resources is dynamically optimized and how the resources are utilized properly. It aims to maximize the utilization of the resources. The data and resource are given to the algorithm which allocates the data to resources and an output is obtained based on the action occurred. Once the action is completed, the performance of every action is measured that contains how the resources are allocated and how efficiently it worked. In addition to performance, resource allocation in cloud environment is also considered. `https://ideas.repec.org/a/rsr/journl/v65y2017i1p3-18.html`.

[382] Marcella SR Martins, Mohamed El Yafrani, Myriam RBS Delgado, Markus Wagner, Belaid Ahiod, and Ricardo Lüders. HSEDA: A heuristic selection approach based on estimation of distribution algorithm for the travelling thief problem. In *the 18th Annual Conference on Genetic and Evolutionary Computation (GECCO)*, Berlin, Germany, 2017. Hyper-heuristics are high-level search techniques which improve the performance of heuristics operating at a higher heuristic level. Usually, these techniques automatically generate or select new simpler components based on the feedback received during the search. Estimation of Distribution Algorithms (EDAs) have been applied as hyper-heuristics, using a probabilistic distribution model to extract and represent interactions between heuristics and its low-level components to provide high-valued problem solutions. In this paper, we consider an EDA-based hyper-heuristic framework which encompasses a Heuristic Selection approach aiming to find best combinations of different known heuristics. A surrogate assisted model evaluates the new heuristic combinations sampled by the EDA probabilistic model using an approximation function. We compare our proposed approach named Heuristic

Selection based on Estimation of Distribution Algorithm (HSEDA) with three state-of-the-art algorithms for the Travelling Thief Problem (TTP). The experimental results show that the approach is competitive, outperforming the other algorithms on most of the medium-sized TTP instances considered in this paper. `http://cs.adelaide.edu.au/~markus/pub/2017gecco-ttpeda.pdf`.

[383] Atiya Masood, Yi Mei, Gang Chen, and Mengjie Zhang. A pso-based reference point adaption method for genetic programming hyper-heuristic in many-objective job shop scheduling. In *Australasian Conference on Artificial Life and Computational Intelligence*, pages 326–338. Springer, 2017. Job Shop Scheduling is an important combinatorial optimisation problem in practice. It usually contains many (four or more) potentially conflicting objectives such as makespan and mean weighted tardiness. On the other hand, evolving dispatching rules using genetic programming has demonstrated to be a promising approach to solving job shop scheduling due to its flexibility and scalability. In this paper, we aim to solve many-objective job shop scheduling with genetic programming and NSGA-III. However, NSGA-III is originally designed to work with uniformly distributed reference points which do not match well with the discrete and non-uniform Pareto front in job shop scheduling problems, resulting in many useless points during evolution. These useless points can significantly affect the performance of NSGA-III and genetic programming. To address this issue and inspired by particle swarm optimisation, a new reference point adaptation mechanism has been proposed in this paper. Experiment results on many-objective benchmark job shop scheduling instances clearly show that prominent improvement in performance can be achieved upon using our reference point adaptation mechanism in NSGA-III and genetic programming. `https://link.springer.com/chapter/10.1007/978-3-319-51691-2_28`.

[384] Pericles BC Miranda and Ricardo BC Prudencio. Generation of particle swarm optimization algorithms: An experimental study using grammar-guided genetic programming. *Applied Soft Computing*, 2017. Particle Swarm Optimization (PSO) is largely used to solve optimization problems effectively. Nonetheless, the PSO performance depends on the fine tuning of different parameters. To make the algorithm design process more independent from human intervention, some researchers have treated this task as an optimization problem. Grammar-Guided Genetic Programming (GGGP) algorithms, in particular, have been widely studied and applied in the context of algorithm optimization. GGGP algorithms produce customized designs based on a set of production rules defined in the grammar, differently from methods that simply select designs in a pre-defined limited search space. Although GGGP algorithms have been largely used in other contexts, they have not been deeply investigated in the generation of PSO algorithms. Thus, this work applies GGGP algorithms in the context of PSO algorithm design problem. Herein, we performed an experimental study comparing different GGGP approaches for the generation of PSO algo-

rithms. The main goal is to perform a deep investigation aiming to identify pros and cons of each approach in the current task. In the experiments, a comparison between a tree-based GGGP approach and commonly used linear GGGP approaches for the generation of PSO algorithms was performed. The results showed that the tree-based GGGP produced better algorithms than the counterparts. We also compared the algorithms generated by the tree-based technique to state-of-the-art optimization algorithms, and it achieved competitive results. `http://www.sciencedirect.com/science/article/pii/S1568494617303836`.

[385] Péricles BC Miranda, Ricardo BC Prudêncio, and Gisele L Pappa. H3AD: A hybrid hyper-heuristic for algorithm design. *Information Sciences*, 2017. Designing an algorithm to solve a given problem is a challenging task due to the variety of possible design choices and the lack of clear guidelines on how to choose and/or combine them. Optimization and machine learning techniques have been used to make the algorithm design process more independent on human intervention. Hyper-heuristic approaches, in particular, have been proposed to search the space of algorithms/heuristics and/or their components, and iteratively combine and adapt them for specific problems. Although flexible to produce customized algorithms, hyper-heuristics can be extremely costly procedures. This paper proposes a novel hybrid hyper-heuristic (H3AD), which combines an automated algorithm selection approach with a generative hyper-heuristic. This combination intends to reduce the cost of providing an algorithm for a new input problem by reusing algorithms previously built by hyper-heuristics to solve similar problems. H3AD was evaluated in a case study to optimize the design of Particle Swarm Optimization algorithms in unconstrained continuous optimization problems. The results showed that H3AD provided appropriate recommendations of algorithms, reusing the algorithms generated by the hyper-heuristic to new input problems. Besides, H3AD drastically reduced the time of providing a customized algorithm when compared to generative hyper-heuristics, without a significant loss of optimization performance. `http://www.sciencedirect.com/science/article/pii/S0020025516314323`.

[386] Mustafa Mısır. Matrix factorization based benchmark set analysis: a case study on hyflex. In *Proceeedings of the 11th International Conference on Simulated Evolution and Learning (SEAL)*. Springer, 2017. The present paper offers an analysis strategy to examine benchmark sets of combinatorial search problems. Experimental analysis has been widely used to compare a set of algorithms on a group of instances from such problem domains. These studies mostly focus on the algorithms' performance rather than the quality of the target benchmark set. In relation to that, the insights about the algorithms' varying performance happen to be highly limited. The goal here is to introduce a benchmark set analysis strategy that can tell the quality of a benchmark set while allowing to retrieve some insights regarding the algorithms' performance. A matrix factorization based strategy is

utilized for this purpose. A Hyper-heuristic framework, i.e. HyFlex, involving 6 problem domains is accommodated as the testbed to perform the analysis on.

[387] Su Nguyen, Yi Mei, and Mengjie Zhang. Genetic programming for production scheduling: a survey with a unified framework. *Complex & Intelligent Systems*, pages 1–26, 2017. Genetic programming has been a powerful technique for automated design of production scheduling heuristics. Many studies have shown that heuristics evolved by genetic programming can outperform many existing heuristics manually designed in the literature. The flexibility of genetic programming also allows it to discover very sophisticated heuristics to deal with complex and dynamic production environments. However, as compared to other applications of genetic programming or scheduling applications of other evolutionary computation techniques, the configurations and requirements of genetic programming for production scheduling are more complicated. In this paper, a unified framework for automated design of production scheduling heuristics with genetic programming is developed. The goal of the framework is to provide the researchers with the overall picture of how genetic programming can be applied for this task and the key components. The framework is also used to facilitate our discussions and analyses of existing studies in the field. Finally, this paper shows how knowledge from machine learning and operations research can be employed and how the current challenges can be addressed. https://link.springer.com/article/10.1007%2Fs40747-017-0036-x.

[388] Su Nguyen and Mengjie Zhang. A PSO-based hyper-heuristic for evolving dispatching rules in job shop scheduling. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 882–889. IEEE, 2017. Automated heuristic design for job shop scheduling has been an interesting and challenging research topic in the last decade. Various machine learning and optimising techniques, usually referred to as hyper-heuristics, have been applied to facilitate the design task. Two main approaches are either to utilise a general structure for dispatching rules and optimise its parameters or to simultaneously search for suitable structures and their parameters. Each approach has its own advantages and disadvantages. In this paper, we focus on the first approach and develop new representations that are flexible enough to represent diverse rules and powerful enough to cope with complex shop conditions. Particle swarm optimisation is used in the proposed hyper-heuristic to find optimal rules based on the representations. The results suggest that the new representations are effective for different shop conditions and obtained rules are very competitive as compared to those evolved by genetic programming. Analyses also show that the proposed hyper-heuristic is significantly faster than genetic programming based hyper-heuristic. http://ieeexplore.ieee.org/abstract/document/7969402/.

[389] Gisele L Pappa. Recipe: A grammar-based framework for automatically evolving classification pipelines. In *Proceedings of the 20th European Conference on Genetic Programming (EuroGP), LNCS*, volume 10196, page 246. Springer, 2017.

Automatic Machine Learning is a growing area of machine learning that has a similar objective to the area of hyper-heuristics: to automatically recommend optimized pipelines, algorithms or appropriate parameters to specific tasks without much dependency on user knowledge. The background knowledge required to solve the task at hand is actually embedded into a search mechanism that builds personalized solutions to the task. Following this idea, this paper proposes RECIPE (REsilient ClassifIcation Pipeline Evolution), a framework based on grammar-based genetic programming that builds customized classification pipelines. The framework is flexible enough to receive different grammars and can be easily extended to other machine learning tasks. RECIPE overcomes the drawbacks of previous evolutionary-based frameworks, such as generating invalid individuals, and organizes a high number of possible suitable data preprocessing and classification methods into a grammar. Results of f-measure obtained by RECIPE are compared to those two state-of-the-art methods, and shown to be as good as or better than those previously reported in the literature. RECIPE represents a first step towards a complete framework for dealing with different machine learning tasks with the minimum required human intervention. https://link.springer.com/chapter/10.1007/978-3-319-55696-3_16.

[390] John Park, Yi Mei, Su Nguyen, Gang Chen, and Mengjie Zhang. Investigating the generality of genetic programming based hyper-heuristic approach to dynamic job shop scheduling with machine breakdown. In *Australasian Conference on Artificial Life and Computational Intelligence*, pages 301–313. Springer, 2017. Dynamic job shop scheduling (DJSS) problems are combinatorial optimisation problems that have been extensively studied in the literature due to their difficulty and their applicability to real-world manufacturing systems, e.g., car manufacturing systems. In a DJSS problem instance, jobs arrive on the shop floor to be processed on specific sequences of machines on the shop floor and unforeseen events such as dynamic job arrivals and machine breakdown occur that affect the properties of the shop floor. Many researchers have proposed genetic programming based hyper-heuristic (GP-HH) approaches to evolve high quality dispatching rules for DJSS problems with dynamic job arrivals, outperforming good man-made rules for the problems. However, no GP-HH approaches have been proposed for DJSS problems with dynamic job arrivals and machine breakdowns, and it is not known how well GP generalises over both DJSS problem instances with no machine breakdown to problem instances with machine breakdown. Therefore, this paper investigates the generality of GP for DJSS problem with dynamic job arrivals and machine breakdowns. To do this, a machine breakdown specific DJSS dataset is proposed, and an analysis procedure is used to observe the differences in the structures of the GP rules when evolved under different machine breakdown scenarios. The results show that performance and the distributions of the terminals for the evolved rules is sensitive to the frequency of machine breakdowns in the training instances used to evolve the rules. http://homepages.ecs.vuw.ac.nz/~yimei/papers/acalci2017-john.pdf.

[391] N. Pillay and D. Beckedahl. EvoHyp - a java toolkit for evolutionary algorithm hyper-heuristics. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 2706–2713, San Sebastian, Spain, 2017. Hyper-heuristics is an emergent technology that has proven to be effective at solving real-world problems. The two main categories of hyper-heuristics are selection and generation. Selection hyper-heuristics select existing low-level heuristics while generation hyper-heuristics create new heuristics. At the inception of the field single point searches were essentially employed by selection hyper-heuristics, however as the field progressed evolutionary algorithms are becoming more prominent. Evolutionary algorithms, namely, genetic programming, have chiefly been used for generation hyper-heuristics. Implementing evolutionary algorithm hyper-heuristics can be quite a time-consuming task which is daunting for first time researchers and practitioners who want to rather focus on the application domain the hyper-heuristic will be applied to which can be quite complex. This paper presents a Java toolkit for the implementation of evolutionary algorithm hyper-heuristics, namely, EvoHyp. EvoHyp includes libraries for a genetic algorithm selection hyper-heuristic (GenAlg), a genetic programming generation hyper-heuristic (GenProg), a distributed version of GenAlg (DistrGenAlg) and a distributed version of GenProg (DistrGenProg). The paper describes the libraries and illustrates how they can be used. The ultimate aim is to provide a toolkit which a non-expert in evolutionary algorithm hyper-heuristics can use. The paper concludes with an overview of future extensions of the toolkit. `http://ieeexplore.ieee.org/abstract/document/7969636/`.

[392] Nelishia Pillay and Ender Özcan. Automated generation of constructive ordering heuristics for educational timetabling. *Annals of Operations Research*, pages 1–28, 2017. Construction heuristics play an important role in solving combinatorial optimization problems. These heuristics are usually used to create an initial solution to the problem which is improved using optimization techniques such as metaheuristics. For examination timetabling and university course timetabling problems essentially graph colouring heuristics have been used for this purpose. The process of deriving heuristics manually for educational timetabling is a time consuming task. Furthermore, according to the no free lunch theorem different heuristics will perform well for different problems and problem instances. Hence, automating the induction of construction heuristics will reduce the man hours involved in creating such heuristics, allow for the derivation of problem specific heuristics and possibly result in the derivation of heuristics that humans have not thought of. This paper presents generation construction hyper-heuristics for educational timetabling. The study investigates the automatic induction of two types of construction heuristics, namely, arithmetic heuristics and hierarchical heuristics. Genetic programming is used to evolve arithmetic heuristics. Genetic programming, genetic algorithms and the generation of random heuristic combinations is examined for the generation of hierarchical heuristics. The hyper-heuristics generating both types of heuristics are applied to the examina-

tion timetabling and the curriculum based university course timetabling problems. The evolved heuristics were found to perform much better than the existing graph colouring heuristics used for this domain. Furthermore, it was found that the while the arithmetic heuristics were more effective for the examination timetabling problem, the hierarchical heuristics produced better results than the arithmetic heuristics for the curriculum based course timetabling problem. Genetic algorithms proved to be the most effective at inducing hierarchical heuristics. `https://link.springer.com/article/10.1007/s10479-017-2625-x`.

[393] Shahrzad M Pour, John H Drake, and Edmund K Burke. A choice function hyper-heuristic framework for the allocation of maintenance tasks in danish railways. *Computers & Operations Research*, 2017. A new signalling system in Denmark aims at ensuring fast and reliable train operations, however imposes very strict time limits on recovery plans in the event of failure. As a result, it is necessary to develop a new approach to the entire maintenance scheduling process. In the largest region of Denmark, the Jutland peninsula, there is a decentralised structure for maintenance planning, whereby the crew start their duties from their home locations rather than starting from a single depot. In this paper, we allocate a set of maintenance tasks in Jutland to a set of maintenance crew members, defining the sub-region that each crew member is responsible for. Two key considerations must be made when allocating tasks to crew members. Firstly a fair balance of workload must exist between crew members and secondly, the distance between two tasks in the same sub-region must be minimised, in order to facilitate quick response in the case of unexpected failure. We propose a perturbative selection hyper-heuristic framework to improve initial solutions by reassigning outliers, those tasks that are far away, to another crew member at each iteration, using one of five low-level heuristics. Results of two hyper-heuristics, using a number of different initial solution construction methods are presented over a set of 12 benchmark problem instances. `http://www.sciencedirect.com/science/article/pii/S0305054817302423`.

[394] Lucas Prestes, Myriam Regattieri de Biase da Silva, Richard Aderbal Goncalves, Carolina Paula de Almeida, Aurora Trinidad Pozo, et al. A hyper-heuristic in moea/d-dra using the upper confidence bound technique. In *Brazilian Conference on Intelligent Systems (BRACIS)*, pages 396–401. IEEE, 2017. The Multi-Objective Evolutionary Algorithm based on Decomposition with Dynamical Resource Allocation (MOEA/D-DRA) has obtained very good results on various multi-objective optimization problems in the past few years. This paper focuses on an attempt to improve even more its performance by introducing a hyper-heuristic mechanism to select the best set of its operators and parameters. In this paper we use Upper Confidence Bound (UCB) as the basis of the hyper-heuristic, and test three versions of the proposed approach. Four well known benchmarks (CEC 2009, WFG, DTLZ and ZDT) and a quality indicator (hypervolume) are used to analyze the performance of the three variants. The

proposed approach is compared with the original MOEA/D-DRA and the results show that tuning the parameters via UCB is an interesting alternative for a hyper-heuristic based version of MOEA/D-DRA on the addressed problems. `https://ieeexplore.ieee.org/abstract/document/8247086/`.

[395] Alejandro Rosales-Pérez, Andrés E Gutiérrez-Rodriguez, José C Ortiz-Bayliss, Hugo Terashima-Marin, and Carlos A Coello Coello. Evolutionary multilabel hyper-heuristic design. In *Evolutionary Computation (CEC), 2017 IEEE Congress on*, pages 2622–2629. IEEE, 2017. Nowadays, heuristics represent a commonly used alternative to solve complex optimization problems. This, however, has given rise to the problem of choosing the most effective heuristic for a given problem. In recent years, one of the most used strategies for this task are the hyper-heuristics, which aim at selecting/generating heuristics to solve a wide range of optimization problems. Most of the existing selection hyper-heuristics attempt to recommend only one heuristic for a given instance. However, for some classes of problems, more than one heuristic can be suitable. With this premise, in this paper, we address this issue through an evolutionary multilabel learning approach for building hyper- heuristics. Unlike traditional approaches, in the multilabel formulation, the result could not be a single recommendation, but a set of potential heuristics. Due to the fact that cooperative coevolutionary algorithms allow us to divide the problem into several subproblems, it results in a natural approach for dealing with multilabel classification. The proposed cooperative coevolutionary multilabel approach aims at choosing the most relevant patterns for each heuristic. For the experimental study included in this paper, we have used a set of constraint satisfaction problems as our study case. Our experimental results suggest that the proposed method is able to generate accurate hyper-heuristics that outperform reference methods. `http://ieeexplore.ieee.org/abstract/document/7969624/`.

[396] Patricia Ryser-Welch. Evolving comprehensible and scalable solvers using cgp for solving some real-world inspired problems, 2017.

[397] Nasser R Sabar, Ayad Turky, Andy Song, and Abdul Sattar. Optimising deep belief networks by hyper-heuristic approach. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 2738–2745. IEEE, 2017. Deep Belief Networks (DBN) have been successful in classification especially image recognition tasks. However, the performance of a DBN is often highly dependent on settings in particular the combination of runtime parameter values. In this work, we propose a hyper-heuristic based framework which can optimise DBNs independent from the problem domain. It is the first time hyper-heuristic entering this domain. The framework iteratively selects suitable heuristics based on a heuristic set, apply the heuristic to tune the DBN to better fit with the current search space. Under this framework the setting of DBN learning is adaptive. Three well-known image reconstruction benchmark sets were used for evaluating the performance of this new approach. Our experimental results show this

hyper-heuristic approach can achieve high accuracy under different scenarios on diverse image sets. In addition state-of-the-art meta-heuristic methods for tuning DBN were introduced for comparison. The results illustrate that our hyper-heuristic approach can obtain better performance on almost all test cases. `http://ieeexplore.ieee.org/abstract/document/7969640/`.

[398] Ram Sharma and A. Charan Kumari. Performance analysis of rectangular and circular shape building deployment for an indoor visible light communication system. *I.J. Computer Network and Information Security*, 7:11–19, 2017. The LED (Light emitting diode) based lighting systems are gaining popularity for its dual use i.e. for energy efficient lighting systems as well as for indoor optical wireless communication systems. Although, Visible light spectrum has the capability to provide very large system bandwidth (in THz), yet these systems have the limitation on account of limited modulation bandwidth. Besides, Visible light communication (VLC) systems also suffer due to multi-path propagation resulting in further depletion of system bandwidth due to pulse broadening. Therefore, one of the deployment objective of a visible light communication (VLC) system is to reduce the root mean square (RMS) delay parameter besides minimizing the number of LEDs. Hence, performance analysis of two geometrical shape structures mainly rectangular and circular models are explored for ubiquitous indoor coverage using hyper- heuristics evolutionary algorithm(HypEA) under spatial receiver mobility. Therefore, it is possible to achieve lower RMS delay spread and hence multi- fold increase in the overall system bandwidth without the use of complex system techniques like OFDM- MIMO etc. `http://www.mecs-press.org/ijcnis/ijcnis-v9-n7/IJCNIS-V9-N7-2.pdf`.

[399] Jorge A Soria-Alcaraz, Andres Espinal, and Marco A Sotelo-Figueroa. Evolvability metric estimation by a parallel perceptron for on-line selection hyper-heuristics. *IEEE Access*, 2017. On-line Hyper-heuristic Selection is a novel and powerful approach to solving complex problems. This approach dynamically selects, based on the state of a given solution, the most promising operator (from a pool of operators) to continue the search process. The dynamic selection is usually based on the analysis of the latest applications of a given operator during actual execution, estimating the potential success of the operator at the current solution state. The estimation can be made by Evolvability Metrics. Calculating an Evolvability metric is computationally expensive since it requires the generation and evaluation of a neighborhood of solutions. This paper aims to estimate the potential success of an operator for a given solution state by using a pre-trained neural network; known as a parallel perceptron. The proposal accelerates the on-line selection process, allowing us to achieve better performance than hyper-heuristic models which directly use evolvability functions. `http://ieeexplore.ieee.org/abstract/document/7914679/`.

[400] Jorge A Soria-Alcaraz, Gabriela Ochoa, Marco A Sotelo-Figeroa, and Edmund K Burke. A methodology for determining an effective subset of heuristics in selec-

tion hyper-heuristics. *European Journal of Operational Research*, 260(3):972–983, 2017. We address the important step of determining an effective subset of heuristics in selection hyper-heuristics. Little attention has been devoted to this in the literature, and the decision is left at the discretion of the investigator. The performance of a hyper-heuristic depends on the quality and size of the heuristic pool. Using more than one heuristic is generally advantageous, however, an unnecessary large pool can decrease the performance of adaptive approaches. Our goal is to bring methodological rigour to this step. The proposed methodology uses non-parametric statistics and fitness landscape measurements from an available set of heuristics and benchmark instances, in order to produce a compact subset of effective heuristics for the underlying problem. We also propose a new iterated local search hyper-heuristic using multi-armed bandits coupled with a change detection mechanism. The methodology is tested on two real-world optimization problems: course timetabling and vehicle routing. The proposed hyper-heuristic with a compact heuristic pool, outperforms state-of-the-art hyper-heuristics and competes with problem-specific methods in course timetabling, even producing new best-known solutions in 5 out of the 24 studied instances. http://www.sciencedirect.com/science/article/pii/S0377221717300772.

[401] Jorge A Soria-Alcaraz, Gabriela Ochoa, Marco A Sotelo-Figueroa, Martin Carpio, and Hector Puga. Iterated vnd versus hyper-heuristics: Effective and general approaches to course timetabling. In *Nature-Inspired Design of Hybrid Intelligent Systems*, pages 687–700. Springer, 2017. The course timetabling problem is one of the most difficult combinatorial problems, it requires the assignment of a fixed number of subjects into a number of time slots minimizing the number of student conflicts. This article presents a comparison between state-of-the-art hyper-heuristics and a newly proposed iterated variable neighborhood descent algorithm when solving the course timetabling problem. Our formulation can be seen as an adaptive iterated local search algorithm that combines several move operators in the improvement stage. Our improvement stage not only uses several neighborhoods, but it also incorporates state-of-the-art reinforcement learning mechanisms to adaptively select them on the fly. Our approach substitutes the adaptive improvement stage by a variable neighborhood descent (VND) algorithm. VND is an ingredient of the more general variable neighborhood search (VNS), a powerful metaheuristic that systematically exploits the idea of neighborhood change. This leads to a more effective search process according course timetabling benchmark results. http://link.springer.com/chapter/10.1007/978-3-319-47054-2_45.

[402] Marco Aurelio Sotelo-Figueroa, Héctor José Puga Soberanes, Juan Martin Carpio, Héctor J Fraire Huacuja, Laura Cruz Reyes, Jorge Alberto Soria Alcaraz, and Andrés Espinal. Generating bin packing heuristic through grammatical evolution based on bee swarm optimization. In *Nature-Inspired Design of Hybrid Intelligent Systems*, pages 655–671. Springer, 2017. In the recent years, Grammati-

cal Evolution (GE) has been used as a representation of Genetic Programming (GP). GE can use a diversity of search strategies including Swarm Intelligence (SI). Bee Swarm Optimization (BSO) is part of SI and it tries to solve the main problems of the Particle Swarm Optimization (PSO): the premature convergence and the poor diversity. In this paper we propose using BSO as part of GE as strategies to generate heuristics that solve the Bin Packing Problem (BPP). A comparison between BSO, PSO, and BPP heuristics is performed through the nonparametric Friedman test. The main contribution of this paper is to propose a way to implement different algorithms as search strategy in GE. In this paper, it is proposed that the BSO obtains better results than the ones obtained by PSO, also there is a grammar proposed to generate online and offline heuristics to improve the heuristics generated by other grammars and humans. `http://link.springer.com/chapter/10.1007/978-3-319-47054-2_43`.

[403] Aleksandra Swiercz. Hyper-heuristics and metaheuristics for selected bio-inspired combinatorial optimization problems. In *Heuristics and Hyper-Heuristics-Principles and Applications*. InTech, 2017. Many decision and optimization problems arising in bioinformatics field are time demanding, and several algorithms are designed to solve these problems or to improve their current best solution approach. Modeling and implementing a new heuristic algorithm may be time-consuming but has strong motivations: on the one hand, even a small improvement of the new solution may be worth the long time spent on the construction of a new method; on the other hand, there are problems for which good-enough solutions are acceptable which could be achieved at a much lower computational cost. In the first case, specially designed heuristics or metaheuristics are needed, while the latter hyper-heuristics can be proposed. The paper will describe both approaches in different domain problems. `https://www.intechopen.com/books/heuristics-and-hyper-heuristics-principles-and-applications/hyper-heuristics-and-metaheuristics-for-selected-bio-inspired-combinatorial-optimi`

[404] Surafel Luleseged Tilahun. Prey predator hyperheuristic. *Applied Soft Computing*, 59:104–114, 2017. Prey predator algorithm is a population based metaheuristic algorithm inspired by the interaction between a predator and its prey. In the algorithm, a solution with a better performance is called best prey and focuses totally on exploitation whereas the solution with least performance is called predator and focuses totally on exploration. The remaining solutions are called ordinary prey and either exploit promising regions by following better performing solutions or explore the solution space by randomly running away from the predator. Recently, it has been shown that by increasing the number of best prey or predator, it is possible to adjust the degree of exploitation and exploration. Even though, this tuning has the advantage of easily controlling these search behaviors, it is not an easy task. As any other metaheuristic algorithm, the performance of prey predator algorithm depends on the proper

degree of exploration and exploitation of the decision space. In this paper, the concept of hyperheuristic is employed to balance the degree of exploration and exploitation of the algorithm. So that it learns and decides the best search behavior for the problem at hand in iterations. The ratio of the number of the best prey and the predators are used as low level heuristics. From the simulation results the balancing of the degree of exploration and exploitation by using hyperheuristic mechanism indeed improves the performance of the algorithm. Comparison with other algorithms shows the effectiveness of the proposed approach. http://www.sciencedirect.com/science/article/pii/S1568494617302260.

[405] Chun-Wei Tsai, Wei-Lun Chang, Kai-Cheng Hu, and Ming-Chao Chiang. An improved hyper-heuristic clustering algorithm for wireless sensor networks. *Mobile Networks and Applications*, pages 1–16, 2017. Clustering is one of the most famous open problems of wireless sensor network (WSN) that has been studied for years because all the sensors in a WSN have only a limited amount of energy. As such, the so-called low-energy adaptive clustering hierarchy (LEACH) was presented to prolong the lifetime of a WSN. Although the original idea of LEACH is to keep each sensor in a WSN from being chosen as a cluster head (CH) too frequently so that the loading of the sensors will be balanced, thus avoiding particular sensors from running out of their energy quickly and particular regions from failing to work, it is far from perfect because LEACH may select an unsuitable set of sensors as the cluster heads. In this paper, a high-performance hyper-heuristic algorithm will be presented to enhance the clustering results of WSN called hyper-heuristic clustering algorithm (HHCA). The proposed algorithm is designed to reduce the energy consumption of a WSN, by using a high-performance metaheuristic algorithm to find a better solution to balance the residual energy of all the sensors so that the number of alive sensor nodes will be maximized. To evaluate the performance of the proposed algorithm, it is compared with LEACH, LEACH with genetic algorithm, and hyper-heuristic algorithm alone in this study. Experimental results show that HHCA is able to provide a better result than all the other clustering algorithms compared in this paper, in terms of the energy consumed. https://link.springer.com/article/10.1007/s11036-017-0854-5.

[406] Raras Tyasnurita, Ender Özcan, and Robert John. Learning heuristic selection using a time delay neural network for open vehicle routing. In *IEEE Congress on Evolutionary Computation (CEC)*, San Sebastian, Spain, 2017. A selection hyper-heuristic is a search method that controls a prefixed set of low-level heuristics for solving a given computationally difficult problem. This study investigates a learning-via demonstrations approach generating a selection hyper-heuristic for Open Vehicle Routing Problem (OVRP). As a chosen 'expert' hyper-heuristic is run on a small set of training problem instances, data is collected to learn from the expert regarding how to decide which low-level heuristic to select and apply to the solution in hand during the search process. In this study, a Time Delay Neural Network (TDNN) is used to extract hidden patterns within the collected

data in the form of a classifier ,i.e an 'apprentice' hyper-heuristic, which is then used to solve the 'unseen' problem instances. Firstly, the parameters of TDNN are tuned using Taguchi orthogonal array as a design of experiments method. Then the influence of extending and enriching the information collected from the expert and fed into TDNN is explored on the behaviour of the generated apprentice hyper-heuristic. The empirical results show that the use of distance between solutions as an additional information collected from the expert generates an apprentice which outperforms the expert algorithm on a benchmark of OVRP instances. http://eprints.nottingham.ac.uk/41373/.

[407] Rinde RS van Lon, Juergen Branke, and Tom Holvoet. Optimizing agents with genetic programming: an evaluation of hyper-heuristics in dynamic real-time logistics. *Genetic Programming and Evolvable Machines*, pages 1–28, 2017. Dynamic pickup and delivery problems (PDPs) require online algorithms for managing a fleet of vehicles. Generally, vehicles can be managed either centrally or decentrally. A common way to coordinate agents decentrally is to use the contract-net protocol (CNET) that uses auctions to allocate tasks among agents. To participate in an auction, agents require a method that estimates the value of a task. Typically, this method involves an optimization algorithm, e.g. to calculate the cost to insert a customer. Recently, hyper-heuristics have been proposed for automated design of heuristics. Two properties of automatically designed heuristics are particularly promising: (1) a generated heuristic computes quickly, it is expected therefore that hyper-heuristics perform especially well for urgent problems, and (2) by using simulation-based evaluation, hyper-heuristics can create a 'rule of thumb' that anticipates situations in the future. In the present paper we empirically evaluate whether hyper-heuristics, more specifically genetic programming (GP), can be used to improve agents decentrally coordinated via CNET. We compare several GP settings and compare the resulting heuristic with existing centralized and decentralized algorithms based on the OptaPlanner optimization library. The tests are conducted in real-time on a dynamic PDP dataset with varying levels of dynamism, urgency, and scale. The results indicate that the evolved heuristic always outperforms the optimization algorithm in the decentralized multi-agent system (MAS) and often outperforms the centralized optimization algorithm. Our paper demonstrates that designing MASs using genetic programming is an effective way to obtain competitive performance compared to traditional operational research approaches. These results strengthen the relevance of decentralized agent based approaches in dynamic logistics. https://link.springer.com/article/10.1007/s10710-017-9300-5.

[408] Rinde RS van Lon, Jürgen Branke, and Tom Holvoet. Enhancing agents with genetic programming: an evaluation of hyper-heuristics in dynamic real-time logistics. *Genetic Programming and Evolvable Machines*, 2017. Dynamic pickup and delivery problems (PDPs) require online algorithms for managing a fleet of vehicles. Generally, vehicles can be managed either centrally or decentrally. A

common way to coordinate agents decentrally is to use the contract-net protocol (CNET) that uses auctions to allocate tasks among agents. To participate in an auction, agents require a method that estimates the value of a task. Typically, this method involves an optimization algorithm, e.g. to calculate the cost to insert a customer. Recently, hyper-heuristics have been proposed for automated design of heuristics. Two properties of automatically designed heuristics are particularly promising: (1) a generated heuristic computes quickly, it is expected therefore that hyper-heuristics perform especially well for urgent problems, and (2) by using simulation-based evaluation, hyper-heuristics can create a 'rule of thumb' that anticipates situations in the future. In the present paper we empirically evaluate whether hyper-heuristics, more specifically genetic programming (GP), can be used to improve agents decentrally coordinated via CNET. We compare several GP settings and compare the resulting heuristic with existing centralized and decentralized algorithms based on the OptaPlanner optimization library. The tests are conducted in real-time on a dynamic PDP dataset with varying levels of dynamism, urgency, and scale. The results indicate that the evolved heuristic always outperforms the optimization algorithm in the decentralized multi-agent system (MAS) and often outperforms the centralized optimization algorithm. Our paper demonstrates that designing MASs using genetic programming is an effective way to obtain competitive performance compared to traditional operational research approaches. These results strengthen the relevance of decentralized agent based approaches in dynamic logistics. `https://link.springer.com/article/10.1007/s10710-017-9300-5`.

[409] Yue Wang, Min-Xia Zhang, and Yu-Jun Zheng. A hyper-heuristic method for uav search planning. In *International Conference in Swarm Intelligence*, pages 454–464. Springer, 2017. Motivated by the wide use of unmanned aerial vehicles (UAV) in search-and-rescue operations, we consider a problem of planning the search sequence and search modes of UAV, the aim of which is to maximize the probability of finding the target in a complex environment with probabilistic belief of target location. We design five meta-heuristic algorithm for solving the complex problem, but find that none of them can always obtain satisfactory solutions on a variety of instances. To overcome this obstacle, we integrate these meta-heuristics into a hyper-heuristic framework, which adaptively manage the low-level heuristics (LLH) by using feedback of their real-time performance in problem solving, and thus can find the most suitable LLH or their combination that can outperform any single LLH on each given instance. Experiments show that the overall performance of the hyper-heuristic is significantly better than any individual heuristic on the test instances. `https://link.springer.com/chapter/10.1007/978-3-319-61833-3_48`.

[410] J. Xie. On the investigation of the large-scale grouping constrained storage location assignment problem, 2017. The primary focus of this study is a novel optimisation problem, namely Storage Location Assignment Problem with Group-

ing Constraint (SLAP-GC). The problem stems from real-world applications and is significant in theoretical values and applicability in resource allocation tasks where groupings must be considered. The aim of this problem is to minimize the total operational cost in a warehouse through stock rearrangement. The problem consists of two interdependent subproblems, grouping same product items and assigning items to minimize picking distance. The interactions between these two subproblems make this problem significantly different from previous Storage Location Assignment Problems (SLAP), a well-studied field in logistics. Existing approaches for SLAP are not directly applicable for SLAP-GC. This dissertation lays a foundation for research on grouping constraints and other optimisation problems with similar interactions between subproblems. Firstly this study presents a formal definition of SLAP-GC. Then it offers a formal proof of NP-completeness of SLAP-GC by reducing from a well-known 3-Partition problem to SLAP-GC. This suggests that the real-world instances of SLAP-GC should not be tackled with exact approaches, but with approximation and heuristic approaches. Then, we explored decomposition and modelling techniques for SLAP-GC and developed three types of promising heuristic approaches: a hyperheuristic approach, a metaheuristic approach and a matheuristic approach. Comprehensive experimental studies are conducted on both synthetic benchmark instances and real-world instances to examine their efficiency, efficacy, and scalability. Through the analysis of the experimental results, the suitability of proposed methods is verified on various SLAP-GC scenarios. In addition, we demonstrate in this study that with the proposed decomposition, large-scale SLAP-GC can be handled efficiently by the three proposed heuristic-based approaches. `https://researchbank.rmit.edu.au/view/rmit:162142`.

[411] Kamal Z Zamli, Fakhrud Din, Graham Kendall, and Bestoun S Ahmed. An experimental study of hyper-heuristic selection and acceptance mechanism for combinatorial t-way test suite generation. *Information Sciences*, 399:121–153, 2017. Recently, many meta-heuristic algorithms have been proposed to serve as the basis of a t-way test generation strategy (where t indicates the interaction strength) including Genetic Algorithms (GA), Ant Colony Optimization (ACO), Simulated Annealing (SA), Cuckoo Search (CS), Particle Swarm Optimization (PSO), and Harmony Search (HS). Although useful, meta-heuristic algorithms that make up these strategies often require specific domain knowledge in order to allow effective tuning before good quality solutions can be obtained. Hyper-heuristics provide an alternative methodology to meta-heuristics which permit adaptive selection and/or generation of meta-heuristics automatically during the search process. This paper describes our experience with four hyper-heuristic selection and acceptance mechanisms namely Exponential Monte Carlo with counter (EMCQ), Choice Function (CF), Improvement Selection Rules (ISR), and newly developed Fuzzy Inference Selection (FIS), using the t-way test generation problem as a case study. Based on the experimental results, we offer insights on why each strategy differs in terms of its performance.

http://www.sciencedirect.com/science/article/pii/S0020025517305820.

[412] Kamal Z Zamli, Fakhrud Din, Graham Kendall, and Bestoun S Ahmed. Supplementary material for the information sciences paper: An experimental study of hyper-heuristic selection and acceptance mechanism for combinatorial t-way test suite generation. *arXiv preprint arXiv:1702.04501*, 2017. Software testing relates to the process of accessing the functionality of a program against some defined specifications. To ensure conformance, test engineers often generate a set of test cases to validate against the user requirements. Owing to the growing complexity of software and its increasing diffusion into various application domains, it is no longer unusual for a software project to have testing teams in more than one location or even distributed over many continents. Owing to the intertwined dependencies of many software development activities and their geographical and temporal issues, there are potentially many overlapping test cases which can cause unwarranted redundancies across the shared modules (i.e. a test for one requirement may be covered by more than one test). In this paper, we explore the application of our newly developed hyperheuristic, called Fuzzy Inference Selection (FIS), for addressing test redundancy reduction problem. This paper presents the supplementary results for the paper : An Experimental Study of Hyper-Heuristic Selection and Acceptance Mechanism for Combinatorial t way Test Suite Generation published in Information Sciences. https://arxiv.org/abs/1702.04501.

[413] Steven Adriaensen and Ann Nowé. Case study: An analysis of accidental complexity in a state-of-the-art hyper-heuristic for hyflex. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 1485–1492. IEEE, 2016. While simplicity is an important factor affecting algorithm re-usability, it is often overlooked in algorithm design, which has a tendency to produce overly complex methods. In this paper we demonstrate Accidental Complexity Analysis (ACA), a research practice targeted at detecting and eliminating accidental complexity, without loss of performance (c.f. refactoring in software engineering), using it to analyze the presence of accidental complexity in GIHH, a state-of-the-art selection hyper-heuristic for HyFlex. We identify various algorithmic sub-mechanisms contributing little to GIHH's overall performance, and validate many other. As an outcome we present Lean-GIHH, a simplified, re-implementation of GIHH. http://ieeexplore.ieee.org/abstract/document/7743965/.

[414] H Murat Afsar, Christian Artigues, Eric Bourreau, and Safia Kedad-Sidhoum. Machine reassignment problem: the roadef/euro challenge 2012. *Annals of Operations Research*, 242(1):1–17, 2016. The ROADEF/EURO challenge is a contest jointly organized by the French Operational Research and Decision Aid society (ROADEF) and the European Operational Research society (EURO). The contest appears on a regular basis since 1999 and always concerns an industrial optimization problem proposed by an industrial partner. Google proposed a subject for the ROADEF/EURO challenge 2012 (http://challenge.roadef.org/2012/en/), presenting a complex and large-scale machine reassignment problem, where a set

of processes assigned to a set of machines have to be reassigned (or moved) while balancing machine usage improvement and moving costs, under resource (more precisely CPU, RAM, disk) and operational constraints. The 2012 challenge edition has been an unprecedented success with 82 registered teams, 48 teams that actually sent a program for qualification, 30 qualified teams and 27 teams that sent a program for the final evaluation. This paper aims at introducing the Annals of Operations Research special issue by presenting the ROADEF/EURO challenge 2012 subject, as well as the methods of the finalist teams and their results. `http://link.springer.com/article/10.1007/s10479-016-2203-7`.

[415] Aftab Ahmed, Muhammad Atif, and Jamil Ahmad. A multilayered heuristic for solving curricula scheduling problems. *Journal of Applied and Emerging Sciences*, 5(1):pp7–11, 2016. Curricula Scheduling problem is recognized essentially on account of its vital significance in academia. The problem is echoed as tough resources placement job against troublesome constraints. The problem has been investigated by research community for several decades because of its inevitable importance and association with Non-deterministic Polynomialtime hard (NP-Hard) complexity. This research article investigates a novel and contemporary approach of using Memetic Algorithms (MA) centered Hyper Heuristic model to scrutinize the performance. The dynamic parameters of higher heuristic are get corrected and improvised with each iteration on the basis of performance measure. The signs learned from the experiments conclude the study-work steps forward in scheduling research and the scope of prospective and significant research direction are noticeable and remain open in the future. The work concluded with implementation of prototype coded in python language. `http://journal.buitms.edu.pk/j/index.php/bj/article/view/126`.

[416] Fawaz Alanazi. Adaptive thompson sampling for hyper-heuristics. In *IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–8. IEEE, 2016. There is an interest in search algorithms capable of learning and adapting their behaviour while solving a given problem. A hyper-heuristic operates on a set of predefined heuristics and applies a machine learning technique to predict which heuristic is the most effective to apply at a given point in time. Thompson Sampling is a machine learning mechanism interacting with the search environment to adapt its behaviour through trial-and-error. Despite the fact that it originated in the 1930s, the work on Thompson Sampling in the literature on search heuristics is limited. This paper is the first study investigating the Thompson Sampling approach in the field of hyper-heuristics. I propose an adaptive Thompson Sampling mechanism for hyper-heuristics and extensively evaluate its performance on a wide range of test models and combinatorial optimisation problems. The proposed algorithm is tested and compared with a large number of hyper-heuristics within a well-known competition for hyper-heuristics called CHeSC 2011. The results reveal that the proposed hyper-heuristic outperforms all the competing hyper-heuristics, including the state-of-the-art algo-

rithm, on three combinatorial optimisation problems: (1) Personnel Scheduling; (2) Permutation Flow-shop, and (3) the Travelling Salesman problem. http://ieeexplore.ieee.org/abstract/document/7850086/.

[417] Fawaz Alanazi and Per Kristian Lehre. Limits to learning in reinforcement learning hyper-heuristics. In *European Conference on Evolutionary Computation in Combinatorial Optimization*, pages 170–185. Springer, 2016. Learning mechanisms in selection hyper-heuristics are used to identify the most appropriate subset of heuristics when solving a given problem. Several experimental studies have used additive reinforcement learning mechanisms, however, these are inconclusive with regard to the performance of selection hyper-heuristics with these learning mechanisms. This paper points out limitations to learning with additive reinforcement learning mechanisms. Our theoretical results show that if the probability of improving the candidate solution in each point of the search process is less than 1 / 2 which is a mild assumption, then additive reinforcement learning mechanisms perform asymptotically similar to the simple random mechanism which chooses heuristics uniformly at random. In addition, frequently used adaptation schemes can affect the memory of reinforcement learning mechanisms negatively. We also conducted experiments on two well-known combinatorial optimisation problems, bin-packing and flow-shop, and the obtained results confirm the theoretical findings. This study suggests that alternatives to the additive updates in reinforcement learning mechanisms should be considered. http://link.springer.com/chapter/10.1007/978-3-319-30698-8_12.

[418] Ekaterina Alekseeva, Mohand Mezmaz, Daniel Tuyttens, and Nouredine Melab. Parallel multi-core hyper-heuristic grasp to solve permutation flow-shop problem. *Concurrency and Computation: Practice and Experience*, 2016. In this paper, we aim to propose a parallel multi-core hyper-heuristic based on greedy randomized adaptive search procedure (GRASP) for the permutation flow-shop problem with the makespan criterion. The GRASP is a well-known two-phase metaheuristic. First, a construction phase builds a complete solution iteratively, component by component, by a greedy randomized algorithm. After that, a local search phase improves this solution. The choice of a component and the order in which it is added in a solution mostly depend on its incremental cost. Thus, a basic GRASP configuration is defined by a cost function, a probabilistic parameter of greediness and a neighbourhood structure. We consider five cost functions and seven well-known neighbourhood structures. In this paper a cost function based on a bounding operator is integrated in GRASP for the first time. Mechanisms that investigate automatically algorithm configurations refer to hyper-heuristics. Our hyper-heuristic investigates 315 GRASP configurations and reports which one produces better results. Parallel multi-core computing is used as a way to efficiently implement the hyper-heuristic. Taillard's benchmark instances are used to test the hyper-heuristic for the permutation flow-shop problem. http://onlinelibrary.wiley.com/doi/10.1002/cpe.3835/full.

[419] Alhanof Almutairi, Ender Ozcan, Ahmed Kheiri, and Warren G Jackson. Performance of selection hyper-heuristics on the extended hyflex domains. In *Proceedings of the 31st International Symposium on Computer and Information Sciences (ISCIS)*, 2016. Selection hyper-heuristics perform search over the space of heuristics by mixing and controlling a predefined set of low level heuristics for solving computationally hard combinatorial optimisation problems. Being reusable methods, they are expected to be applicable to multiple problem domains, hence performing well in cross-domain search. HyFlex is a general purpose heuristic search API which separates the high level search control from the domain details enabling rapid development and performance comparison of heuristic search methods, particularly hyper-heuristics. In this study, the performance of six previously proposed selection hyper-heuristics are evaluated on three recently introduced extended HyFlex problem domains, namely 0-1 Knapsack, Quadratic Assignment and Max-Cut. The empirical results indicate the strong generalising capability of two adaptive selection hyper-heuristics which perform well across the 'unseen' problems in addition to the six standard HyFlex problem domains. `http://www.cs.nott.ac.uk/~pszeo/docs/publications/iscis2016_17.pdf`.

[420] Khaled Alrajhi. Heuristic algorithms for static and dynamic frequency assignment problems, 2016. This thesis considers the frequency assignment problem (FAP), which is a real world problem of assigning frequencies to wireless communication connections (also known as requests) while satisfying a set of constraints in order to prevent a loss of signal quality. This problem has many different applications such as mobile phones, TV broadcasting, radio and military operations. In this thesis, two variants of the FAP are considered, namely the static and the dynamic FAPs. The static FAP does not change over time, while the dynamic FAP changes over time as new requests gradually be-come known and frequencies need to be assigned to those requests effectively and promptly. The dynamic FAP has received little attention so far in the literature com-pared with the static FAP. This thesis consists of two parts: the first part discusses and develops three heuristic algorithms, namely tabu search (TS), ant colony optimization (ACO) and hyper heuris-tic (HH), to solve the static FAP. These heuristic algorithms are chosen to represent different characteristics of heuristic algorithms in order to identify an appropriate solu-tion method for this problem. Several novel and existing techniques have been used to improve the performance of these heuristic algorithms. In terms of TS, one of the nov-el techniques aims to determine a lower bound on the number of frequencies that are required from each domain for a feasible solution to exist, based on the underlying graph colouring model. These lower bounds are used to ensure that we never waste time trying to find a feasible solution with a set of frequencies that do not satisfy the lower bounds, since there is no feasible solution in this search area. Another novel technique hybridises TS with multiple neighbourhood structures, one of which is used as a diversification technique. In terms of ACO, the concept of a well-known graph colouring algorithm, namely recursive largest first, is used. Moreover, some of

the key factors in producing a high quality ACO implementation are examined such as differ-ent definitions of visibility and trail, and optimization of numerous parameters. In terms of HH, simple and advanced low level heuristics each with an associated inde-pendent tabu list are applied in this study. The lower bound on the number of fre-quencies that are required from each domain for a feasible solution to exist is also used. Based on the experimental results, it is found that the best performing heuristic algo-rithm is TS, with HH also being competitive, whereas ACO achieves poor perfor-mance. Additionally, TS shows competitive performance compared with other algo-rithms in the literature. In the second part of this thesis, various approaches are designed to solve the dynamic FAP. The best heuristic algorithms considered in the first part of this thesis are used to construct these approaches. It is interesting to investigate whether heuristic algorithms which work well on the static FAP also prove efficient on the dynamic FAP. Addi-tionally, several techniques are applied to improve the performance of these approach-es. One of these, called the Gap technique, is novel. This technique aims to identify a good frequency to be assigned to a given request. Based on the experimental results, it is found that the best approach for the dynamic FAP shows competitive results com-pared with other approaches in the literature. Finally, this thesis proposes a novel ap-proach to solve the static FAP by modelling it as a dynamic FAP through dividing this problem into smaller sub-problems, which are then solved in turn in a dynamic process. The lower bound on the number of frequencies that are required from each domain for a feasible solution to exist, based on the underlying graph colouring model, and the Gap technique are also used. The proposed approach shows the ability to improve the results which have been found by the heuristic algorithms in the first part of this thesis (which solve the static FAP as a whole). Moreover, it shows competitive results compared with other algorithms in the literature. `http://orca.cf.ac.uk/94194/`.

[421] Juan Aparicio, Martin Gonzalez, Jose J Lopez-Espin, and Jesus T Pastor. A parameterized scheme of metaheuristics to solve np-hard problems in data envelopment analysis. In *Advances in Efficiency and Productivity*, pages 195–224. Springer, 2016. Data Envelopment Analysis (DEA) is a well-known methodology for estimating technical efficiency from a set of inputs and outputs of Decision Making Units (DMUs). This paper is devoted to computational aspects of DEA models when the determination of the least distance to the Pareto-efficient frontier is the goal. Commonly, these models have been addressed in the literature by applying unsatisfactory techniques, based essentially on combinatorial NP-hard problems. Recently, some heuristics have been introduced to solve these situations. This work improves on previous heuristics for the generation of valid solutions. More valid solutions are generated and with lower execution time. A parameterized scheme of metaheuristics is developed to improve the solutions obtained through heuristics. A hyper-heuristic is used over the parameterized scheme. The hyper-heuristic searches in a space of metaheuristics and generates metaheuristics that provide solutions close to the optimum. The

method is competitive versus exact methods, and has a lower execution time. http://link.springer.com/chapter/10.1007/978-3-319-48461-7_9.

[422] MEM Asha and P Vivekanandan. Rule based scheduling algorithm for scheduling mechanism in large scale data center. *Asian Journal of Research in Social Sciences and Humanities*, 6(12):96–104, 2016. Rule Based Scheduling Algorithm have been widely used in the cloud computing as it is simple and easy to implement the Scheduling criteria in terms of energy efficiency and less delay, In this paper, we propose Improved Hyper Heuristic Scheduling which is used to find the candidate solution (low level heuristic) form Scheduling Solutions (heuristics algorithms) from the simulated annealing and genetic algorithm in dynamic large scale Cloud Computing system with diversity operator as sequence dependent and sequence independent scheduling. Specifically, Resources and workloads characterised using the simulated annealing and improved genetic algorithm with n point crossover. Hyper heuristic algorithm is used select best possible solution to the dynamic workload to candidate solutions. The Simulation results on cloudsim proves that proposed system outperforms existing state of approaches in terms of reduced make span and flow time for the task scheduling and resource management. http://www.indianjournals.com/ijor.aspx?target=ijor:ajrssh&volume=6&issue=12&article=008.

[423] Shahriar Asta, Ender Özcan, and Tim Curtois. A tensor based hyper-heuristic for nurse rostering. *Knowledge-Based Systems*, 98:185–199, 2016. Nurse rostering is a well-known highly constrained scheduling problem requiring assignment of shifts to nurses satisfying a variety of constraints. Exact algorithms may fail to produce high quality solutions, hence (meta)heuristics are commonly preferred as solution methods which are often designed and tuned for specific (group of) problem instances. Hyper-heuristics have emerged as general search methodologies that mix and manage a predefined set of low level heuristics while solving computationally hard problems. In this study, we describe an online learning hyper-heuristic employing a data science technique which is capable of self-improvement via tensor analysis for nurse rostering. The proposed approach is evaluated on a well-known nurse rostering benchmark consisting of a diverse collection of instances obtained from different hospitals across the world. The empirical results indicate the success of the tensor-based hyper-heuristic, improving upon the best-known solutions for four of the instances. http://www.sciencedirect.com/science/article/pii/S0950705116000514.

[424] Shahriar Asta, Ender Özcan, and Andrew J Parkes. CHAMP: Creating heuristics via many parameters for online bin packing. *Expert Systems with Applications*, 63:208–221, 2016. The online bin packing problem is a well-known bin packing variant and which requires immediate decisions to be made for the placement of a lengthy sequence of arriving items of various sizes one at a time into fixed capacity bins without any overflow. The overall goal is maximising the average bin fullness. We investigate a 'policy matrix' representation, which assigns a score

for each decision option independently and the option with the highest value is chosen, for one-dimensional online bin packing. A policy matrix might also be considered as a heuristic with many parameters, where each parameter value is a score. We hence effectively investigate a framework which can be used for creating heuristics via many parameters. The proposed framework combines a Genetic Algorithm optimiser, which searches the space of heuristics in policy matrix form, and an online bin packing simulator, which acts as the evaluation function. The empirical results indicate the success of the proposed approach, providing the best solutions for almost all item sequence generators used during the experiments. We also present a novel fitness landscape analysis on the search space of policies. This study hence gives evidence of the potential for automated discovery by intelligent systems of powerful heuristics for online problems; reducing the need for expensive use of human expertise. `http://www.sciencedirect.com/science/article/pii/S0957417416303499`.

[425] Alex R Bertels and Daniel R Tauritz. Why asynchronous parallel evolution is the future of hyper-heuristics: A cdcl sat solver case study. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion*, pages 1359–1365. ACM, 2016. Evolutionary Algorithms (EAs) are inherently parallel due to their ability to simultaneously evaluate the fitness of individuals. Synchronous Parallel EAs (SPEAs) leverage this with the intent to gain significant speed-ups when executed on multiple processors. However, many important problem classes lead to large variations in fitness evaluation times, such as is often the case in hyper-heuristics where the time complexity of executing one individual may differ greatly from that of another. Asynchronous Parallel EAs (APEAs) omit the generational synchronization step of traditional EAs which work in well-defined cycles. They can provide scalability improvements proportional to the variation in fitness evaluation times of the evolved individuals, and therefore should be considered for use in hyper-heuristics. This paper provides an empirical analysis of the improvements obtained by applying APEAs, compared to SPEAs, on a case study involving the evolution of conflict-driven clause learning Boolean satisfiability solvers, demonstrating that APEAs are the future of hyper-heuristics. `http://dl.acm.org/citation.cfm?id=2931729`.

[426] Alex Raymond Bertels. Automated design of boolean satisfiability solvers employing evolutionary computation, 2016. Modern society gives rise to complex problems which sometimes lend themselves to being transformed into Boolean satisfiability (SAT) decision problems; this thesis presents an example from the program understanding domain. Current conflict-driven clause learning (CDCL) SAT solvers employ all-purpose heuristics for making decisions when finding truth assignments for arbitrary logical expressions called SAT instances. The instances derived from a particular problem class exhibit a unique underlying structure which impacts a solver's effectiveness. Thus, tailoring the solver heuristics to a particular problem class can significantly enhance the solver's

performance; however, manual specialization is very labor intensive. Automated development may apply hyper-heuristics to search program space by utilizing problem-derived building blocks. This thesis demonstrates the potential for genetic programming (GP) powered hyper-heuristic driven automated design of algorithms to create tailored CDCL solvers, in this case through custom variable scoring and learnt clause scoring heuristics, with significantly better performance on targeted classes of SAT problem instances. As the run-time of GP is often dominated by fitness evaluation, evaluating multiple offspring in parallel typically reduces the time incurred by fitness evaluation proportional to the number of parallel processing units. The naive synchronous approach requires an entire generation to be evaluated before progressing to the next generation; as such, heterogeneity in the evaluation times will degrade the performance gain, as parallel processing units will have to idle until the longest evaluation has completed. This thesis shows empirical evidence justifying the employment of an asynchronous parallel model for GP powered hyper-heuristics applied to SAT solver space, rather than the generational synchronous alternative, for gaining speed-ups in evolution time. Additionally, this thesis explores the use of a multi-objective GP to reveal the trade-off surface between multiple CDCL attributes. `http://scholarsmine.mst.edu/masters_theses/7549/`.

[427] Juergen Branke, Su Nguyen, Christoph W Pickardt, and Mengjie Zhang. Automated design of production scheduling heuristics: a review. *IEEE Transactions on Evolutionary Computation*, 20(1):110–124, 2016. Hyper-heuristics have recently emerged as a powerful approach to automate the design of heuristics for a number of different problems. Production scheduling is a particularly popular application area for which a number of different hyper-heuristics have been developed and are shown to be effective, efficient, easy to implement, and reusable in different shop conditions. In particular, they seem to be a promising way to tackle highly dynamic and stochastic scheduling problems, an aspect that is specifically emphasized in this survey. Despite their success and the substantial number of papers in this area, there is currently no systematic discussion of the design choices and critical issues involved in the process of developing such approaches. This paper strives to fill this gap by summarizing the state-of-the-art approaches, suggesting a taxonomy, and providing the interested researchers and practitioners with guidelines for the design of hyper-heuristics in production scheduling. This paper also identifies challenges and open questions and highlights various directions for future work. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7101236`.

[428] Jianjun Chen, Ruibin Bai, Haibo Dong, Rong Qu, and Graham Kendall. A dynamic truck dispatching problem in marine container terminal. In *IEEE Symposium on Computational Intelligence in Scheduling and Network Design (SSCI)*, pages 1–8, 2016. In this paper, a dynamic truck dispatching problem of a marine container terminal is described and discussed. In this problem, a few containers,

encoded as work instructions, need to be transferred between yard blocks and vesselby a fleet of trucks. Both the yard blocks and the quay are equipped with cranes to support loading/unloading operations. In order to service more vessels, any unnecessary idle time between quay crane (QC) operations need to be minimised to speed up the container transfer process. Due to the unpredictable port situations that can affect routing plans and the short calculation time allowed to generate one, static solution methods are not suitable for this problem. In this paper, we introduce a new mathematical model that minimises both the QC makespan and the truck travelling time. Three dynamic heuristics are proposed and a genetic algorithm hyperheuristic (GAHH) under development is also described. Experiment results show promising capabilities the GAHH may offer. `http://eprints.nottingham.ac.uk/39207/`.

[429] Shaomiao Chen, Zhiyong Li, Bo Yang, and Günter Rudolph. Quantum-inspired hyper-heuristics for energy-aware scheduling on heterogeneous computing systems. *IEEE Transactions on Parallel and Distributed Systems*, 27(6):1796–1810, 2016. Power and performance tradeoff optimization is one of the most significant issues on heterogeneous multiprocessor or multicomputer systems (HMCSs) with dynamically variable voltage. In this paper, the problem is defined as energy-constrained performance optimization and performance-constrained energy optimization. Task scheduling for precedence-constrained parallel applications represented by a directed acyclic graph (DAG) in HMCSs is an NP-HARD problem. Over the last three decades, several task scheduling techniques have been developed for energy-aware scheduling. However, it is impossible for a single task scheduling technique to outperform all other techniques for all types of applications and situations. Motivated by these observations, hyperheuristic framework is introduced. Moreover, a quantum-inspired high-level learning strategy is proposed to improve the performance of this framework. Meanwhile, a fast solution evaluation technique is designed to reduce the computational burden for each iteration step. Experimental results show that the fast solution evaluation technique can improve average algorithm search speed by 38 percent and that the proposed algorithm generally exhibits outstanding convergence performance. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7173041`.

[430] Yujie Chen, Philip Mourdjis, Fiona Polack, Peter Cowling, and Stephen Remde. Evaluating hyperheuristics and local search operators for periodic routing problems. In *European Conference on Evolutionary Computation in Combinatorial Optimization*, pages 104–120. Springer, 2016. Meta-heuristics and hybrid heuristic approaches have been successfully applied to Periodic Vehicle Routing Problems (PVRPs). However, to be competitive, these methods require careful design of specific search strategies for each problem. By contrast, hyperheuristics use the performance of low level heuristics to automatically select and tailor search strategies. Hyperheuristics have been successfully applied to problem domains such as timetabling and production scheduling. In

this study, we present a comprehensive analysis of hyperheuristic approaches to solving PVRPs. The performance of hyperheuristics is compared to published performance of state-of-the-art meta-heuristics. http://link.springer.com/chapter/10.1007/978-3-319-30698-8_8.

[431] Aurelia Ciupe, Serban Meza, and Bogdan Orza. Heuristic optimization for the resource constrained project scheduling problem: A systematic mapping. In *Federated Conference on Computer Science and Information Systems (FedCSIS)*, pages 619–626. IEEE, 2016. Context: Heuristic optimization has been of strong focus in the recent modeling of the Resource Constrained Project Scheduling Problem (RCPSP), but lack of evidence exists in systematic assessments. New solution methods arise from random evaluation of existing studies. Objective: The current work conducts a secondary study, aiming to systemize existing primary studies in heuristic optimization techniques applied to solving classes of RCPSPs. Method: The systemizing framework consists of performing a systematic mapping study (SM), following a 3-steped protocol. Results: 371 primary studies have been depicted from the multi-stage search and filtering process, to which inclusion and exclusion criteria have been applied. Results have been visually mapped in several distributions. Conclusions: Specific RCPSP classes have been grounded and therefore a rigorous classification is required before performing a systematic mapping. Focusing on recent developments of the RCPSP (2010-2015, a strong interest has been acknowledged on solution methods incorporating AI techniques in meta- and hyper-heuristic algorithms. http://ieeexplore.ieee.org/abstract/document/7733302/.

[432] Carlos Contreras-Bolton, Carlos Rey, Sergio Ramos-Cossio, Claudio Rodriguez, Felipe Gatica, and Victor Parada. Automatically produced algorithms for the generalized minimum spanning tree problem. *Scientific Programming*, 2016, 2016. The generalized minimum spanning tree problem consists of finding a minimum cost spanning tree in an undirected graph for which the vertices are divided into clusters. Such spanning tree includes only one vertex from each cluster. Despite the diverse practical applications for this problem, the NP-hardness continues to be a computational challenge. Good quality solutions for some instances of the problem have been found by combining specific heuristics or by including them within a metaheuristic. However studied combinations correspond to a subset of all possible combinations. In this study a technique based on a genotype-phenotype genetic algorithm to automatically construct new algorithms for the problem, which contain combinations of heuristics, is presented. The produced algorithms are competitive in terms of the quality of the solution obtained. This emerges from the comparison of the performance with problem-specific heuristics and with metaheuristic approaches. http://www.hindawi.com/journals/sp/2016/1682925/abs/.

[433] Kassem Danach. Hyperheuristics in logistics, 2016. Success in using exact methods for large scale combinatorial optimization is still limited to certain problems

or to specific classes of instances of problems. The alternative way is either using metaheuristics or matheuristics that rely on exact methods in some ways. In the context of combinatorial optimization, we are interested in heuristics to choose heuristics invoked to solve the addressed problem. In this thesis, we focus on hyperheuristic optimization in logistic problems. We focus on proposing a hyperheuristic framework that carries out a search in the space of heuristic algorithms and learns how to change the incumbent heuristic in a systematic way along the process in such a way that a good sequence of heuristics produces high quality solutions. We propose HHs for two problems in logistics: the workover rig scheduling problem and the hub location routing problem. Then, we compare the performances of several HHs described in the literature for the latter problem, which embed different heuristic selection methods such as a random selection, a choice function, a Q-Learning approach, and an ant colony based algorithm. The computational results prove the efficiency of HHs for the two problems in hand, and the relevance of including Lagrangian relaxation information for the second problem. `https://tel.archives-ouvertes.fr/tel-01485160/`.

[434] Nguyen Thi Thanh Dang and Patrick De Causmaecker. Characterization of neighborhood behaviours in a multi-neighborhood local search algorithm. *arXiv preprint arXiv:1603.06459*, 2016. We consider a multi-neighborhood local search algorithm with a large number of possible neighborhoods. Each neighborhood is accompanied by a weight value which represents the probability of being chosen at each iteration. These weights are fixed before the algorithm runs, and are considered as parameters of the algorithm. Given a set of instances, off-line tuning of the algorithm's parameters can be done by automated algorithm configuration tools (e.g., SMAC). However, the large number of neighborhoods can make the tuning expensive and difficult even when the number of parameters has been reduced by some intuition. In this work, we propose a systematic method to characterize each neighborhood's behaviours, representing them as a feature vector, and using cluster analysis to form similar groups of neighborhoods. The novelty of our characterization method is the ability of reflecting changes of behaviours according to hardness of different solution quality regions. We show that using neighborhood clusters instead of individual neighborhoods helps to reduce the parameter configuration space without misleading the search of the tuning procedure. Moreover, this method is problem-independent and potentially can be applied in similar contexts. `http://arxiv.org/abs/1603.06459`.

[435] Nguyen Thi Thanh Dang and Patrick De Causmaecker. Characterization of neighborhood behaviours in a multi-neighborhood local search algorithm. In *Proceedings of the 10th Learning and Intelligent OptimizatioN Conference (LION)*, volume 10079 of *LNCS*, pages 234–239, Naples, Italy, 2016. We consider a multi-neighborhood local search framework with a large number of possible neighborhoods. Each neighborhood is accompanied by a weight value which represents the probability of being chosen at each iteration. These weights are fixed before the

algorithm runs, and can be tuned by off-the-shelf off-line automated algorithm configuration tools (e.g., SMAC). However, the large number of parameters might deteriorate the tuning tool's efficiency, especially in our case where each run of the algorithm is not computationally cheap, even when the number of parameters has been reduced by some intuition. In this work, we propose a systematic method to characterize each neighborhood's behaviours, representing them as a feature vector, and using cluster analysis to form similar groups of neighborhoods. The novelty of our characterization method is the ability of reflecting changes of behaviours according to hardness of different solution quality regions based on simple statistics collected during any algorithm runs. We show that using neighborhood clusters instead of individual neighborhoods helps to reduce the parameter configuration space without misleading the search of the tuning procedure. Moreover, this method is problem-independent and potentially can be applied in similar contexts. `http://link.springer.com/chapter/10.1007/978-3-319-50349-3_17`.

[436] Paul Dempster and John H Drake. Two frameworks for cross-domain heuristic and parameter selection using harmony search. In *Harmony Search Algorithm*, pages 83–94. Springer, 2016. Harmony Search is a metaheuristic technique for optimizing problems involving sets of continuous or discrete variables, inspired by musicians searching for harmony between instruments in a performance. Here we investigate two frameworks, using Harmony Search to select a mixture of continuous and discrete variables forming the components of a Memetic Algorithm for cross-domain heuristic search. The first is a single-point based framework which maintains a single solution, updating the harmony memory based on performance from a fixed starting position. The second is a population-based method which co-evolves a set of solutions to a problem alongside a set of harmony vectors. This work examines the behaviour of each framework over thirty problem instances taken from six different, real-world problem domains. The results suggest that population co-evolution performs better in a time-constrained scenario, however both approaches are ultimately constrained by the underlying metaphors. `http://link.springer.com/chapter/10.1007/978-3-662-47926-1_10`.

[437] Tansel Dokeroglu and Ahmet Cosar. A novel multistart hyper-heuristic algorithm on the grid for the quadratic assignment problem. *Engineering Applications of Artificial Intelligence*, 52:10–25, 2016. There is a growing interest towards the design of reusable general purpose search methods that are applicable to different problems instead of tailored solutions to a single particular problem. Hyper-heuristics have emerged as such high level methods that explore the space formed by a set of heuristics (move operators) or heuristic components for solving computationally hard problems. A selection hyper-heuristic mixes and controls a predefined set of low level heuristics with the goal of improving an initially generated solution by choosing and applying an appropriate heuristic to a solution in hand and deciding whether to accept or reject the new solution at each step under

an iterative framework. Designing an adaptive control mechanism for the heuristic selection and combining it with a suitable acceptance method is a major challenge, because both components can influence the overall performance of a selection hyper-heuristic. In this study, we describe a novel iterated multi-stage hyper-heuristic approach which cycles through two interacting hyper-heuristics and operates based on the principle that not all low level heuristics for a problem domain would be useful at any point of the search process. The empirical results on a hyper-heuristic benchmark indicate the success of the proposed selection hyper-heuristic across six problem domains beating the state-of-the-art approach. `http://www.sciencedirect.com/science/article/pii/S0952197616300136`.

[438] John H Drake, Ender Özcan, and Edmund K Burke. A case study of controlling crossover in a selection hyper-heuristic framework using the multidimensional knapsack problem. *Evolutionary computation*, 24(1):113–141, 2016. Hyper-heuristics are high-level methodologies for solving complex problems that operate on a search space of heuristics. In a selection hyper-heuristic framework, a heuristic is chosen from an existing set of low-level heuristics and applied to the current solution to produce a new solution at each point in the search. The use of crossover low-level heuristics is possible in an increasing number of general-purpose hyper-heuristic tools such as HyFlex and Hyperion. However, little work has been undertaken to assess how best to utilise it. Since a single-point search hyper-heuristic operates on a single candidate solution, and two candidate solutions are required for crossover, a mechanism is required to control the choice of the other solution. The frameworks we propose maintain a list of potential solutions for use in crossover. We investigate the use of such lists at two conceptual levels. First, crossover is controlled at the hyper-heuristic level where no problem-specific information is required. Second, it is controlled at the problem domain level where problem-specific information is used to produce good-quality solutions to use in crossover. A number of selection hyper-heuristics are compared using these frameworks over three benchmark libraries with varying properties for an NP-hard optimisation problem: the multidimensional 0-1 knapsack problem. It is shown that allowing crossover to be managed at the domain level outperforms managing crossover at the hyper-heuristic level in this problem domain. `http://www.mitpressjournals.org/doi/abs/10.1162/EVCO_a_00145`.

[439] Iain Dunning, Swati Gupta, and John Silberholz. What works best when? a systematic evaluation of heuristics for max-cut and qubo. *Optimization Online e-Prints*, 2016. Though empirical testing is broadly used to evaluate heuristics, there are shortcomings with how it is often applied in practice. In a systematic review of Max-Cut and Quadratic Unconstrained Binary Optimization (QUBO) heuristics papers, we found only 4% publish source code, only 14% compare heuristics with identical termination criteria, and most experiments are performed with an artificial, homogeneous set of problem instances. To address these limitations, we implement and release as open-source a code-base of 10

MaxCut and 27 QUBO heuristics. We perform heuristic evaluation using cloud computing across a library of 3,296 instances. This large-scale evaluation provides insight into the types of problem instances for which each heuristic performs well or poorly. Because no single heuristic outperforms all others across all problem instances, we use machine learning to predict which heuristic will work best on a previously unseen problem instance, a key question facing practitioners. http://www.optimization-online.org/DB_HTML/2015/05/4895.html.

[440] Achiya Elyasaf, Pavel Vaks, Nimrod Milo, Moshe Sipper, and Michal Ziv-Ukelson. Learning heuristics for mining rna sequence-structure motifs. In *Genetic Programming Theory and Practice XIII*, pages 21–38. Springer, 2016. The computational identification of conserved motifs in RNA molecules is a major-yet largely unsolved-problem. Structural conservation serves as strong evidence for important RNA functionality. Thus, comparative structure analysis is the gold standard for the discovery and interpretation of functional RNAs.In this paper we focus on one of the functional RNA motif types, sequence-structure motifs in RNA molecules, which marks the molecule as targets to be recognized by other molecules.We present a new approach for the detection of RNA structure (including pseudoknots), which is conserved among a set of unaligned RNA sequences. Our method extends previous approaches for this problem, which were based on first identifying conserved stems and then assembling them into complex structural motifs. The novelty of our approach is in simultaneously preforming both the identification and the assembly of these stems. We believe this novel unified approach offers a more informative model for deciphering the evolution of functional RNAs, where the sets of stems comprising a conserved motif co-evolve as a correlated functional unit.Since the task of mining RNA sequence-structure motifs can be addressed by solving the maximum weighted clique problem in an n-partite graph, we translate the maximum weighted clique problem into a state graph. Then, we gather and define domain knowledge and low-level heuristics for this domain. Finally, we learn hyper-heuristics for this domain, which can be used with heuristic search algorithms (e.g., A*, IDA*) for the mining task. The hyper-heuristics are evolved using HH-Evolver, a tool for domain-specific, hyper-heuristic evolution. Our approach is designed to overcome the computational limitations of current algorithms, and to remove the necessity of previous assumptions that were used for sparsifying the graph.This is still work in progress and as yet we have no results to report. However, given the interest in the methodology and its previous success in other domains we are hopeful that these shall be forthcoming soon. http://link.springer.com/chapter/10.1007/978-3-319-34223-8_2.

[441] David Espinoza-Nevárez, José Carlos Ortiz-Bayliss, Hugo Terashima-Marín, and Gustavo Gatica. Selection and generation hyper-heuristics for solving the vehicle routing problem with time windows. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion*, pages 139–140. ACM, 2016. The vehicle routing problem is a classic optimization problem

with many variants. One of the variants is given by the inclusion of the time windows constraint which requires the clients to be served within a delimited time frame. Because of its complexity, vehicle routing problems are usually solved by using heuristics without optimality guarantee. This paper describes two hyper-heuristics capable of producing results comparable to the ones obtained by the best-performing heuristics on different sets of benchmark instances. `http://dl.acm.org/citation.cfm?id=2909051`.

[442] Iztok Fajfar, Janez Puhan, and Árpád Bűrmen. Evolving a nelder-mead algorithm for optimization with genetic programming. *Evolutionary Computation*, 2016. We used genetic programming to evolve a direct search optimization algorithm, similar to that of the standard downhill simplex optimization method proposed by Nelder and Mead (1965). In the training process, we used several ten-dimensional quadratic functions with randomly displaced parameters and different randomly generated starting simplices. The genetically obtained optimization algorithm showed overall better performance than the original Nelder-Mead method on a standard set of test functions. We observed that many parts of the genetically produced algorithm were seldom or never executed, which allowed us to greatly simplify the algorithm by removing the redundant parts. The resulting algorithm turns out to be considerably simpler than the original Nelder-Mead method while still performing better than the original method. `http://www.mitpressjournals.org/doi/abs/10.1162/EVCO_a_00174`.

[443] Alexandre Silvestre Ferreira. A cross-domain multi-armed bandit hyper-heuristic, 2016. Many real word optimization problems are very complex with many variables and constraints, and cannot be solved by exact methods in a reasonable computational time. As an alternative, meta-heuristics emerged as an efficient way to solve this type of problems even though they cannot ensure optimal values. The main issue of meta-heuristics is that they are built using domain-specific knowledge, therefore they require a great effort to be used in a new domain. In order to solve this problem, the concept of Hyper-heuristics were proposed. Hyper-heuristics are search methods that aim to solve optimization problems by selecting or generating heuristics. Selection hyper-heuristics choose from a pool of heuristics a good one to be applied at the current stage of the optimization process. The selection mechanism is the main part of a selection hyper-heuristic and has a great impact on its performance. Although there are several works focused on selection hyperheuristics, there is no unanimity about which is the best way to define a selection strategy. In this dissertation, a deterministic selection strategy based on the concepts of the MultiArmed Bandit (MAB) problem is proposed to cross-domain optimization. Multi-armed bandit approaches define a selection function with two components, the first is based on the performance of an operator and the second based on the number of times that the operator was used. These approaches had showed a promising performance over the Adaptive Operator Selection context. However, there are few works on literature

that aim the hyper-heuristic context, as proposed here. The proposed approach is integrated into the HyFlex framework, that was developed to facilitate the implementation and comparison of hyper-heuristics. An empirical parameter configuration was performed and the best setup was compared to the top ten CHeSC 2011 algorithms using the same methodology adopted during the competition. The results obtained were good comparable to those attained by the literature. Moreover, it was concluded that the behavior of MAB selection is heavily affected by its parameters. As this is not a desirable behavior to hyper-heuristics, future research will investigate ways to better deal with the parameter setting. `http://acervodigital.ufpr.br/handle/1884/41803`.

[444] Michael Freitag and Torsten Hildebrandt. Automatic design of scheduling rules for complex manufacturing systems by multi-objective simulation-based optimization. *CIRP Annals-Manufacturing Technology*, 65(1):433–436, 2016. Complex manufacturing systems pose challenges for production planning and control. Amongst other objectives, orders have to be finished according to their due-dates. However, avoiding both earliness and tardiness requires a high level of process control. This article describes the use of simulation-based multi-objective optimization (multi-objective Genetic Programming) as a hyper-heuristic to automatically develop improved dispatching rules specifically for this control problem. Using a complex manufacturing scenario from semiconductor manufacturing as an example, it is shown that the resulting rules significantly outperform state-of-the-art dispatching rules from literature. `http://www.sciencedirect.com/science/article/pii/S000785061630066X`.

[445] Gian Mauricio Fritsche. Hyper-heuristic based particle swarm optimization for many-objective problems, 2016. Multi-objective Particle Swarm Optimization (MOPSO) is a promising meta-heuristic to solve Many-Objective Problems (MaOPs), however, its performance decreases as the number of objective functions increases. Selecting a good combination of leader and archiving methods helps the algorithm to deal with the challenges caused by this increase in the number of objectives, but finding the most appropriate combination for a given problem is a hard task. To deal with this issue, previous works proposed the use of a simple hyper-heuristic to select dynamically a good combination of leader and archiving methods and achieved promising results. In this work, we hypothesize that by using more advanced heuristic selection methods we could further improve the performance of the algorithm. To investigate this hypothesis we conducted experimental studies comparing four heuristic selection methods. After selecting the best performing variant from this study, we conducted a second empirical study to compare this variant to a state-of-the- art optimizer, where the resulting algorithm outperformed it in most of the problems investigated. `http://acervodigital.ufpr.br/handle/1884/41790`.

[446] Jacomine Grobler. A multi-objective hyper-heuristic for the flexible job shop scheduling problem with additional constraints. In *3rd International Conference*

on Soft Computing & Machine Intelligence (ISCMI), pages 58–62. IEEE, 2016. This paper proposes a multi-objective hyperheuristic (MOO-HMHH) algorithm for the flexible job shop scheduling problem (FJSP) with sequence-dependent set-up times, auxiliary resources and machine down time. Two variations of the algorithm were implemented and evaluated on real customer datasets. The hyper-heuristic algorithms compared well to their constituent algorithms and promising results were obtained with respect to the increased generality of the hyperheuristics. http://ieeexplore.ieee.org/abstract/document/8057439/.

[447] Jacomine Grobler and Andries P Engelbrecht. Hyper-heuristics for the flexible job shop scheduling problem with additional constraints. In *International Conference in Swarm Intelligence*, pages 3–10. Springer, 2016. This paper investigates a highly relevant real world scheduling problem, namely the multi-objective flexible job shop scheduling problem (FJSP) with sequence-dependent set-up times, auxiliary resources and machine down time. A hyper-heuristic algorithm is presented which makes use of a set of meta-heuristic algorithms which are self-adaptively selected at different stages of the optimization process to optimize a set of candidate solutions. This meta-hyper-heuristic algorithm was tested on a number of real world production scheduling data sets and was also benchmarked against the previous state-of-the-art job shop scheduling algorithms applied to this specific problem. In addition to the competitive results obtained, the self-adaptive nature of the algorithm avoids the resource intensive process of developing a meta-heuristic algorithm for one specific problem instance. http://link.springer.com/chapter/10.1007/978-3-319-41009-8_1.

[448] Giovani Guizzo and Silvia R Vergilio. Metaheuristic design pattern: Visitor for genetic operators. In *the 5th Brazilian Conference on Intelligent System (BRACIS)*, 2016. Metaheuristics, such as Genetic Algorithms (GAs), and hyper-heuristics have been widely studied and applied in the literature. This led to the development of several frameworks to aid the execution and development of such algorithms. Consequently, the reusability, scalability and maintainability became fundamental points to be attacked by developers. Such points can be improved using Design Patterns, but despite their advantages, few works have explored their usage with metaheuristics and hyper-heuristics. In order to contribute to this research topic, we present a solution based on the Visitor pattern used to design genetic operators. A case study is presented with the Hyper-heuristic for the Integration and Test Order problem (HITO). This case study shows that the proposed solution can increase the reusability of the implemented operators, and also enable easy addition of new genetic operators and representations. https://www.researchgate.net/profile/Giovani_Guizzo/publication/308050005_Metaheuristic_Design_Pattern_Visitor_for_Genetic_Operators/links/57d8233708ae601b39af98f5.pdf.

[449] Düriye Betül Gümüs, Ender Ozcan, and Jason Atkin. An analysis of the taguchi method for tuning a memetic algorithm with reduced computational time budget.

In *Proceedings of the 31st International Symposium on Computer and Information Sciences (ISCIS)*, 2016. Selection hyper-heuristics perform search over the space of heuristics by mixing and controlling a predefined set of low level heuristics for solving computationally hard combinatorial optimisation problems. Being reusable methods, they are expected to be applicable to multiple problem domains, hence performing well in cross-domain search. HyFlex is a general purpose heuristic search API which separates the high level search control from the domain details enabling rapid development and performance comparison of heuristic search methods, particularly hyper-heuristics. In this study, the performance of six previously proposed selection hyper-heuristics are evaluated on three recently introduced extended HyFlex problem domains, namely 0-1 Knapsack, Quadratic Assignment and Max-Cut. The empirical results indicate the strong generalising capability of two adaptive selection hyper-heuristics which perform well across the 'unseen' problems in addition to the six standard HyFlex problem domains. `http://www.cs.nott.ac.uk/~pszeo/docs/publications/iscis2016_25.pdf`.

[450] Düriye Betül Gümüs, Ender Ozcan, and Jason Atkin. An investigation of tuning a memetic algorithm for cross-domain search. In *IEEE Congress on Evolutionary Computation (CEC)*. IEEE, 2016. Memetic algorithms, which hybridise evolutionary algorithms with local search, are well-known metaheuristics for solving combinatorial optimisation problems. A common issue with the application of a memetic algorithm is determining the best initial setting for the algorithmic parameters, but these can greatly influence its overall performance. Unlike traditional studies where parameters are tuned for a particular problem domain, in this study we do tuning that is applicable to cross-domain search. We extend previous work by tuning the parameters of a steady state memetic algorithm via a 'design of experiments' approach and provide surprising empirical results across nine problem domains, using a cross-domain heuristic search tool, namely HyFlex. The parameter tuning results show that tuning has value for cross-domain search. As a side gain, the results suggest that the crossover operators should not be used and, more interestingly, that single point based search should be preferred over a population based search, turning the overall approach into an iterated local search algorithm. The use of the improved parameter settings greatly enhanced the crossdomain performance of the algorithm, converting it from a poor performer in previous work to one of the stronger competitors. `http://www.cs.nott.ac.uk/~pszeo/docs/publications/cec2016_bg.pdf`.

[451] Aldy Gunawan, Hoong Chuin Lau, and Mustafa Mısır. Designing and comparing multiple portfolios of parameter configurations for online algorithm selection. In *Proceedings of the 10th Learning and Intelligent OptimizatioN Conference (LION)*, volume 10079 of *LNCS*, pages 91–106, Naples, Italy, 2016. Algorithm portfolios seek to determine an effective set of algorithms that can be used within an algorithm selection framework to solve problems. A limited number of these portfolio studies focus on generating different versions of a target

algorithm using different parameter configurations. In this paper, we employ a Design of Experiments (DOE) approach to determine a promising range of values for each parameter of an algorithm. These ranges are further processed to determine a portfolio of parameter configurations, which would be used within two online Algorithm Selection approaches for solving different instances of a given combinatorial optimization problem effectively. We apply our approach on a Simulated Annealing-Tabu Search (SA-TS) hybrid algorithm for solving the Quadratic Assignment Problem (QAP) as well as an Iterated Local Search (ILS) on the Travelling Salesman Problem (TSP). We also generate a portfolio of parameter configurations using best-of-breed parameter tuning approaches directly for the comparison purpose. Experimental results show that our approach lead to improvements over best-of-breed parameter tuning approaches. `http://link.springer.com/chapter/10.1007/978-3-319-50349-3_7`.

[452] Emma Hart and Kevin Sim. A hyper-heuristic ensemble method for static job-shop scheduling. *Evolutionary computation*, 24(4):609–635, 2016. We describe a new hyper-heuristic method NELLI-GP for solving job-shop scheduling problems (JSSP) that evolves an ensemble of heuristics. The ensemble adopts a divide-and-conquer approach in which each heuristic solves a unique subset of the instance set considered. NELLI-GP extends an existing ensemble method called NELLI by introducing a novel heuristic generator that evolves heuristics composed of linear sequences of dispatching rules: each rule is represented using a tree structure and is itself evolved. Following a training period, the ensemble is shown to outperform both existing dispatching rules and a standard genetic programming algorithm on a large set of new test instances. In addition, it obtains superior results on a set of 210 benchmark problems from the literature when compared to two state-of-the-art hyperheuristic approaches. Further analysis of the relationship between heuristics in the evolved ensemble and the instances each solves provides new insights into features that might describe similar instances. `http://www.mitpressjournals.org/doi/abs/10.1162/EVCO_a_00183`.

[453] Ahmed Hassan and Nelishia Pillay. A hyper-heuristic approach to solving the ski-lodge problem. In *Advances in Nature and Biologically Inspired Computing*, pages 201–210. Springer, 2016. Hyper-heuristics seek solution methods instead of solutions and thus provides a higher level of generality compared to bespoke meta-heuristics and traditional heuristic approaches. In this paper, a hyper-heuristic is proposed to solve the ski-lodge problem which involves allocating shared-time apartments to customers during a skiing season in a way that achieves a certain objective while respecting the constraints of the problem. Prior approaches to the problem include simulated annealing and genetic algorithm. To the best of our knowledge, this is the first time the ski-lodge problem is approached from a hyper-heuristic perspective. Although the aim of hyper-heuristics is to provide good results over problem sets rather than producing best results for certain problem instances, for completeness and to get an idea of the quality of

solutions, the results of the proposed hyper-heuristic are compared to that of genetic algorithm and simulated annealing. The hyper-heuristic was found to perform better than simulated annealing and comparatively to the genetic algorithm, producing better results for some of the instances. Furthermore, the hyper-heuristic has better overall performance over the problem set being considered. http://link.springer.com/chapter/10.1007/978-3-319-27400-3_18.

[454] Nozomi Hitomi and Daniel Selva. A hyperheuristic approach to leveraging domain knowledge in multi-objective evolutionary algorithms. In *ASME 2016 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers, 2016. Evolutionary algorithms have shown much success in solving real-world design problems, but they are considered computationally inefficient because they rely on many objective-function evaluations instead of leveraging domain knowledge to guide the optimization. An evolutionary algorithm's performance can be improved by utilizing operators called domain-specific heuristics that incorporate domain knowledge, but existing knowledge-intensive algorithms utilize one or two domain-specific heuristics, which limits the amount of incorporated knowledge or treats all knowledge as equally effective. We propose a hyperheuristic approach that efficiently utilizes multiple domain-specific heuristics that incorporate knowledge from different sources by allocating computational resources to the effective ones. Furthermore, a hyperheuristic allows the simultaneous use of conventional evolutionary operators that assist in escaping local optima. This paper empirically demonstrates the efficacy of the proposed hyperheuristic approach on a multi-objective design problem for an Earth observation satellite system. Results show that the hyperheuristic approach significantly improves the search performance compared to an evolutionary algorithm that does not use any domain knowledge. http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=2591657.

[455] Libin Hong, John H Drake, John R Woodward, and Ender Özcan. Automatically designing more general mutation operators of evolutionary programming for groups of function classes using a hyper-heuristic. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference*, pages 725–732. ACM, 2016. In this study we use Genetic Programming (GP) as an offline hyper-heuristic to evolve a mutation operator for Evolutionary Programming. This is done using the Gaussian and uniform distributions as the terminal set, and arithmetic operators as the function set. The mutation operators are automatically designed for a specific function class. The contribution of this paper is to show that a GP can not only automatically design a mutation operator for Evolutionary Programming (EP) on functions generated from a specific function class, but also can design more general mutation operators on functions generated from groups of function classes. In addition, the automatically designed mutation operators also

show good performance on new functions generated from a specific function class or a group of function classes. http://dl.acm.org/citation.cfm?id=2908958.

[456] Rachel Hunt. Genetic programming hyper-heuristics for job shop scheduling, 2016. Scheduling problems arise whenever there is a choice of order in which a number of tasks should be performed; they arise commonly, daily and everywhere. A job shop is a common manufacturing environment in which a schedule for processing a set of jobs through a set of machines needs to be constructed. Job shop scheduling (JSS) has been called a fascinating challenge as it is computationally hard and prevalent in the real-world. Developing more effective ways of scheduling jobs could increase profitability through increasing throughput and decreasing costs. Dispatching rules (DRs) are one of the most popular scheduling heuristics. DRs are easy to implement, have low computational cost, and cope well with the dynamic nature of real-world manufacturing environments. However, the manual development of DRs is time consuming and requires expert knowledge of the scheduling environment. Genetic programming (GP) is an evolutionary computation method which is ideal for automatically discovering DRs. This is a hyper-heuristic approach, as GP is searching the search space of heuristic (DR) solutions rather than constructing a schedule directly. The overall goal of this thesis is to develop GP based hyper-heuristics for the efficient evolution (automatic generation) of robust, reusable and effective scheduling heuristics for JSS environments, with greater interpretability. Firstly, this thesis investigates using GP to evolve optimal DRs for the static two-machine JSS problem with makespan objective function. The results show that some evolved DRs were equivalent to an optimal scheduling algorithm. This validates both the GP based hyper-heuristic approach for generating DRs for JSS and the representation used. Secondly, this thesis investigates developing "less-myopic" DRs through the use of wider-looking terminals and local search to provide additional fitness information. The results show that incorporating features of the state of the wider shop improves the mean performance of the best evolved DRs, and that the inclusion of local search in evaluation evolves DRs which make better decisions over the local time horizon, and attain lower total weighted tardiness. Thirdly, this thesis proposes using strongly typed GP (STGP) to address the challenging issue of interpretability of DRs evolved by GP. Several grammars are investigated and the results show that the DRs evolved in the semantically constrained search space of STGP do not have (on average) performance that is as good as unconstrained. However, the interpretability of evolved rules is substantially improved. Fourthly, this thesis investigates using multiobjective GP to encourage evolution of DRs which are more readily interpretable by human operators. This approach evolves DRs with similar performance but smaller size. Fragment analysis identifies popular combinations of terminals which are then used as high level terminals; the inclusion of these terminals improved the mean performance of the best evolved DRs. Through this thesis the following major contributions have been made: (1) the first use of GP to evolve optimal DRs for the static two-machine job shop

with makespan objective function; (2) an approach to developing less-myopic DRs through the inclusion of wider looking terminals and the use of local search to provide additional fitness information over an extended decision horizon; (3) the first use of STGP for the automatic discovery of DRs with better interpretability and semantic validity for increased trust; and (4) the first multiobjective GP approach that considers multiple objectives investigating the trade-off between scheduling behaviour and interpretability. This is also the first work that uses analysis of evolved GP individuals to perform feature selection and construction for JSS. `http://researcharchive.vuw.ac.nz/handle/10063/5219`.

[457] Daniel Karapetyan, Abraham P. Punnen, and Andrew J. Parkes. Multi-component approach to the bipartite boolean quadratic programming problem. *CoRR*, abs/1605.02038, 2016. We study the Bipartite Boolean Quadratic Programming Problem (BBQP) which is an extension of the well known Boolean Quadratic Programming Problem (BQP). Applications of the BBQP include mining discrete patterns from binary data, approximating matrices by rank-one binary matrices, computing the cut-norm of a matrix, and solving optimisation problems such as maximum weight biclique, bipartite maximum weight cut, maximum weight induced sub-graph of a bipartite graph, etc. For the BBQP, we first present several algorithmic components, specifically, hillclimbers and mutations, and then show how to combine them in a high-performance metaheuristic. Instead of hand-tuning a standard metaheuristic to test the efficiency of the hybrid of the components, we chose to use an automated generation of a multi-component metaheuristic to save human time, and also improve objectivity in the analysis and comparisons of components. For this we designed a new metaheuristic schema which we call Conditional Markov Chain Search (CMCS). We show that CMCS is flexible enough to model several standard metaheuristics; this flexibility is controlled by multiple numeric parameters, and so is convenient for automated generation. We study the configurations revealed by our approach and show that the best of them outperforms the previous state-of-the-art BBQP algorithm by several orders of magnitude. In our experiments we use benchmark instances introduced in the preliminary version of this paper and described here, which have already become the de facto standard in the BBQP literature. `http://arxiv.org/abs/1605.02038`.

[458] Deepak Karunakaran, Gang Chen, and Mengjie Zhang. Parallel multi-objective job shop scheduling using genetic programming. In *Australasian Conference on Artificial Life and Computational Intelligence*, pages 234–245. Springer, 2016. In recent years, multi-objective optimization for job shop scheduling has become an increasingly important research problem for a wide range of practical applications. Aimed at effectively addressing this problem, the usefulness of an evolutionary hyper-heuristic approach based on both genetic programming and island models will be thoroughly studied in this paper. We focus particularly on evolving energy-aware dispatching rules in the form of genetic programs that can sched-

ule jobs for the purpose of minimizing total energy consumption, makespan and total tardiness in a job shop. To improve the opportunity of identifying desirable dispatching rules, we have also explored several alternative topologies of the island model. Our experimental results clearly showed that, with the help of the island models, our evolutionary algorithm could outperform some general-purpose multi-objective optimization methods, including NSGA-II and SPEA-2. `http://link.springer.com/chapter/10.1007/978-3-319-28270-1_20`.

[459] Geetinder kaur and Sarabjit kaur. Improved hyper-heuristic scheduling with load-balancing and rasa for cloud computing systems. *International Journal of Grid and Distributed Computing*, 9(1):13–24, 2016. Nowadays cloud computing has turned into a key innovation and has become a great solution for indulging a flexible utility oriented, online allocation and storage of computing resources and client's information in lower expense, on- interest and dynamically scalable framework on pay per use premise. This technology is a new pattern emerging in IT environment with immense necessities of framework and resources. Job Scheduling Problem is an essential issue. For efficient usage and managing resources, administrations, scheduling plays a critical role. This paper apportion the performance enhancement of Hyper- Heuristic Scheduling Approach to schedule cloudlets and resources, by taking account of both , computation time and transmission cost with two detection operators. Load Balancing and RASA concept is applied for efficient Load Scheduling, resource utilization and thereby enhancing the overall performance of cloud computing environment. The numerical investigations of HHSA were performed on CloudSim. Experimental results generated via simulation shows that enhanced heuristic scheduling approach is much better than individual heuristic approach in terms of minimizing makespan time. `http://www.earticle.net/Article.aspx?sn=267931`.

[460] Ahmed Kheiri, Mustafa Mısır, and Ender Ozcan. Ensemble move acceptance in selection hyper-heuristics. In *Proceedings of the 31st International Symposium on Computer and Information Sciences (ISCIS)*, 2016. Selection hyper-heuristics are high level search methodologies which control a set of low level heuristics while solving a given problem. Move acceptance is a crucial component of selection hyper-heuristics, deciding whether to accept or reject a new solution at each step during the search process. This study investigates group decision making strategies as ensemble methods exploiting the strengths of multiple move acceptance methods for improved performance. The empirical results indicate the success of the proposed methods across six combinatorial optimisation problems from a benchmark as well as an examination timetabling problem. `http://www.cs.nott.ac.uk/~pszeo/docs/publications/iscis2016_23.pdf`.

[461] Ahmed Kheiri and Ender Özcan. An iterated multi-stage selection hyper-heuristic. *European Journal of Operational Research*, 250(1):77–90, 2016. There is a growing interest towards the design of reusable general purpose search methods that are applicable to different problems instead of tailored solutions

to a single particular problem. Hyper-heuristics have emerged as such high level methods that explore the space formed by a set of heuristics (move operators) or heuristic components for solving computationally hard problems. A selection hyper-heuristic mixes and controls a predefined set of low level heuristics with the goal of improving an initially generated solution by choosing and applying an appropriate heuristic to a solution in hand and deciding whether to accept or reject the new solution at each step under an iterative framework. Designing an adaptive control mechanism for the heuristic selection and combining it with a suitable acceptance method is a major challenge, because both components can influence the overall performance of a selection hyper-heuristic. In this study, we describe a novel iterated multi-stage hyper-heuristic approach which cycles through two interacting hyper-heuristics and operates based on the principle that not all low level heuristics for a problem domain would be useful at any point of the search process. The empirical results on a hyper-heuristic benchmark indicate the success of the proposed selection hyper-heuristic across six problem domains beating the state-of-the-art approach. `http://www.sciencedirect.com/science/article/pii/S0377221715008255`.

[462] Ahmed Kheiri, Ender Ozcan, Rhyd Lewis, and Jonathan Thompson. A sequence-based selection hyper-heuristic - a case study in nurse rostering. In *the 11th International Confenference on Practice and Theory of Automated Timetabling (PATAT)*, pages 503–505, 2016. The nurse rostering problem has been of interest to practitioners and researchers in the fields of operational research and artificial intelligence. This problem is known to be NP-hard [1]. We have joined the second international nurse rostering competition (INRC-II1) to solve an extended version of the problem, referred to as the multi-stage nurse rostering problem, using a sequence-based selection hyper-heuristic method. The full description of the problem can be found at the competition website. We present our solution method in this study. `http://www.patatconference.org/patat2016/files/proceedings/paper_45.pdf`.

[463] Ahmed Kheiri, Ender Özcan, and Andrew J. Parkes. A stochastic local search algorithm with adaptive acceptance for high-school timetabling. *Annals of Operations Research*, 239(1):135–151, 2016. Automating high school timetabling is a challenging task. This problem is a well known hard computational problem which has been of interest to practitioners as well as researchers. High schools need to timetable their regular activities once per year, or even more frequently. The exact solvers might fail to find a solution for a given instance of the problem. A selection hyper-heuristic can be defined as an easy-to-implement, easy-to-maintain and effective 'heuristic to choose heuristics' to solve such computationally hard problems. This paper describes the approach of the team hyper-heuristic search strategies and timetabling (HySST) to high school timetabling which competed in all three rounds of the third international timetabling competition. HySST generated the best new solutions for three given instances

in Round 1 and gained the second place in Rounds 2 and 3. It achieved this by using a fairly standard stochastic search method but significantly enhanced by a selection hyper-heuristic with an adaptive acceptance mechanism. http://dx.doi.org/10.1007/s10479-014-1660-0.

[464] A Charan Kumari and K Srinivas. Hyper-heuristic approach for multi-objective software module clustering. *Journal of Systems and Software*, 117:384–401, 2016. In the software maintenance phase of software development life cycle, one of the main concerns of software engineers is to group the modules into clusters with maximum cohesion and minimum coupling. To analyze the efficacy of Multi-objective Hyper-heuristic Evolutionary Algorithm (MHypEA) in solving real-world clustering problems and to compare the results with the reported results in the literature for single as well as multi-objective formulations of the problem and also to present a CASE tool that assists software engineers in software module clustering process. The paper reports on empirical evaluation of the performance of MHypEA with the reported results in the literature. The comparison is mainly based on two factors - quality of the obtained solutions and the computational effort. On all the attempted problems, MHypEA reported good results in comparison to all the studies that were reported on multi-objective formulation of the problem, with a computational effort of nearly one-twentieth of the computational effort required by the other multi-objective algorithms. The hyper-heuristic approach is able to produce high quality clustered systems with less computational effort. http://www.sciencedirect.com/science/article/pii/S0164121216300231.

[465] Viktor M Kureychik, Vladimir Vl Kureychik, Roman Potarusov, and Liliya Kureychik. Heuristics methods for solving the block packing problem. In *Information Technologies in Science, Management, Social Sphere and Medicine (ITSMSSM 2016)*. Atlantis Press, 2016. In the given paper one-dimensional Bin Packing Problem which plays an important role for the optimization of transportations and production activities is considered. The Hybrid Genetic Algorithm for one-dimensional Bin Packing Problem is proposed. For this purpose two evolution models (de Vries' evolution model and Lamarck's evolution model) have been adapted. Besides, new problem-oriented genetic operators are developed. The main advantage of the suggested approach is that it never decreases the quality of solution so it allows obtaining valid Bin Packing Problem solutions. Two effective local search algorithms allowing to improve of Bin Packing Problem solutions by getting quasi-optimal and optimal packings are proposed. Computational experiments show that a new hybrid approach based on genetic algorithm intended for solving one-dimensional BPP provides approximation and optimal solutions for all benchmarks in-stances in a tolerable computational time as well as demonstrate the robustness of the proposed approach. http://www.atlantis-press.com/php/download_paper.php?id=25856109.

[466] Yuanjun Laili, Lin Zhang, Fei Tao, and Pingchuan Ma. Rotated neighbor

learning-based auto-configured evolutionary algorithm. *Science China Information Sciences*, pages 1–13, 2016. More and more evolutionary operators have been integrated and manually configured together to solve wider range of problems. Considering the very limited progress made on the automatic configuration of evolutionary algorithms (EAs), a rotated neighbor learning-based auto-configured evolutionary algorithm (RNLACEA) is presented. In this framework, multiple EAs are combined as candidates and automatically screened for different scenarios with a rotated neighbor structure. According to a ranking record and a group of constraints, the algorithms can be better scheduled to improve the searching efficiency and accelerate the searching pace. Experimental studies based on 14 classical EAs and 22 typical benchmark problems demonstrate that RNLACEA outperforms other six representative auto-adaptive EAs and has high scalability and robustness in solving different kinds of numerical optimization problems. `http://link.springer.com/article/10.1007/s11432-015-5372-0`.

[467] Dongni Li, Rongxin Zhan, Dan Zheng, Miao Li, and Ikou Kaku. A hybrid evolutionary hyper-heuristic approach for intercell scheduling considering transportation capacity. *IEEE Transactions on Automation Science and Engineering*, 13(2):1072–1089, 2016. The problem ofintercell scheduling considering transportation capacity with the objective of minimizing total weighted tardiness is addressed in this paper, which in nature is the coordination of production and transportation. Since it is a practical decision-making problem with high complexity and large problem instances, a hybrid evolutionary hyper-heuristic (HEH) approach, which combines heuristic generation and heuristic selection, is developed in this paper. In order to increase the diversity and effectiveness of heuristic rules, genetic programming is used to automatically generate new rules based on the attributes of parts, machines, and vehicles. The new rules are added to the candidate rule set, and a rule selection genetic algorithm is developed to choose appropriate rules for machines and vehicles. Finally, scheduling solutions are obtained using the selected rules. A comparative evaluation is conducted, with some state-of-the-art hyper-heuristic approaches which lack some of the strategies proposed in HEH, with a meta-heuristic approach that is suitable for large scale scheduling problems, and with adaptations of some well-known heuristic rules. Computational results show that the new rules generated in HEH have similarities to the best-performing human-made rules, but are more effective due to the evolutionary processes in HEH. Moreover, the HEH approach has advantages over other approaches in both computational efficiency and solution quality, and is especially suitable for problems with large instance sizes. Note to Practitioners-Our survey of the equipment manufacturing industry in China indicates that, for complex products like synthetic transmission devices, intercell transfers occur in the processing routes of more than 51% of parts. More than 47% of tardy parts are caused by inefficient intercell cooperation. Therefore, intercell transfers are inevitable and it is worth an effort to find out an effective approach to intercell scheduling. To solv- intercell scheduling problems, two characteristics in industrial

environments of complex products cannot be neglected. The first one is the large problem sizes, which involve up to hundreds of parts and thousands of operations; and the second one is the importance of transportation to intercell scheduling, which involves allocation and utilization of vehicles. However, sufficient transportation capacity is taken as a common assumption in most of research with respect to intercell scheduling, which shields the transportation dimension and hinders the application of these intercell scheduling approaches. Therefore, intercell scheduling with limited transportation capacity is considered, and a hybrid evolutionary hyper-heuristic is proposed in this paper. The advantages of this approach lie in that, (i) as a hyper-heuristic, it provides high computational efficiency, which is suitable for industrial environments with large problem sizes; and (ii) genetic programming is employed to generate problem-specific heuristic rules, which enhances the learning and searching ability of the approach. We compare the proposed approach with the man-made heuristic rules that are widely used in practice. Experimental results indicate that, for hundreds of parts and thousands of operations, given the same running time, our approach outperforms man-made rules with an average gap of 60.6% in minimizing total weighted tardiness. Therefore, our approach is advantageous in both computational efficiency and solution quality, and is especially suitable for the intercell scheduling problems in practice. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7270346`.

[468] Viktor Lindberg. Evaluation of school timetabling algorithms, 2016. Most schools have the problem that they need to organise the meetings between students and teachers in lectures and place these lectures in a timetable. Four different algorithms that can be used to solve this problem will be evaluated in this thesis. The algorithms are Simulated Annealing, Particle Swarm Optimisation, Hyper-Heuristic Genetic Algorithm and Iterated Local Search. In this thesis a description of the algorithms will be given and then evaluated by running them on a set of different known timetabling problems and have their results compared with each other to find out which algorithm is best suited for use in a potential end-user application. Simulated Annealing combined with Iterated Local Search gave the best resultsin this thesis. `http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1053036&dswid=-1007`.

[469] José Matias Cutillas Lozano, Domingo Giménez, and Luis Pedro Garcia. Optimizing metaheuristics and hyperheuristics through multi-level parallelism on a many-core system. In *2016 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW)*, pages 786–795. IEEE, 2016. Hyperheuristics based on parameterized metaheuristic schemas are computationally demanding. To reduce execution times, a shared-memory schema of hyperheuristics is used, with four levels of parallelism, with two being selected for the hyperheuristic and two for the metaheuristics. The parallel schema is executed in a many-core system in "native mode", and the four-level parallelism allows us to take full advantage of the massive parallelism offered by this architecture. An

auto-tuning methodology is used to select the number of threads used at each level. A theoretical model of the execution time of the parameterized metaheuristic schema is developed, and the model is adapted to a particular metaheuristic by experimentation. The massive parallelism in a many-core system can help to obtain satisfactory fitness and an important reduction in execution times, for which the four-levels parallelism schema is useful, and the auto-tuning engine facilitates the optimum selection of the number of threads at each level. The best results are obtained with a relatively low number of threads distributed among the four levels of parallelism between the hyper and metaheuristics. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7529941&tag=1`.

[470] E Mamatha, S Saritha, and CS Reddy. Stochastic scheduling algorithm for distributed cloud networks using heuristic approach. *International Journal of Advanced Networking and Applications*, 8(1):3009, 2016. Rule based heuristic scheduling algorithms in real time and cloud computing Systems employ for resource or task scheduling since they are suitable to implement for NP-complete problems. However, they are simple but there is much room to improve these algorithms. This study presents a heuristic scheduling algorithm, called High performance hyper-heuristic scheduling algorithm (HHSA) using detection operator, to find better scheduling solutions for real and cloud computing systems. The two operators - diversity detection and improvement detection operators - are employed in this algorithm to determine the timing to determine the heuristic algorithm. These two are employed to dynamically determine a low level heuristic that can be used to find better solution. To evaluate the performance of this method, authors examined the above method with several scheduling algorithms and results prove that Hyper Heuristic Scheduling Algorithm can significantly decrease the makespan of task scheduling when compared with all other scheduling algorithms. A novel high-performance hyper-heuristic algorithm is proposed for scheduling on cloud computing systems to reduce the makespan. This algorithm can be applied to both sequence dependent and sequence independent scheduling problems. `http://www.ijana.in/papers/V8I1-8.pdf`.

[471] Thainá Mariani, Giovani Guizzo, Silvia R Vergilio, and Aurora TR Pozo. Grammatical evolution for the multi-objective integration and test order problem. In *Proceedings of the Annual Genetic and Evolutionary Computation Conference (GECCO)*, pages 1069–1076. ACM, 2016. Search techniques have been successfully applied for solving different software testing problems. However, choosing, implementing and configuring a search technique can be hard tasks. To reduce efforts spent in such tasks, this paper presents an offline hyper-heuristic named GEMOITO, based on Grammatical Evolution (GE). The goal is to automatically generate a Multi-Objective Evolutionary Algorithm (MOEA) to solve the Integration and Test Order (ITO) problem. The MOEAs are distinguished by components and parameters values, described by a grammar. The proposed hyper-heuristic is compared to conventional MOEAs and to a selection

hyper-heuristic used in related work. Results show that GEMOITO can generate MOEAs that are statistically better or equivalent to the compared algorithms. `http://dl.acm.org/citation.cfm?id=2908816`.

[472] David Meignan, Silvia Schwarze, and Stefan Voß. Improving local-search metaheuristics through look-ahead policies. *Annals of Mathematics and Artificial Intelligence*, 76(1-2):59–82, 2016. As a basic principle, look-ahead approaches investigate the outcomes of potential future steps to evaluate the quality of alternative search directions. Different policies exist to set up look-ahead methods differing in the object of inspection and in the extensiveness of the search. In this work, two original look-ahead strategies are developed and tested through numerical experiments. The first method introduces a look-ahead mechanism that acts as a hyper-heuristic for comparing and selecting local-search operators. The second method uses a look-ahead strategy on a lower level in order to guide a local-search metaheuristic. The proposed approaches are implemented using a hyper-heuristic framework. They are tested against alternative methods using two different competition benchmarks, including a comparison with results given in literature. Furthermore, in a second set of experiments, a detailed investigation regarding the influence of particular parameter values is executed for one method. The experiments reveal that the inclusion of a simple look-ahead principle into an iterated local-search procedure significantly improves the outcome regarding the considered benchmarks. `http://link.springer.com/article/10.1007/s10472-015-9453-y`.

[473] Andre Mendes, Julian Togelius, and Andy Nealen. Hyper-heuristic general video game playing. In *Proceedings of IEEE Computational Intelligence and Games*. IEEE, 2016. In general video game playing, the challenge is to create agents that play unseen games proficiently. Stochastic tree search algorithms, like Monte Carlo Tree Search, perform relatively well on this task. However, performance is nontransitive: different agents perform best in different games, which means that there is not a single agent that is the best in all the games. Rather, some types of games are dominated by a few agents whereas other different agents dominate other types of games. Thus, it should be possible to construct a hyper-agent that selects from a portfolio, in which constituent sub-agents will play a new game best. Since there is no knowledge about the games, the agent needs to use available features to predict the most suitable algorithm. This work constructs such a hyper-agent using the General Video Game Playing Framework (GVGAI). The proposed method achieves promising results that show the applicability of hyper-heuristics in general video game playing and related tasks. `http://julian.togelius.com/Mendes2016HyperHeuristic.pdf`.

[474] Péricles BC Miranda and Ricardo BC Prudêncio. Tree-based grammar genetic programming to evolve particle swarm algorithms. In *Intelligent Systems (BRACIS), 2016 5th Brazilian Conference on*, pages 25–30. IEEE, 2016.

[475] Mitra Montazeri. HHFS: Hyper-heuristic feature selection. *Intelligent Data Analysis*, 20(4):953–974, 2016. Feature selection is an important machine learning field which can provide a key role for the challenging problem of classifying high-dimensional data. This problem is finding effective features among the set of all features in such that the final feature set can improve accuracy and reduce complexity. Since feature selection is an NP-Hard problem, many heuristic algorithms have been studied so far to solve this problem. In this paper, we propose a novel method based on hyper-heuristic approach to find an efficient proper feature subset which is named Hyper-Heuristic Feature Selection (HHFS). In the proposed method, Low level heuristics are categorized into two groups: the first group contains exploiters which cause to exploit the search space efficiently by improving the quality of the candidate solution at hand; the second one includes explorer heuristics which explore the solution space by dwelling on random perturbations. Since each region of the solution space can have its own characteristics, an appropriate low level heuristic should be selected and applied to the current solution. We propose Genetic Algorithm to select among the set of low level heuristic and balance between exploitation and exploration. It chooses the low level heuristic based on the existing functional history of low level heuristic. We aim to investigate the role of cooperation between low level heuristics within a hyper-heuristic framework to find the best feature subset. Since different low level heuristics have different strengths and weaknesses, we believe that cooperation can allow the strengths of one low level heuristic to compensate for the weaknesses of another. In this study, we also propose Adaptive Hyper-Heuristic Feature Selection (AHHFS) which is an extension of HHFS. Empirical study of the proposed method on several commonly used data sets from UCI repository indicates that it outperforms recent methods in the literature for feature selection. `http://content.iospress.com/articles/intelligent-data-analysis/ida840`.

[476] Mitra Montazeri, Mahdieh Soleymani Baghshah, and Aliakbar Niknafs. Selecting efficient features via a hyper-heuristic approach. *arXiv preprint arXiv:1601.05409*, 2016. By Emerging huge databases and the need to efficient learning algorithms on these datasets, new problems have appeared and some methods have been proposed to solve these problems by selecting efficient features. Feature selection is a problem of finding efficient features among all features in which the final feature set can improve accuracy and reduce complexity. One way to solve this problem is to evaluate all possible feature subsets. However, evaluating all possible feature subsets is an exhaustive search and thus it has high computational complexity. Until now many heuristic algorithms have been studied for solving this problem. Hyper-heuristic is a new heuristic approach which can search the solution space effectively by applying local searches appropriately. Each local search is a neighborhood searching algorithm. Since each region of the solution space can have its own characteristics, it should be chosen an appropriate local search and apply it to current solution. This task is tackled to a supervisor. The supervisor chooses a local search based on the functional history of local searches. By doing this task,

it can trade of between exploitation and exploration. Since the existing heuristic cannot trade of between exploration and exploitation appropriately, the solution space has not been searched appropriately in these methods and thus they have low convergence rate. For the first time, in this paper use a hyper-heuristic approach to find an efficient feature subset. In the proposed method, genetic algorithm is used as a supervisor and 16 heuristic algorithms are used as local searches. Empirical study of the proposed method on several commonly used data sets from UCI data sets indicates that it outperforms recent existing methods in the literature for feature selection. `http://arxiv.org/abs/1601.05409`.

[477] Philip Mourdjis, Yujie Chen, Fiona Polack, Peter Cowling, and Martin Robinson. Variable neighbourhood descent with memory: A hybrid metaheuristic for supermarket resupply. In *International Workshop on Hybrid Metaheuristics*, pages 32–46. Springer, 2016. Supermarket supply chains represent an area in which optimisation of vehicle routes and scheduling can lead to huge cost and environmental savings. As just-in-time ordering practices become more common, traditionally fixed resupply routes and schedules are increasingly unable to meet the demands of the supermarkets. Instead, we model this as a dynamic pickup and delivery problem with soft time windows (PDPSTW). We present the variable neighbourhood descent with memory (VNDM) hybrid metaheuristic (HM) and compare its performance against Q-learning (QL), binary exponential back off (BEBO) and random descent (RD) hyperheuristics on published benchmark and real-world instances of the PDPSTW. We find that VNDM consistently generates the highest quality solutions, with the fewest routes or shortest distances, amongst the methods tested. It is capable of finding the best known solutions to 55 of 176 published benchmarks as well as producing the best results on our real-world data set, supplied by Transfaction Ltd. `http://link.springer.com/chapter/10.1007/978-3-319-39636-1_3`.

[478] Sangeetha Muthuraman and V Prasanna Venkatesan. Design of qos based web service selection/composition hyper-heuristic model. In *Proceedings of the International Conference on Informatics and Analytics*, page 80. ACM, 2016. A web service selection/composition problem is a NP-complete problem that cannot be solved in polynomial time. An efficient solution is essential to solve this problem. This solution may be attained by following hyper-heuristic strategies. As a first step in addressing the problem, this paper presents a new web services selection/composition model which enables such a hyper-heuristic notion. Various parts of this proposed model can be implemented by using different algorithms thus enabling many hybrid implementations. In this paper the proposed model has been implemented by using a reference score and trust based service selection algorithm and a strategic tree based service composition algorithm. To realize this implementation agent based architecture has been proposed. A well defined QOS model has been used to accurately receive customer's request and update service specific quality values. The algorithms implemented are efficient as the compu-

tational complexities of these algorithms have been greatly reduced and also a fault tolerant approach has been adopted. The experimental results illustrate that the proposed model and algorithms have effectively solved the web services selection/composition problem. `http://dl.acm.org/citation.cfm?id=2980430`.

[479] Su Nguyen. A learning and optimizing system for order acceptance and scheduling. *The International Journal of Advanced Manufacturing Technology*, 86(5–8):2021–2036, 2016. Order acceptance and scheduling is an interesting scheduling problem when scheduling and acceptance decisions need to be handled simultaneously. The complexity of the problem causes difficulty for many solution methods. In this paper, we proposed a learning and optimizing system to deal with the order acceptance and scheduling problem with a single-machine and dependent setup times. The aim of this system is to combine the advantages of the hyper-heuristic for learning useful scheduling rules and the meta-heuristic for further refining the solutions from the obtained rules. The experiments show that the proposed system is very effective as compared to other heuristics proposed in the literature. The analyses also show the benefits of scheduling rules obtained by the hyper-heuristic, especially for large-scale problem instances. `http://link.springer.com/article/10.1007/s00170-015-8321-6`.

[480] Nomzamo Ntombela and Nelishia Pillay. Evolving construction heuristics for the symmetric travelling salesman problem. In *Proceedings of the Annual Conference of the South African Institute of Computer Scientists and Information Technologists*, page 30. ACM, 2016.

[481] Cecilia E Nugraheni and Luciana Abednego. Multi agent hyper-heuristics based framework for production scheduling problem. In *International Conference on Informatics and Computing (ICIC)*, pages 309–313. IEEE, 2016. This paper investigates the potential use of hyper-heuristics and multi agent approach for solution of the real single machine production scheduling problem. A framework consisting of six agents is proposed. The agents are Problem Agent, Trainer Agent, Training Dataset Agent, Heuristic Pool Agent, Algorithm Agent, Advisor Agent, and Solver Agent. Three Algorithm Agents are proposed to solve the problem, i.e. Genetic Programming Hyper-Heuristics (GPHH) agent, Genetic Algorithm Hyper-Heuristic (GAHH) agent, and Simulated Annealing Hyper-Heuristics (SAHH) agent. Experimental results show that the performance of GAHH is comparable with SAHH. While GPHH agent outperforms GAHH algorithm agent and SAHH algorithm agent, and also six other benchmark heuristics including MRT, SPT, LPT, EDD, LDD, and MON rules with respect to minimum tardiness and minimum flow time objectives. `http://ieeexplore.ieee.org/abstract/document/7905735/`.

[482] Cecilia E Nugraheni and Luciana Abednego. On the development of hyper heuristics based framework for scheduling problems in textile industry. *International Journal of Modeling and Optimization*, 6(5):272, 2016. Textile industry, which

is one of the most prominent industries in Indonesia, faces a problem caused by the condition of machine productions. This situation leads to a need of good machine scheduling system. Generally, production processes in textile industry belong to the flow shop scheduling problems (FSSP). Many approaches/heuristics have been proposed for solving FSSP. Two of them are Palmer's algorithm and Gupta's algorithm. This paper investigates a method, called genetic algorithm hyper-heuristic, for combining those heuristics in order to obtain some new better heuristics. This method is then implemented in a framework. `http://www.ijmo.org/index.php?m=content&c=index&a=show&catid=65&id=666`.

[483] Fidan Nuriyeva and Gözde Kizilateş. Gezgin satici problemi icin merkezden kenarlara hipersezgisel yontem. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 20:319–323, 2016. TURKISH: Bu makalede Gezgin Satici Problemi icin yeni bir hipersezgisel algoritma onerilmistir. Bu yontemde once N adet sehir icerisinden merkez sehir ve 4 uc sehir secilip, sonra ise merkez ile ikiser-ikiser uc sehirlerin orta noktalari belirlenerek merkez sehirden baslanarak bu 9 sehirden gecen bir devre olusturulmustur. Daha sonra "en kisa yol" ve "ekleme sezgiseli" algoritmalari kullanilarak bulunan devre tum sehirlerden gececek sekilde genisletilmistir. Onerilen algoritmalar ile kutuphane problemleri uzerinde hesaplama denemeleri yapilmis, elde edilen sonuclar "en yakin komsu" algoritmasindan elde edilen sonuclar ile karsilastirilmistir. Hesaplama denemeleri onerilen algoritmanin verimli oldugunu gostermektedir. `http://dergipark.ulakbim.gov.tr/sdufenbed/article/view/5000180342`.

[484] Berk Orbay, Refik Güllü, and Wolfgang Hörmann. A model selection framework for pricing options. *SSRN 2812392*, 2016. Empirical studies show that even the best performing option pricing models cannot sustain their performance for all contracts. It can also be added that each model can give the best price estimate for at least a set of contracts. Our aim is to detect which model (and parametrization) is the best price estimate for each individual contract and delta hedging. A model selection framework is proposed to achieve this aim. Both model selection and individual models are benchmarked with different error metrics and underlying assets. Results indicate that model selection is a good and consistent way of pricing option contracts. `http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2812392`.

[485] José Carlos Ortiz-Bayliss, Hugo Terashima-Marín, and Santiago Enrique Conant-Pablos. Combine and conquer: an evolutionary hyper-heuristic approach for solving constraint satisfaction problems. *Artificial Intelligence Review*, pages 1–23, 2016. Selection hyper-heuristics are a technology for optimization in which a high-level mechanism controls low-level heuristics, so as to be capable of solving a wide range of problem instances efficiently. Hyper-heuristics are used to generate a solution process rather than producing an immediate solution to a given problem. This process is a re-usable mechanism that can be applied both to seen and unseen problem instances. In this paper, we propose a selection hyper-heuristic process

with the intention to rise the level of generality and solve consistently well a wide range of constraint satisfaction problems. The hyper-heuristic technique is based on a messy genetic algorithm that generates high-level heuristics formed by rules (condition -¿ heuristic). The high-level heuristics produced are seen to be good at solving instances from certain parts of the parameterized space of problems, producing results using effort comparable to the best single heuristic per instance. This is beneficial, as the choice of best heuristic varies from instance to instance, so the high-level heuristics are definitely preferable to selecting any one low-level heuristic for all instances. The results confirm the robustness of the proposed approach and how high-level heuristics trained for some specific classes of instances can also be applied to unseen classes without significant lost of efficiency. This paper contributes to the understanding of heuristics and the way they can be used in a collaborative way to benefit from their combined strengths. `http://link.springer.com/article/10.1007/s10462-016-9466-x`.

[486] José Carlos Ortiz-Bayliss, Hugo Terashima-Marín, and Santiago Enrique Conant-Pablos. A neuro-evolutionary hyper-heuristic approach for constraint satisfaction problems. *Cognitive Computation*, 8(3):429–441, 2016. Constraint satisfaction problems represent an important topic of research due to their multiple applications in various areas of study. The most common way to solve this problem involves the use of heuristics that guide the search into promising areas of the space. In this article, we present a novel way to combine the strengths of distinct heuristics to produce solution methods that perform better than such heuristics on a wider range of instances. The methodology proposed produces neural networks that represent hyper-heuristics for variable ordering in constraint satisfaction problems. These neural networks are generated and trained by running a genetic algorithm that has the task of evolving the topology of the networks and some of their learning parameters. The results obtained suggest that the produced neural networks represent a feasible alternative for coding hyper-heuristics that control the use of different heuristics in such a way that the cost of the search is minimized. `http://link.springer.com/article/10.1007/s12559-015-9368-2`.

[487] Lucas Parada, Carlos Herrera, Mauricio Sepúlveda, and Víctor Parada. Evolution of new algorithms for the binary knapsack problem. *Natural Computing*, 15(1):181–193, 2016. Due to its NP-hard nature, it is still difficult to find an optimal solution for instances of the binary knapsack problem as small as 100 variables. In this paper, we developed a three-level hyper-heuristic framework to generate algorithms for the problem. From elementary components and multiple sets of problem instances, algorithms are generated. The best algorithms are selected to go through a second step process, where they are evaluated with problem instances that differ in size and difficulty. The problem instances are generated according to methods that are found in the literature. In all of the larger problem instances, the generated algorithms have less than 1 % error with respect to the optimal solution. Additionally, generated algorithms are effi-

cient, taking on average fractions of a second to find a solution for any instance, with a standard deviation of 1 s. In terms of structure, hyper-heuristic algorithms are compact in size compared with those in the literature, allowing an in-depth analysis of their structure and their presentation to the scientific world. `http://link.springer.com/article/10.1007/s11047-015-9483-8`.

[488] John Park, Yi Mei, Gang Chen, and Mengjie Zhang. Niching genetic programming based hyper-heuristic approach to dynamic job shop scheduling: An investigation into distance metrics. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion*, pages 109–110. ACM, 2016. This paper investigates the application of fitness sharing to a coevolutionary genetic programming based hyper-heuristic (GP-HH) approach to a dynamic job shop scheduling (DJSS) problem that evolves an ensemble of dispatching rules. Evolving ensembles using GP-HH for DJSS problem is a relatively unexplored area, and has been shown to outperform standard GP-HH procedures that evolve single rules. As a fitness sharing algorithm has not been applied to the specific GP-HH approach, we investigate four different phenotypic distance measures as part of a fitness sharing algorithm. The fitness sharing algorithm may potentially improve the diversity of the constituent members of the ensemble and improve the quality of the ensembles. The results show that the niched coevolutionary GP approaches evolve smaller sized rules than the base coevolutionary GP approaches, but have similar performances. `http://dl.acm.org/citation.cfm?id=2908985`.

[489] John Park, Yi Mei, Su Nguyen, Gang Chen, Mark Johnston, and Mengjie Zhang. Genetic programming based hyper-heuristics for dynamic job shop scheduling: Cooperative coevolutionary approaches. In *European Conference on Genetic Programming*, pages 115–132. Springer, 2016. Job shop scheduling (JSS) problems are optimisation problems that have been studied extensively due to their computational complexity and application in manufacturing systems. This paper focuses on a dynamic JSS problem to minimise the total weighted tardiness. In dynamic JSS, attributes of a job are only revealed after it arrives at the shop floor. Dispatching rule heuristics are prominent approaches to dynamic JSS problems, and Genetic Programming based Hyper-heuristic (GP-HH) approaches have been proposed to automatically generate effective dispatching rules for dynamic JSS problems. Research on static JSS problems shows that high quality ensembles of dispatching rules can be evolved by a GP-HH that uses cooperative coevolution. Therefore, we compare two coevolutionary GP approaches to evolve ensembles of dispatching rules for dynamic JSS problems. First, we adapt the Multilevel Genetic Programming (MLGP) approach, which has never been applied to JSS problems. Second, we extend an existing approach for a static JSS problem, called Ensemble Genetic Programming for Job Shop Scheduling (EGP-JSS), by adding "less-myopic" terminals that take job and machine attributes outside of the scope of the attributes commonly used in the literature. The results show that MLGP for JSS evolves ensembles that are significantly better than

single "less-myopic" rules evolved using GP with only little difference in computation time. In addition, the rules evolved using EGP-JSS perform better than the MLGP-JSS rules, but MLGP-JSS evolves rules significantly faster than EGP-JSS. `http://link.springer.com/chapter/10.1007/978-3-319-30668-1_8`.

[490] Hernan Peraza-Vázquez, Aidé M Torres-Huerta, and Abelardo Flores-Vela. Self-adaptive differential evolution hyper-heuristic with applications in process design. *Computación y Sistemas*, 20(2), 2016. The paper presents a differential evolution (DE)-based hyper-heuristic algorithm suitable for the optimization of mixed-integer non-linear programming (MINLP) problems. The hyper-heuristic framework includes self-adaptive parameters, an epsilon-constrained method for handling constraints, and 18 DE variants as low-level heuristics. Using the proposed approach, we solved a set of classical test problems on process synthesis and design and compared the results with those of several state-of-the-art evolutionary algorithms. To verify the consistency of the proposed approach, the above-mentioned comparison was made with respect to the percentage of convergences to the global optimum (NRC) and the average number of objective function evaluations (NFE) over several trials. Thus, we found that the proposed methodology significantly improves performance in terms of NRC and NFE. `http://www.cys.cic.ipn.mx/ojs/index.php/CyS/article/view/2334`.

[491] B. Perumal, RHaldar, and S. Rajkumar. Bin packing problems: comparative analysis of heuristic techniques for different dimensions. *International Journal Of Pharmacy & Technology*, 8(2):13305–13319, 2016.

[492] Nelishia Pillay. Evolving construction heuristics for the curriculum based university course timetabling problem. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 4437–4443. IEEE, 2016. In solving combinatorial optimization problems construction heuristics are generally used to create an initial solution which is improved using optimization techniques like genetic algorithms. These construction heuristics are usually derived by humans and this is usually quite a time consuming task. Furthermore, according to the no free lunch theorem different heuristics are effective for different problem instances. Ideally we would like to derive construction heuristics for different problem instances or classes of problems. However, due to the time it takes to manually derive construction heuristics it is generally not feasible to induce problem instance specific heuristics. The research presented in the paper forms part of the initiative aimed at automating the derivation of construction heuristics. Genetic programming is used to evolve construction heuristics for the curriculum based university course timetabling (CB-CTT) problem. Each heuristic is a hierarchical combination of problem characteristics and a period selection heuristic. The paper firstly presents and analyses the performance of known construction heuristics for CB-CTT. The analysis has shown that different heuristics are effective for different problem instances. The paper then presents the genetic programming approach for the automated induction of construction heuristics for the CB-CTT problem and

evaluates the approach on the ITC 2007 problem instances for the second international timetabling competition. The evolved heuristics performed better than the known construction heuristics, producing timetables with lower soft constraint costs. http://ieeexplore.ieee.org/abstract/document/7744354/.

[493] Nelishia Pillay. A generative hyper-heuristic for deriving heuristics for classical artificial intelligence problems. In *Advances in Nature and Biologically Inspired Computing*, pages 337–346. Springer, 2016. A recent direction of hyper-heuristics is the automated design of intelligent systems with the aim of reducing the man hours needed to implement such systems. One of the design decisions that often has to be made when developing intelligent systems is the low-level construction heuristic to use. These are usually rules of thumb derived based on human intuition. Generally a heuristic is derived for a particular domain. However, according to the no free lunch theorem different low-level heuristics will be effective for different problem instances. Deriving low-level heuristics for problem instances will be time consuming and hence we examine the automatic induction of low-level heuristics using hyper-heuristics. We investigate this for classical artificial intelligence. At the inception of the field of artificial intelligence search methods to solve problems were generally uninformed, such as the depth first and breadth first searches, and did not take any domain specific knowledge into consideration. As the field matured domain specific knowledge in the form of heuristics were used to guide the search, thereby reducing the search space. Search methods using heuristics to guide the search became known as informed searches, such as the best-first search, hill-climbing and the A* algorithm. Heuristics used by these searches are problem specific rules of thumb created by humans. This study investigates the use of a generative hyper-heuristic to derive these heuristics. The hyper-heuristic employs genetic programming to evolve the heuristics. The approach was tested on two classical artificial intelligence problems, namely, the 8-puzzle problem and Towers of Hanoi. The genetic programming system was able to evolve heuristics that produced solutions for 20 8-puzzle problems and 5 instances of Towers of Hanoi. Furthermore, the heuristics induced were able to produce solutions to the instances of the 8-puzzle problem which could not be solved using the A* algorithm with the number of tiles out of place heuristic and at least one admissible heuristic was evolved for all 25 problems. http://link.springer.com/chapter/10.1007/978-3-319-27400-3_30.

[494] Nelishia Pillay. A review of hyper-heuristics for educational timetabling. *Annals of Operations Research*, 239(1):3–38, 2016. Educational timetabling problems, namely, university examination timetabling, university course timetabling and school timetabling, are combinatorial optimization problems requiring the allocation of resources so as to satisfy a specified set of constraints. Hyper-heuristics have been successfully applied to a variety of combinatorial optimization problems. This is a rapidly growing field which aims at providing generalized solutions to combinatorial optimization problems by exploring a heuris-

tic space instead of a solution space. From the research conducted thus far it is evident that hyper-heuristics are effective at solving educational timetabling problems and have the potential of advancing this field by providing a generalized solution to educational timetabling as a whole. Given this, the paper provides an overview and critical analysis of hyper-heuristics for educational timetabling and proposes future research directions, focusing on using hyper-heuristics to provide a generalized solution to educational timetabling. http://link.springer.com/article/10.1007/s10479-014-1688-1.

[495] Aaron S Pope, Daniel R Tauritz, and Alexander D Kent. Evolving random graph generators: A case for increased algorithmic primitive granularity. In *IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–8. IEEE, 2016. Random graph generation techniques provide an invaluable tool for studying graph related concepts. Unfortunately, traditional random graph models tend to produce artificial representations of real-world phenomenon. Manually developing customized random graph models for every application would require an unreasonable amount of time and effort. In this work, a platform is developed to automate the production of random graph generators that are tailored to specific applications. Elements of existing random graph generation techniques are used to create a set of graph-based primitive operations. A hyper-heuristic approach is employed that uses genetic programming to automatically construct random graph generators from this set of operations. This work improves upon similar research by increasing the level of algorithmic sophistication possible with evolved solutions, allowing more accurate modeling of subtle graph characteristics. The versatility of this approach is tested against existing methods and experimental results demonstrate the potential to outperform conventional and state of the art techniques for specific applications. http://ieeexplore.ieee.org/abstract/document/7849929/.

[496] Chao Qian, Ke Tang, and Zhi-Hua Zhou. Selection hyper-heuristics can provably be helpful in evolutionary multi-objective optimization. In *International Conference on Parallel Problem Solving from Nature (PPSN)*, pages 835–846. Springer, 2016. Selection hyper-heuristics are automated methodologies for selecting existing low-level heuristics to solve hard computational problems. They have been found very useful for evolutionary algorithms when solving both single and multi-objective real-world optimization problems. Previous work mainly focuses on empirical study, while theoretical study, particularly in multi-objective optimization, is largely insufficient. In this paper, we use three main components of multi-objective evolutionary algorithms (selection mechanisms, mutation operators, acceptance strategies) as low-level heuristics, respectively, and prove that using heuristic selection (i.e., mixing low-level heuristics) can be exponentially faster than using only one low-level heuristic. Our result provides theoretical support for multi-objective selection hyper-heuristics, and might be

helpful for designing efficient heuristic selection methods in practice. https://link.springer.com/chapter/10.1007/978-3-319-45823-6_78.

[497] Patricia Ryser-Welch, Julian F Miller, Jerry Swan, and Martin A Trefzer. Iterative cartesian genetic programming: Creating general algorithms for solving travelling salesman problems. In *European Conference on Genetic Programming*, pages 294–310. Springer, 2016. Evolutionary algorithms have been widely used to optimise or design search algorithms, however, very few have considered evolving iterative algorithms. In this paper, we introduce a novel extension to Cartesian Genetic Programming that allows it to encode iterative algorithms. We apply this technique to the Traveling Salesman Problem to produce human-readable solvers which can be then be independently implemented. Our experimental results demonstrate that the evolved solvers scale well to much larger TSP instances than those used for training. http://link.springer.com/chapter/10.1007/978-3-319-30668-1_19.

[498] Wells Lucas Santo. Hyperheuristics for artificial general intelligence and a general tree search algorithm, 2016.

[499] Eduardo Segredo, Eduardo Lalla-Ruiz, Emma Hart, Ben Paechter, and Stefan Voss. Hybridisation of evolutionary algorithms through hyper-heuristics for global continuous optimisation. In *Proceedings of the 10th Learning and Intelligent OptimizatioN Conference (LION)*, volume 10079 of *LNCS*, pages 296–305, Naples, Italy, 2016. Choosing the correct algorithm to solve a problem still remains an issue 40 years after the Algorithm Selection Problem was first posed. Here we propose a hyper-heuristic which can apply one of two meta-heuristics at the current stage of the search. A scoring function is used to select the most appropriate algorithm based on an estimate of the improvement that might be made by applying each algorithm. We use a differential evolution algorithm and a genetic algorithm as the two meta-heuristics and assess performance on a suite of 18 functions provided by the Generalization-based Contest in Global Optimization (genopt). The experimental evaluation shows that the hybridisation is able to provide an improvement with respect to the results obtained by both the differential evolution scheme and the genetic algorithm when they are executed independently. In addition, the high performance of our hybrid approach allowed two out of the three prizes available at genopt to be obtained. http://link.springer.com/chapter/10.1007/978-3-319-50349-3_25.

[500] Liang Shen. Evolutionary algorithms with mixed strategy, 2016. During the last several decades, many kinds of population based Evolutionary Algorithms have been developed and considerable work has been devoted to computational methods which are inspired by biological evolution and natural selection, such as Evolutionary Programming and Clonal Selection Algorithm. The objective of these algorithms is not only to find suitable adjustments to the current population and hence the solution, but also to perform the process efficiently. However, a pa-

rameter setting that was optimal at the beginning of the algorithm may become unsuitable during the evolutionary process. Thus, it is preferable to automatically modify the control parameters during the runtime process. The approach required could have a bias on the distribution towards appropriate directions of the search space, thereby maintaining sufficient diversity among individuals in order to enable further ability of evolution. This thesis has offered an initial approach to developing this idea. The work starts from a clear understanding of the literature that is of direct relevance to the aforementioned motivations. The development of this approach has been built upon the basis of the fundamental and generic concepts of evolutionary algorithms. The work has exploited and benefited from a range of representative evolutionary computational mechanisms. In particular, essential issues in evolutionary algorithms such as parameter control, including the general aspects of parameter tuning and typical means for implementing parameter control have been investigated. Both the hyperheuristic algorithm and the memetic algorithm have set up a comparative work for the present development. This work has developed several novel techniques that contribute towards the advancement of evolutionary computation and optimization. One such novel approach is to construct a mixed strategy based on the concept of local fitness landscape. It exploits the concepts of fitness landscape and local fitness landscape. Both theoretical description and experimental investigation of this local fitness landscape-based mixed strategy have been provided, and systematic comparisons with alternative approaches carried out. Another contribution of this thesis is the innovative application of mixed strategy. This is facilitated by encompassing two mutation operators into the mixed strategy, which are borrowed from classical differential evolution techniques. Such an improved method has been shown to be simple and easy for implementation. The work has been utilised to deal with the problem of protein folding in bioinformatics. It is demonstrated that the proposed algorithm possesses an appropriate balance between exploration and exploitation. The use of this improved algorithm is less likely to fall into local optimal, entailing a faster and better convergence in resolving challenging realistic application problems. `http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.693292`.

[501] Fernando Silva, Luis Correia, and Anders Lyhne Christensen. Online hyper-evolution of controllers in multirobot systems. In *Self-Adaptive and Self-Organizing Systems (SASO), 2016 IEEE 10th International Conference on*, pages 11–20. IEEE, 2016. In this paper, we introduce online hyper-evolution (OHE) to accelerate and increase the performance of online evolution of robotic controllers. Robots executing OHE use the different sources of feedback information traditionally associated with controller evaluation to find effective evolutionary algorithms and controllers online during task execution. We present two approaches: OHE-fitness, which uses the fitness score of controllers as the criterion to select promising algorithms over time, and OHE-diversity, which relies on the behavioural diversity of controllers for algorithm selection. Both OHE-fitness and OHE-diversity are distributed across groups of robots that evolve

in parallel. We assess the performance of OHE-fitness and of OHE-diversity in two foraging tasks with differing complexity, and in five configurations of a dynamic phototaxis task with varying evolutionary pressures. Results show that our OHE approaches: (i) outperform multiple state-of-the-art algorithms as they facilitate controllers with superior performance and faster evolution of solutions, and (ii) can increase effectiveness at different stages of evolution by combining the benefits of multiple algorithms over time. Overall, our study shows that OHE is an effective new paradigm to the synthesis of controllers for robots. `http://ieeexplore.ieee.org/abstract/document/7774382/`.

[502] Kevin Sim and Emma Hart. A combined generative and selective hyper-heuristic for the vehicle routing problem. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference*, pages 1093–1100. ACM, 2016. Hyper-heuristic methods for solving vehicle routing problems (VRP) have proved promising on a range of data. The vast majority of approaches apply selective hyper-heuristic methods that iteratively choose appropriate heuristics from a fixed set of pre-defined low-level heuristics to either build or perturb a candidate solution. We propose a novel hyper-heuristic called GP-MHH that operates in two stages. The first stage uses a novel Genetic Programming (GP) approach to evolve high quality constructive heuristics; these can be used with any existing method that relies on a candidate solution(s) as its starting point. In the second stage, a perturbative hyper-heuristic is applied to candidate solutions created from the new heuristics. The new constructive heuristics are shown to outperform existing low-level heuristics. When combined with a naive perturbative hyper-heuristic they provide results which are both competitive with known optimal values and outperform a recent method that also designs new heuristics on some standard benchmarks. Finally, we provide results on a set of rich VRPs, showing the generality of the approach. `http://dl.acm.org/citation.cfm?id=2908942`.

[503] Dominik Sisejkovic. Evolution of scheduling heuristics for the resource constrained scheduling problem, 2016. In this thesis the problem of scheduling tasks is addressed by means of genetic programming with focus on the resource constrained scheduling problem as a mathematical model. As part of a very large body of research called machine learning, genetic programming is used to learn and evolve suitable scheduling heuristics to be applied efficiently to generate feasible schedules for a larger set of problem instances taking performance and solution reusability into account. `http://bib.irb.hr/datoteka/845388.Final_0036466662_54.pdf`.

[504] Evgenii Sopov. A selection hyper-heuristic with online learning for control of genetic algorithm ensemble. *International Journal of Hybrid Intelligent Systems*, 13(2):125–135, 2016. Evolutionary algorithms (EAs), in general, and genetic algorithms (GAs), in particular, are popular and efficient search metaheuristics, which have been applied for many complex optimization problems. At the same time, the performance of EAs depends on appropriate choice of the EA's struc-

ture and parameters. One of the ways to automate the EA design is to apply a hyper-heuristic approach. The hyper-heuristic is a high-level approach that can select and apply an appropriate low-level heuristic at each decision point. In this paper, we present a selection hyper-heuristic with online learning that is used to design and adaptively control an ensemble of many different genetic algorithms. The proposed approach combines concepts of the island model and cooperative and competitive coevolutions. The general method and some particular applications are discussed. The experimental results for a wide range of optimization problems are presented. The experiments show that the proposed approach outperforms its component metaheuristics on average. It also outperforms some state-of-the-art techniques. The main advantage of the approach is that it does not require the participation of the human-expert, because it operates in an automated, self-configuring way. `http://content.iospress.com/articles/international-journal-of-hybrid-intelligent-systems/his230`.

[505] Jorge A Soria-Alcaraz, Ender Özcan, Jerry Swan, Graham Kendall, and Martin Carpio. Iterated local search using an add and delete hyper-heuristic for university course timetabling. *Applied Soft Computing*, 40:581–593, 2016. Hyper-heuristics are (meta-)heuristics that operate at a higher level to choose or generate a set of low-level (meta-)heuristics in an attempt of solve difficult optimization problems. Iterated local search (ILS) is a well-known approach for discrete optimization, combining perturbation and hill-climbing within an iterative framework. In this study, we introduce an ILS approach, strengthened by a hyper-heuristic which generates heuristics based on a fixed number of add and delete operations. The performance of the proposed hyper-heuristic is tested across two different problem domains using real world benchmark of course timetabling instances from the second International Timetabling Competition Tracks 2 and 3. The results show that mixing add and delete operations within an ILS framework yields an effective hyper-heuristic approach. `http://www.sciencedirect.com/science/article/pii/S1568494615007760`.

[506] Alejandro Sosa-Ascencio, Gabriela Ochoa, Hugo Terashima-Marin, and Santiago Enrique Conant-Pablos. Grammar-based generation of variable-selection heuristics for constraint satisfaction problems. *Genetic Programming and Evolvable Machines*, 17(2):119–144, 2016. We propose a grammar-based genetic programming framework that generates variable-selection heuristics for solving constraint satisfaction problems. This approach can be considered as a generation hyper-heuristic. A grammar to express heuristics is extracted from successful human-designed variable-selection heuristics. The search is performed on the derivation sequences of this grammar using a strongly typed genetic programming framework. The approach brings two innovations to grammar-based hyper-heuristics in this domain: the incorporation of if-then-else rules to the function set, and the implementation of overloaded functions capable of handling different input dimensionality. Moreover, the heuristic search space is ex-

plored using not only evolutionary search, but also two alternative simpler strategies, namely, iterated local search and parallel hill climbing. We tested our approach on synthetic and real-world instances. The newly generated heuristics have an improved performance when compared against human-designed heuristics. Our results suggest that the constrained search space imposed by the proposed grammar is the main factor in the generation of good heuristics. However, to generate more general heuristics, the composition of the training set and the search methodology played an important role. We found that increasing the variability of the training set improved the generality of the evolved heuristics, and the evolutionary search strategy produced slightly better results. `https://link.springer.com/article/10.1007/s10710-015-9249-1`.

[507] Alejandro Sosa-Ascencio, Hugo Terashima-Marin, José C Ortiz-Bayliss, and Santiago E Conant-Pablos. Grammar-based selection hyper-heuristics for solving irregular bin packing problems. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO) Companion*, pages 111–112. ACM, 2016. This article describes a grammar-based hyper-heuristic model for selecting heuristics to solve the two-dimensional bin packing problem (2D-PBB) with irregular pieces and regular objects. We propose to use a genetic programming approach to generate rules for selecting one suitable heuristic according to the features that characterize the problem state. The experiments confirm the idea that the results produced by the proposed approach are able to rival those obtained by some heuristics described in the literature. `http://dl.acm.org/citation.cfm?id=2908970`.

[508] Andrei Strickler, Jackson A Prado Lima, Silvia R Vergilio, and Aurora TR Pozo. Deriving products for variability test of feature models with a hyper-heuristic approach. *Applied Soft Computing*, 49:1232–1242, 2016. Deriving products from a Feature Model (FM) for testing Software Product Lines (SPLs) is a hard task. It is important to select a minimum number of products but, at the same time, to consider the coverage of testing criteria such as pairwise, among other factors. To solve such problems Multi-Objective Evolutionary Algorithms (MOEAs) have been successfully applied. However, to design a solution for this and other software engineering problems can be very difficult, because it is necessary to choose among different search operators and parameters. Hyper-heuristics can help in this task, and have raised interest in the Search-Based Software Engineering (SBSE) field. Considering the growing adoption of SPL in the industry and crescent demand for SPL testing approaches, this paper introduces a hyper-heuristic approach to automatically derive products to variability testing of SPLs. The approach works with MOEAs and two selection methods, random and based on FRR-MAB (Fitness Rate Rank based Multi-Armed Bandit). It was evaluated with real FMs and the results show that the proposed approach outperforms the traditional algorithms used

in the literature, and that both selection methods present similar performance. http://www.sciencedirect.com/science/article/pii/S1568494616303994.

[509] Takwa Tlili, Hiba Yahyaoui, and Saoussen Krichen. An iterated variable neighborhood descent hyperheuristic for the quadratic multiple knapsack problem. In *Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing 2015*, pages 245–251. Springer, 2016. The Quadratic Multiple Knapsack Problem (QMKP) is a variant of the well-known NP-hard knapsack problem that assign profits not only to individual items but also to pairs of items. QMKP aims to maximize a quadratic objective function subject to a linear capacity constraint. In this paper, we focus on proposing a hyper-heuristic approach based in the iterated variable neighborhood descent algorithm for solving the QMKP. Numerical investigations based on well-known benchmark instances are conducted. The results clearly demonstrate the good performance of the proposed algorithm in solving the QMKP. http://link.springer.com/chapter/10.1007/978-3-319-23509-7_17.

[510] Otakar Trunda and Robert Brunetto. Fitness landscape analysis of hyper-heuristic transforms for the vertex cover problem. In *the 16th ITAT Conference Information Technologies - Applications and Theory - the 4th international workshop on Computational Intelligence and Data Mining*, volume 1649. 2016. Hyper-heuristics have recently proved efficient in several areas of combinatorial search and optimization, especially scheduling. The basic idea of hyper-heuristics is based on searching for search-strategy. Instead of traversing the solution-space, the hyper-heuristic traverses the space of algorithms to find or construct an algorithm best suited for the given problem instance. The observed efficiency of hyper-heuristics is not yet fully explained on the theoretical level. The leading hypothesis suggests that the fitness landscape of the algorithm-space is more favorable to local search techniques than the original space. In this paper, we analyse properties of fitness landscapes of the problem of minimal vertex cover. We focus on properties that are related to efficiency of meta-heuristics such as locality and fitness-distance correlation. We compare properties of the original space and the algorithm space trying to verify the hypothesis explaining hyper-heuristics performance. Our analysis shows that the hyper-heuristic space really has some more favorable properties than the original space. http://ceur-ws.org/Vol-1649/179.pdf.

[511] Enrique Urra, Claudio Cubillos, Daniel Cabrera-Paniagua, and Gaston Lefranc. Automatic parameter configuration for an elite solution hyper-heuristic applied to the multidimensional knapsack problem. In *2016 6th International Conference on Computers Communications and Control (ICCCC)*, pages 213–219. IEEE, 2016. Hyper-heuristics are methods for problem solving that decouple the search mechanisms from the domain features, providing a reusable approach across different problems. Even when they make a difference regarding metaheuristics under this perspective, proposals in literature commonly expose parameters for controlling

their behavior such as metaheuristics does. Several internal mechanisms for automatically adapt those parameters can be implemented, but they require extra design effort and their validation no necessarily is generalizable to multiple domains. Such effort is prohibitive for their practical application on decision-support systems. Rather than implementing internal adapting mechanisms, the exploration of automatic parameter configuration through external tools is performed in this work. A new hyper-heuristic implementation based on a elite set of solutions was implemented and automatically configured with SMAC (Sequential Model-Based Algorithm Configuration), a state-of-art tool for automatic parameter configuration. Experiments with and without automated configuration are performed over the Multidimensional Knapsack Problem (MKP). Comparative results demonstrate the effectiveness of the tool for improving the algorithm performance. Additionally, results provided insights that configurations applied over subsets of instances could provide better improvements in the algorithm performance. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7496763.

[512] Enrique Urra, Claudio Cubillos, and Daniel Cabrera Paniagua. A hyper-heuristic based on an adapter layer for transportation combinatorial problems. *IEEE Latin America Transactions*, 14(6):2764–2769, 2016. Hyper-heuristics are optimization techniques for solving hard combinatorial problems. Their main feature is that their design involves an important decoupling of the search components from the problem domain ones. This allows them to extend their applicability to different problem domains without major redesign, unlike traditional methods such as metaheuristics. In this work, a hyper-heuristic is evaluated for a transportation problem. The implemented hyper-heuristic uses a greedy operator, and it implements an adapter layer that would allow it to be used in other similar problems. Experimental results shows balanced solution quality and CPU time performance, regarding other metaheuristics in literature. http://ieeexplore.ieee.org/abstract/document/7555251/.

[513] Alexander A Visheratin, Mikhail Melnik, and Denis Nasonov. Automatic workflow scheduling tuning for distributed processing systems. *Procedia Computer Science*, 101:388–397, 2016. Modern scientific applications are composed of various methods, techniques and models to solve complicated problems. Such composite applications commonly are represented as workflows. Workflow scheduling is a well-known optimization problem, for which there is a great amount of solutions. Most of the algorithms contain parameters, which affect the result of a method. Thus, for the efficient scheduling it is important to tune parameters of the algorithms. Moreover, performance models, which are used for the estimation of obtained solutions, are crucial parts of workflow scheduling. In this work we present a combined approach for automatic parameters tuning and performance models construction in the background of the WMS lifecycle. Algorithms tuning is provided by hyper-heuristic genetic algorithm, whereas models construction is performed via symbolic regression methods. Developed

algorithm was evaluated using CLAVIRE platform and is applicable for any distributed computing systems to optimize the execution of composite applications. http://www.sciencedirect.com/science/article/pii/S1877050916327144.

[514] David J Walker and Ed Keedwell. Multi-objective optimisation with a sequence-based selection hyper-heuristic. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO) Companion*, pages 81–82. ACM, 2016. Hyper-heuristics have been used widely to solve optimisation problems, often single-objective and discrete in nature. Herein, we extend a recently-proposed selection hyper-heuristic to the multi-objective domain and with it optimise continuous problems. The MOSSHH algorithm operates as a hidden Markov model, using transition probabilities to determine which low-level heuristic or sequence of heuristics should be applied next. By incorporating dominance into the transition probability update rule, and an elite archive of solutions, MOSSHH generates solutions to multi-objective problems that are competitive with bespoke multi-objective algorithms. When applied to test problems, it is able to find good approximations to the true Pareto front, and yields information about the type of low-level heuristics that it uses to solve the problem. http://dl.acm.org/citation.cfm?id=2909016.

[515] DJ Walker, E Keedwell, and D Savic. Multi-objective optimisation of a water distribution network with a sequence-based selection hyper-heuristic. the 14th International Conference on Computing and Control for the Water Industry, 2016. Multi-objective hyper-heuristics are fast becoming an efficient way of optimising complex problems. The water distribution network design problem is an example of such a problem, and this work employs a recent hyper-heuristic that generates sequences of low-level heuristics to solve the multi-objective water distribution design problem. The results presented are comparable to those generated by state-of-the-art metaheuristics, as well as a single-objective version of the algorithm from the literature. The information revealed from analysing the sequences generated to solve the problem reveal important information about the nature of the problem space that is not available from the metaheuristics, and the entire Pareto front can be explored in a single run as opposed to the multiple runs needed with the original single-objective algorithm. https://ore.exeter.ac.uk/repository/handle/10871/24217.

[516] DJ Walker and EK Keedwell. Towards many-objective optimisation with hyper-heuristics: Identifying good heuristics with indicators. In *Proceedings of the 14th International Conference on Parallel Problem Solving from Nature (PPSN)*, LNCS. Springer, 2016. The use of hyper-heuristics is increasing in the multi-objective optimisation domain, and the next logical advance in such methods is to use them in the solution of many-objective problems. Such problems comprise four or more objectives and are known to present a significant challenge to standard dominance-based evolutionary algorithms. We in- corporate three comparison operators as alternatives to dominance and investigate their potential to

optimise many-objective problems with a hyper-heuristic from the literature. We discover that the best results are obtained using either the favour relation or hypervolume, but conclude that changing the comparison operator alone will not allow for the generation of estimated Pareto fronts that are both close to and fully cover the true Pareto front. https://ore.exeter.ac.uk/repository/handle/10871/22312.

[517] Tingxi Wen, Huirong Wang, Ming-Fa Hsieh, Lingwei Xie, Daoyuan Wang, Weizhen Luo, and Huailin Dong. An online chronic diseases consulting system: A hyper heuristic algorithm using random and greedy strategy for complex scheduling problems. *Journal of Medical Imaging and Health Informatics*, 6(1):233–239, 2016. This study attempts to develop an online chronic diseases consulting system by using a customized heuristic algorithm for complex scheduling of medical experts to consult patients in a major hospital. Methods: We proved this problem is NP-complete problem and used heuristic algorithms to solve it. When the data set is small, most existing algorithms can reach the optimal solution using linear programming. However, traditional greedy algorithm and off-trap strategy fail to give reasonable results in large data set. In this study, we used the algorithm with appropriate oblivion strategy for efficient convergence and optimal solution. Results: To compare different algorithms, synthetic data sets of different size and a year's clinical data set provided by the hospital were used. The outcome of our algorithm was closely matched to the optimal solution from linear programming for sixty synthetic data sets. In addition, our algorithm is more efficient than that of linear programming when clinical data set was used. Meanwhile we found that the outcome is an approximate optimal solution and the algorithm is able to save a lot of cost for the hospital in practice. Conclusions: In this paper, we analyzed the results obtained from the algorithms of data set of different size and found that the algorithm can handle large volumes of data efficiently and reduce cost of hospitals. http://www.ingentaconnect.com/content/asp/jmihi/2016/00000006/00000001/art00031.

[518] John R Woodward, Colin G Johnson, and Alexander EI Brownlee. Connecting automatic parameter tuning, genetic programming as a hyper-heuristic, and genetic improvement programming. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion*, pages 1357–1358. ACM, 2016. Automatically designing algorithms has long been a dream of computer scientists. Early attempts which generate computer programs from scratch, have failed to meet this goal. However, in recent years there have been a number of different technologies with an alternative goal of taking existing programs and attempting to improving them.These methods form a range of methodologies, from the limited ability to change (for example only the parameters) to the complete ability to change the whole program. These include; automatic parameter tuning (APT), using GP as a hyper-heuristic (GPHH), and GI, which we will now briefly review. Part of research is building links between existing work, and

the aim of this paper is to bring together these currently separate approaches. http://dl.acm.org/citation.cfm?id=2931728.

[519] Xiuli Wu, Pietro Consoli, Leandro Minku, Gabriela Ochoa, and Xin Yao. An evolutionary hyper-heuristic for the software project scheduling problem. In Julia Handl, Emma Hart, Peter R. Lewis, Manuel Lopez-Ibanez, Gabriela Ochoa, and Ben Paechter, editors, *14th International Conference on Parallel Problem Solving from Nature (PPSN)*, volume 9921 of *LNCS*. Springer, Edinburgh, UK, 2016. Software project scheduling plays an important role in reducing the cost and duration of software projects. It is an NP-hard combinatorial optimization problem that has been addressed based on single and multi-objective algorithms. However, such algorithms have always used fixed genetic operators, and it is unclear which operators would be more appropriate across the search process. In this paper, we propose an evolutionary hyper-heuristic to solve the software project scheduling problem. Our novelties include the following: (1) this is the first work to adopt an evolutionary hyper-heuristic for the software project scheduling problem; (2) this is the first work for adaptive selection of both crossover and mutation operators; (3) we design different credit assignment methods for mutation and crossover; and (4) we use a sliding multi-armed bandit strategy to adaptively choose both crossover and mutation operators. The experimental results show that the proposed algorithm can solve the software project scheduling problem effectively. http://link.springer.com/chapter/10.1007/978-3-319-45823-6_4.

[520] Fan Xue and Geoffrey QP Shen. CMA–VNS2: An efficient hyper-heuristic algorithm for combinatorial black-box optimization. Technical report, 2016. The CMA-VNS2 (Covariance Matrix Adaptation Variable Neighborhood Search, version 2016) solver is a hyper-heuristic entry for the second Combinatorial Black-Box Optimization Competition (CBBOC 2016). https://www.researchgate.net/profile/Fan_Xue2/publication/305995366_CMA-VNS2_An_efficient_hyper-heuristic_algorithm_for_combinatorial_black-box_optimization/links/57a96e1d08ae0107eee7202d.pdf.

[521] Peng-Yeng Yin, Kuo-Hsien Chuang, and Gwo-Jen Hwang. Developing a context-aware ubiquitous learning system based on a hyper-heuristic approach by taking real-world constraints into account. *Universal Access in the Information Society*, 15(3):315–328, 2016. In a context-aware ubiquitous learning environment, learning systems are aware of students' locations and learning status in the real world via the use of sensing technologies which provide personalized guidance or support. In such a learning environment that guides students to observe and learn from real-world targets, various physical world constraints need to be taken into account when planning learning paths for individuals. In this study, an optimization problem is formulated by taking the relevance of real-world learning targets and the environmental constraints into account when determining personalized learning paths in the real world to maximize students' learning efficacy. Moreover, a hyper-heuristic approach is proposed to efficiently find quality learning paths

for individual students. To evaluate the performance of the proposed approach, the teachers' feedback was collected and analyzed based on the learning activities conducted in an elementary school natural science course; in addition, the performances of the proposed algorithm and other approaches were compared based on a set of test data. `http://dx.doi.org/10.1007/s10209-014-0390-z`.

[522] Peng-Yeng Yin, Sin-Ru Lyu, and Ya-Lan Chuang. Cooperative coevolutionary approach for integrated vehicle routing and scheduling using cross-dock buffering. *Engineering Applications of Artificial Intelligence*, 52:40–53, 2016. Cross-docking technology transships products from incoming vehicles directly to outgoing vehicles by using the warehouse as a temporary buffer instead of a place for storage and retrieval. The supply chain management (SCM) with cross-docks is both effective and efficient where no storage is facilitated at the cross-dock and the order-picking is replaced by fast consolidation. However, cross-docking involves interrelated operations such as vehicle routing and vehicle scheduling which require proper planning and synchronization. Traditional cross-docking methods treat the operations separately and overlook the potential advantage of cooperative planning. This paper proposes a bi-objective mathematical formulation for the cross-docking with the noted new challenges. As the addressed problem is highly constrained, we develop a cooperative coevolution approach consisting of Hyper-heuristics and Hybrid-heuristics for achieving continuous improvement in alternating objectives. The performance of our approach is illustrated with real geographical data and is compared with existing models. Statistical tests based on intensive simulations, including the convergence 95% confidence analysis and the worst-case analysis, are conducted to provide reliable performance guarantee. `http://www.sciencedirect.com/science/article/pii/S095219761630015X`.

[523] Kamal Z Zamli, Basem Y Alkazemi, and Graham Kendall. A tabu search hyper-heuristic strategy for t-way test suite generation. *Applied Soft Computing*, 44:57–74, 2016. This paper proposes a novel hybrid t-way test generation strategy (where t indicates interaction strength), called High Level Hyper-Heuristic (HHH). HHH adopts Tabu Search as its high level meta-heuristic and leverages on the strength of four low level meta-heuristics, comprising of Teaching Learning based Optimization, Global Neighborhood Algorithm, Particle Swarm Optimization, and Cuckoo Search Algorithm. HHH is able to capitalize on the strengths and limit the deficiencies of each individual algorithm in a collective and synergistic manner. Unlike existing hyper-heuristics, HHH relies on three defined operators, based on improvement, intensification and diversification, to adaptively select the most suitable meta-heuristic at any particular time. Our results are promising as HHH manages to outperform existing t-way strategies on many of the benchmarks. `http://www.sciencedirect.com/science/article/pii/S1568494616301302`.

[524] Ju Zhao, Yong-Wu Zhou, and M.I.M. Wahab. Joint optimization models for shelf display and inventory control considering the impact of spatial relationship on demand. *European Journal of Operational Research*, 255(3):797–808, 2016.

This research investigates joint optimization models for shelf space allocation and display location with multi-item replenishment. The demand for each item is considered to be dependent not only on its and other items' allocated shelf space and displayed locations, but also on spatial relationships between items. Joint optimization models are developed for two different scenarios: (a) each item is replenished individually; and (b) multiple items are replenished jointly. A multi-stage simulated annealing (SA) based hyper-heuristic algorithm is proposed to solve both joint optimization models. These models are then evaluated numerically for different problem sizes. The results demonstrate that: (1) the proposed SA based hyper-heuristic algorithm is robust and efficient for both joint optimization models; and (2) the model for the joint replenishment policy leads to a higher profit than that of the model for the individual replenishment policy. Hence, the joint optimization model with joint replenishment policy will be helpful for retailers making decisions about shelf display arrangement and inventory control for multiple items. `http://www.sciencedirect.com/science/article/pii/S0377221716303459`.

[525] Jinghui Zhong and Wentong Cai. A hyper-heuristic framework for agent-based crowd modeling and simulation. In *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems*, pages 1331–1332. International Foundation for Autonomous Agents and Multiagent Systems, 2016. This paper proposes a hyper-heuristic crowd modeling framework to generate realistic crowd dynamics that can match video data. In the proposed framework, motions of agents are driven by a high-level heuristic (HH) which intelligently selects way-points for agents based on the current situations. Three low-level heuristics are defined and used as building blocks of the HH. Based on the newly defined building blocks and fitness evaluation function, the Self-Learning Gene Expression Programming (SL-GEP) is utilized to automatically evolve a suitable HH. To test its effectiveness, the proposed framework is applied to learn suitable HHs based on real video data. The best HH learned is then applied to generate crowd simulations and the simulation results demonstrate that the proposed method is effective to generate realistic crowd dynamics. `http://dl.acm.org/citation.cfm?id=2937145`.

[526] Steven Adriaensen, Gabriela Ochoa, and Ann Nowé. A benchmark set extension and comparative study for the HyFlex framework. In *IEEE Congress on Evolutionary Computation (CEC)*, pages 784–791. IEEE, 2015. In this work we conduct a comparative study of several publicly available, state-of-the-art hyper-heuristics for HyFlex in order to assess their generality across domains. To this purpose we extend the HyFlex benchmark set with 3 new problem domains: The 0-1 Knap Sack, Quadratic Assignment and Max-Cut Problem. To our knowledge, this is the first public extension of the benchmark since the CHeSC 2011 competition. In addition, this is the first study testing the Fair-Share Iterated Local Search (FS-ILS) method, designed in prior research, using a semi-automated

design approach, on new unseen problem domains. We show that, of the methods compared, Adap-HH (CHeSC 2011 winner) clearly perfoms the most consistently, overall. In addition, we identify a weakness of, as well as a way to further simplify the FS-ILS method. Finally, we found that, overall, the state-of-the-art methods compared, generalized much better than a naive baseline. http://ieeexplore.ieee.org/document/7256971/.

[527] Fardin Ahmadizar, Khabat Soltanian, Fardin AkhlaghianTab, and Ioannis Tsoulos. Artificial neural network development by means of a novel combination of grammatical evolution and genetic algorithm. *Engineering Applications of Artificial Intelligence*, 39:1–13, 2015.

[528] Leena N. Ahmed, Ender Ozcan, and Ahmed Kheiri. Solving high school timetabling problems worldwide using selection hyper-heuristics. *Expert Systems with Applications*, 42(13):5463–5471, 2015. High school timetabling is one of those recurring NP-hard real-world combinatorial optimisation problems that has to be dealt with by many educational institutions periodically, and so has been of interest to practitioners and researchers. Solving a high school timetabling problem requires scheduling of resources and events into time slots subject to a set of constraints. Recently, an international competition, referred to as ITC 2011 was organised to determine the state-of-the-art approach for high school timetabling. The problem instances, obtained from eight different countries across the world used in this competition became a benchmark for further research in the field. Selection hyper-heuristics are general-purpose improvement methodologies that control/mix a given set of low level heuristics during the search process. In this study, we evaluate the performance of a range of selection hyper-heuristics combining different reusable components for high school timetabling. The empirical results show the success of the approach which embeds an adaptive great-deluge move acceptance method on the ITC 2011 benchmark instances. This selection hyper-heuristic ranks the second among the previously proposed approaches including the ones competed at ITC 2011. http://www.sciencedirect.com/science/article/pii/S0957417415001670.

[529] Rajni Aron, Inderveer Chana, and Ajith Abraham. A hyper-heuristic approach for resource provisioning-based scheduling in grid environment. *The Journal of Supercomputing*, 71(4), 2015. Grid computing being immensely based on the concept of resource sharing has always been closely associated with a lot many challenges. Growth of Resource provisioning-based scheduling in large-scale distributed environments like Grid computing brings in new requirement challenges that are not being considered in traditional distributed computing environments. Resources being the backbone of the system, their efficient management plays quite an important role in its execution environment. Many constraints such as heterogeneity and dynamic nature of resources need to be taken care as steps toward managing Grid resources efficiently. The most important challenge in Grids being the job-resource mapping as per the users' requirement in the most secure way. The

mapping of the jobs to appropriate resources for execution of the applications in Grid computing is found to be an NP-complete problem. Novel algorithm is required to schedule the jobs on the resources to provide reduced execution time, increased security and reliability. The main aim of this paper is to present an efficient strategy for secure scheduling of jobs on appropriate resources. A novel particle swarm optimization-based hyper-heuristic resource scheduling algorithm has been designed and used to schedule jobs effectively on available resources without violating any of the security norms. Performance of the proposed algorithm has also been evaluated through the GridSim toolkit. We have compared our resource scheduling algorithm with existing common heuristic-based scheduling algorithms experimentally. The results thus obtained have shown a better performance by our algorithm than the existing algorithms, in terms of giving more reduced cost and makespan of user's application being submitted to the Grids. `http://link.springer.com/article/10.1007/s11227-014-1373-9`.

[530] Shahriar Asta, Daniel Karapetyan, Ahmed Kheiri, Ender Özcan, and Andrew J Parkes. Combining monte-carlo and hyper-heuristic methods for the multi-mode resource-constrained multi-project scheduling problem. *arXiv preprint arXiv:1511.04387*, 2015. Multi-mode resource and precedence-constrained project scheduling is a well-known challenging real-world optimisation problem. An important variant of the problem requires scheduling of activities for multiple projects considering availability of local and global resources while respecting a range of constraints. This problem has been addressed by a competition, and associated set of benchmark instances, as a part of the MISTA 2013 conference. A critical aspect of the benchmarks is that the primary objective is to minimise the sum of the project completion times, with the usual makespan minimisation as a secondary objective. We observe that this leads to an expected different overall structure of good solutions and discuss the effects this has on the algorithm design. This paper presents the resulting competition winning approach; it is a carefully designed hybrid of Monte-Carlo tree search, novel neighbourhood moves, memetic algorithms, and hyper-heuristic methods. The implementation is also engineered to increase the speed with which iterations are performed, and to exploit the computing power of multicore machines. The resulting information-sharing multi-component algorithm significantly outperformed the other approaches during the competition, producing the best solution for 17 out of the 20 test instances and performing the best in around 90% of all the trials. `http://arxiv.org/abs/1511.04387`.

[531] Shahriar Asta and Ender Ozcan. A tensor-based selection hyper-heuristic for cross-domain heuristic search. *Information Sciences*, 299:412–432, 2015. Hyper-heuristics have emerged as automated high level search methodologies that manage a set of low level heuristics for solving computationally hard problems. A generic selection hyper-heuristic combines heuristic selection and move acceptance methods under an iterative single point-based search framework. At each

step, the solution in hand is modified after applying a selected heuristic and a decision is made whether the new solution is accepted or not. In this study, we represent the trail of a hyper-heuristic as a third order tensor. Factorization of such a tensor reveals the latent relationships between the low level heuristics and the hyper-heuristic itself. The proposed learning approach partitions the set of low level heuristics into two subsets where heuristics in each subset are associated with a separate move acceptance method. Then a multi-stage hyper-heuristic is formed and while solving a given problem instance, heuristics are allowed to operate only in conjunction with the associated acceptance method at each stage. To the best of our knowledge, this is the first time tensor analysis of the space of heuristics is used as a data science approach to improve the performance of a hyper-heuristic in the prescribed manner. The empirical results across six different problem domains from a benchmark indeed indicate the success of the proposed approach. `http://www.sciencedirect.com/science/article/pii/S0020025514011591`.

[532] Rodrigo C. Barros, Marcio P. Basgalupp, and Andre C.P.L.F. de Carvalho. Investigating fitness functions for a hyper-heuristic evolutionary algorithm in the context of balanced and imbalanced data classification. *Genetic Programming and Evolvable Machines*, 16(3), 2015. In this paper, we analyse in detail the impact of different strategies to be used as fitness function during the evolutionary cycle of a hyper-heuristic evolutionary algorithm that automatically designs decision-tree induction algorithms (HEAD-DT). We divide the experimental scheme into two distinct scenarios: (1) evolving a decision-tree induction algorithm from multiple balanced data sets; and (2) evolving a decision-tree induction algorithm from multiple imbalanced data sets. In each of these scenarios, we analyse the difference in performance of well-known classification performance measures such as accuracy, F-Measure, AUC, recall, and also a lesser-known criterion, namely the relative accuracy improvement. In addition, we analyse different schemes of aggregation, such as simple average, median, and harmonic mean. Finally, we verify whether the best-performing fitness functions are capable of providing HEAD-DT with algorithms more effective than traditional decision-tree induction algorithms like C4.5, CART, and REPTree. Experimental results indicate that HEAD-DT is a good option for generating algorithms tailored to (im)balanced data, since it outperforms state-of-the-art decision-tree induction algorithms with statistical significance. `http://link.springer.com/article/10.1007%2Fs10710-014-9235-z#`.

[533] Marcio Basgalupp and Rodrigo Barrosand Vili Podgorelec. Evolving decision-tree induction algorithms with a multi-objective hyper-heuristic. In *the 30th Annual ACM Symposium on Applied Computing (SAC)*, Salamanca, Spain, 2015.

[534] Muhammed Beyaz, Tansel Dokeroglu, and Ahmet Cosar. Robust hyper-heuristic algorithms for the offline oriented/non-oriented 2d bin packing problems. *Applied Soft Computing*, 36:236–245, 2015. The offline 2D bin packing problem (2DBPP) is an NP-hard combinatorial optimization problem in which objects

with various width and length sizes are packed into minimized number of 2D bins. Various versions of this well-known industrial engineering problem can be faced frequently. Several heuristics have been proposed for the solution of 2DBPP but it has not been possible to find the exact solutions for large problem instances. Next fit, first fit, best fit, unified tabu search, genetic and memetic algorithms are some of the state-of-the-art methods successfully applied to this important problem. In this study, we propose a set of novel hyper-heuristic algorithms that select/combine the state-of-the-art heuristics and local search techniques for minimizing the number of 2D bins. The proposed algorithms introduce new crossover and mutation operators for the selection of the heuristics. Through the results of exhaustive experiments on a set of offline 2DBPP benchmark problem instances, we conclude that the proposed algorithms are robust with their ability to obtain high percentage of the optimal solutions. `http://www.sciencedirect.com/science/article/pii/S1568494615004561`.

[535] Jürgen Branke, Torsten Hildebrandt, and Bernd Scholz-Reiter. Hyper-heuristic evolution of dispatching rules: A comparison of rule representations. *Evolutionary Computation*, 23(2):249–277, 2015. Dispatching rules are frequently used for real-time, online scheduling in complex manufacturing systems. Design of such rules is usually done by experts in a time consuming trial-and-error process. Recently, evolutionary algorithms have been proposed to automate the design process. There are several possibilities to represent rules for this hyper-heuristic search. Because the representation determines the search neighborhood and the complexity of the rules that can be evolved, a suitable choice of representation is key for a successful evolutionary algorithm. In this paper we empirically compare three different representations, both numeric and symbolic, for automated rule design: A linear combination of attributes, a representation based on artificial neural networks, and a tree representation. Using appropriate evolutionary algorithms (CMA-ES for the neural network and linear representations, genetic programming for the tree representation), we empirically investigate the suitability of each representation in a dynamic stochastic job shop scenario. We also examine the robustness of the evolved dispatching rules against variations in the underlying job shop scenario, and visualize what the rules do, in order to get an intuitive understanding of their inner workings. Results indicate that the tree representation using an improved version of genetic programming gives the best results if many candidate rules can be evaluated, closely followed by the neural network representation that already leads to good results for small to moderate computational budgets. The linear representation is found to be competitive only for extremely small computational budgets. `http://www.mitpressjournals.org/doi/abs/10.1162/EVCO_a_00131`.

[536] Jose-Matias Cutillas-Lozano and Domingo Gimenez Canovas. Modelling parallel metaheuristics and hyperheuristics for auto-tuning. *Annals of Multicore and GPU Programming*, 3(1):32–54, 2015. This paper studies the auto-tuning of par-

allel metaheuristics and hyperheuristics. The modelling of the shared-memory scheme is considered for both types of algorithms, and a first study of message-passing metaheuristic schemes is introduced. A theoretical model of the execution time of a parametrized metaheuristic scheme is empirically adapted for a particular metaheuristic through experimentation. The parallelization of the shared-memory scheme is achieved through the independent parallelization of the basic functions in the metaheuristic scheme. The model is used to decide at running time the number of threads to obtain a reduced execution time. The number of threads is different for the different basic functions in the scheme, and depends on the problem to be solved, the metaheuristic or hyperheuristic scheme, the implementation of the basic functions and the computational system where the problem is solved. The auto-tuning methodology for shared-memory parametrized metaheuristic schemes can in turn be applied to shared-memory hyperheuristics developed on top of them. In the case of the message-passing scheme, an island model implemented with the master-slave scheme is used, and new metaheuristic-parallelism parameters representing the migration frequency, the size of the migration and the number of processes are introduced. The applicability of the proposal is shown with a minimization of electricity consumption in exploitation of wells problem and with the problem of obtaining satisfactory metaheuristics for that problem. Experimental results with these two problems show that satisfactory execution times can be achieved in metaheuristics with auto-tuning techniques based on theoretical-empirical models of the execution time. http://revistaseug.ugr.es/index.php/amgp/article/view/2970.

[537] Kassem Danach, Jomana Al-Haj Hassan, Wissam Khalil, and Shahin Gelareh. Routing heterogeneous mobile hospital with different patients priorities: Hyper-heuristic approach. In *the 5th International Conference on Digital Information and Communication Technology and its Applications (DICTAP)*, Beirut, Lebanon, 2015. http://ieeexplore.ieee.org/xpl/login.jsp?tp=andarnumber=7113189.

[538] Kassem Danach, Wissam Khalil, and Shahin Gelareh. Multiple strings planing problem in maritime service network: Hyper-heuristic approach. In *the 3rd International Conference on Technological Advances in Electrical*, Electronics and Computer Engineering (TAEECE), Beirut, Lebanon, 2015. http://ieeexplore.ieee.org/xpl/login.jsp?tp=andarnumber=7113605.

[539] Bei Dong, Licheng Jiao, and Jianshe Wu. Graph-based hybrid hyper-heuristic channel scheduling algorithm in multicell networks. *Transactions on Emerging Telecommunications Technologies*, 2015. In this paper, we consider the scheduling problem that minimises the number of required channel without violation of traffic demand by considering the intercell interference and intracell interference simultaneously. This concerned problem is proved to be a non-deterministic polynomial-time hard problem. We propose a graph-based hyper-heuristic method composed of two level heuristics: the high level heuristic and a set of low level

heuristics. A sequence of graph-based low level heuristics is generated to guide the channel assignment process, and then searching in the heuristic space by the high level heuristic obtains the best channel scheduling scheme. The performance is tested on 20 benchmark problems, which show that the proposed graph-based hyper-heuristic algorithm is effective and outperforms the existing method. `http://onlinelibrary.wiley.com/doi/10.1002/ett.2923/pdf`.

[540] John H. Drake, Ender Ozcan, and Edmund Burke. *Genetic and Evolutionary Computing, Advances in Intelligent Systems and Computing*, chapter Modified Choice Function Heuristic Selection for the Multidimensional Knapsack Problem. 2015. Hyper-heuristics are a class of high-level search methods used to solve computationally difficult problems, which operate on a search space of low-level heuristics rather than solutions directly. Previous work has shown that selection hyper-heuristics are able to solve many combinatorial optimisation problems, including the multidimensional 0-1 knapsack problem (MKP). The traditional framework for iterative selection hyper-heuristics relies on two key components, a heuristic selection method and a move acceptance criterion. Existing work has shown that a hyper-heuristic using Modified Choice Function heuristic selection can be effective at solving problems in multiple problem domains. Late Acceptance Strategy is a hill climbing metaheuristic strategy often used as a move acceptance criteria in selection hyper-heuristics. This work compares a Modified Choice Function - Late Acceptance Strategy hyper-heuristic to an existing selection hyper-heuristic method from the literature which has previously performed well on standard MKP benchmarks. `http://link.springer.com/chapter/10.1007%2F978-3-319-12286-1_23`.

[541] John H. Drake, Ender Ozcan, and Edmund K. Burke. A comparison of crossover control mechanisms within single-point selection hyper-heuristics using hyflex. In *the IEEE Congress on Evolutionary Computation (CEC)*, Sendai, Japan, 2015.

[542] John H. Drake, Ender Ozcan, and Edmund K. Burke. A modified choice function hyper-heuristic controlling unary and binary operators. In *the IEEE Congress on Evolutionary Computation (CEC)*, Sendai, Japan, 2015. Hyper-heuristics are a class of high-level search methodologies which operate on a search space of low-level heuristics or components, rather than on solutions directly. Traditional iterative selection hyper-heuristics rely on two key components, a heuristic selection method and a move acceptance criterion. Choice Function heuristic selection scores heuristics based on a combination of three measures, selecting the heuristic with the highest score. Modified Choice Function heuristic selection is a variant of the Choice Function which emphasises intensification over diversification within the heuristic search process. Previous work has shown that improved results are possible in some problem domains when using Modified Choice Function heuristic selection over the classic Choice Function, however in most of these cases crossover low-level heuristics (operators) are omitted. In this paper, we introduce crossover low-level heuristics into a Modified Choice Function selection hyper-heuristic and

present results over six problem domains. It is observed that although on average there is an increase in performance when using crossover low-level heuristics, the benefit of using crossover can vary on a per-domain or per-instance basis. http://www.cs.nott.ac.uk/~jqd/files/CEC2015-CF-AM.pdf.

[543] Anas Elhag and Ender Ozcan. A grouping hyper-heuristic framework: Application on graph colouring. *Expert Systems with Applications*, 42(13), 2015. Grouping problems are hard to solve combinatorial optimisation problems which require partitioning of objects into a minimum number of subsets while a given objective is simultaneously optimised. Selection hyper-heuristics are high level general purpose search methodologies that operate on a space formed by a set of low level heuristics rather than solutions. Most of the recently proposed selection hyper-heuristics are iterative and make use of two key methods which are employed successively; heuristic selection and move acceptance. In this study, we present a novel generic selection hyper-heuristic framework containing a fixed set of reusable grouping low level heuristics and an unconventional move acceptance mechanism for solving grouping problems. This framework deals with one solution at a time at any given decision point during the search process. Also, a set of high quality solutions, capturing the trade-off between the number of groups and the additional objective for the given grouping problem, is maintained. The move acceptance mechanism embeds a local search approach which is capable of progressing improvements on those trade-off solutions. The performance of different selection hyper-heuristics with various components under the proposed framework is investigated on graph colouring as a representative grouping problem. Then, the top performing hyper-heuristics are applied to a benchmark of examination timetabling instances. The empirical results indicate the effectiveness and generality of the proposed framework enabling grouping hyper-heuristics to achieve high quality solutions in both domains. http://www.sciencedirect.com/science/article/pii/S0957417415000536.

[544] Alexandre Silvestre Ferreira, Aurora Pozo, and Richard Aderbal Gonçalves. An ant colony based hyper-heuristic approach for the set covering problem. 2015. The Set Covering Problem (SCP) is a NP-hard combinatorial optimization problem that is challenging for meta-heuristic algorithms. In the optimization literature, several approaches using meta-heuristics have been developed to tackle the SCP and the quality of the results provided by these approaches highly depends on customized operators that demands high effort from researchers and practitioners. In order to alleviate the complexity of designing metaheuristics, a methodology called hyper-heuristic has emerged as a possible solution. A hyper-heuristic is capable of dynamically selecting simple low-level heuristics accordingly to their performance, alleviating the design complexity of the problem solver and obtaining satisfactory results at the same time. In a previous study, we proposed a hyper-heuristic approach based on Ant Colony Optimization (ACO-HH) for solving the SCP. This paper extends our previous ef-

forts, presenting better results and a deeper analysis of ACO-HH parameters and behavior, specially about the selection of low-level heuristics. The paper also presents a comparison with an ACO meta-heuristic customized for the SCP. `http://gredos.usal.es/jspui/handle/10366/127627`.

[545] Richard A Gonçalves, Josiel N Kuk, Carolina P Almeida, and Sandra M Venske. Decomposition based multiobjective hyper heuristic with differential evolution. In *Computational Collective Intelligence*, pages 129–138. Springer, 2015. Hyper-Heuristics is a high-level methodology for selection or generation of heuristics for solving complex problems. Despite their success, there is a lack of multi-objective hyper-heuristics. Our approach, named MOEA/D-HH SWSW , is a multi-objective selection hyper-heuristic that expands the MOEA/D framework. MOEA/D decomposes a multiobjective optimization problem into a number of subproblems, where each subproblem is handled by an agent in a collaborative manner. MOEA/D-HH SWSW uses an adaptive choice function with sliding window proposed in this work to determine the low level heuristic (Differential Evolution mutation strategy) that should be applied by each agent during a MOEA/D execution. MOEA/D-HH SWSW was tested in a well established set of 10 instances from the CEC 2009 MOEA Competition. MOEA/D-HH SWSW was favourably compared with state-of-the-art multi-objective optimization algorithms. `https://link.springer.com/chapter/10.1007/978-3-319-24306-1_13`.

[546] Richard A. Goncalves, Josiel N. Kuk, Carolina P. Almeida, and Sandra M. Venske. Moea/d-hh: A hyper-heuristic for multi-objective problems. In *the 8th International Conference on Evolutionary Multi-Criterion Optimization (EMO)*, Guimaraes, Portugal, 2015. Hyper-Heuristics is a high-level methodology for selection or automatic generation of heuristics for solving complex problems. Despite the hyper-heuristics success, there is still only a few multi-objective hyper-heuristics. Our approach, MOEA/D-HH, is a multi-objective selection hyper-heuristic that expands the MOEA/D framework. It uses an innovative adaptive choice function proposed in this work to determine the low level heuristic (Differential Evolution mutation strategy) that should be applied to each individual during a MOEA/D execution. We tested MOEA/D-HH in a well established set of 10 instances from the CEC 2009 MOEA Competition. MOEA/D-HH is compared with some important multi-objective optimization algorithms and the resultsobtained are promising. `http://link.springer.com/chapter/10.1007/978-3-319-15934-8_7`.

[547] Jacomine Grobler. The heterogeneous meta-hyper-heuristic: from low level heuristics to low level meta-heuristics, 2015. Meta-heuristics have already been used extensively for the successful solution of a wide range of real world problems. A few industrial engineering examples include inventory optimization, production scheduling, and vehicle routing, all areas which have a significant impact on the economic success of society. Unfortunately, it is not always easy to predict which

meta-heuristic from the multitude of algorithms available, will be best to address a specific problem. Furthermore, many algorithm development options exist with regards to operator selection and parameter setting. Within this context, the idea of working towards a higher level of automation in algorithm design was born. Hyper-heuristics promote the design of more generally applicable search methodologies and tend to focus on performing relatively well on a large set of different types of problems. This thesis develops a heterogeneous meta-hyper-heuristic algorithm (HMHH) for single-objective unconstrained continuous optimization problems. The algorithm development process focused on investigating the use of meta-heuristics as low level heuristics in a hyper-heuristic context. This strategy is in stark contrast to the problem-specific low level heuristics traditionally employed in a hyper-heuristic framework. Alternative low level meta-heuristics, entity-to-algorithm allocation strategies, and strategies for incorporating local search into the HMHH algorithm were evaluated to obtain an algorithm which performs well against both its constituent low level meta-heuristics and four state-of-the-art multi-method algorithms. Finally, the impact of diversity management on the HMHH algorithm was investigated. Hyper-heuristics lend themselves to two types of diversity management, namely solution space diversity (SSD) management and heuristic space diversity (HSD) management. The concept of heuristic space diversity was introduced and a quantitative metric was defined to measure heuristic space diversity. An empirical evaluation of various solution space diversity and heuristic space diversity intervention mechanisms showed that the systematic control of heuristic space diversity has a significant impact on hyper-heuristic performance. https://repository.up.ac.za/handle/2263/43789.

[548] Jacomine Grobler, Andries P. Engelbrecht, Graham Kendall, and V.S.S. Yadavalli. Heuristic space diversity control for improved meta-hyper-heuristic performance. *Information Sciences*, 300:49–62, 2015. This paper expands on the concept of heuristic space diversity and investigates various strategies for the management of heuristic space diversity within the context of a meta-hyper-heuristic algorithm in search of greater performance benefits. Evaluation of various strategies on a diverse set of floating-point benchmark problems shows that heuristic space diversity has a significant impact on hyper-heuristic performance. An exponentially increasing strategy (EIHH) obtained the best results. The value of a priori information about constituent algorithm performance on the benchmark set in question was also evaluated. Finally, EIHH demonstrated good performance when compared to a popular population based algorithm portfolio algorithm and the best performing constituent algorithm. https://www.sciencedirect.com/science/article/pii/S0020025514010822.

[549] Giovani Guizzo, Gian Mauricio Fritsche, Silvia Regina Vergilio, and Aurora Trinidad Ramirez Pozo. A hyper-heuristic for the multi-objective integration and test order problem. In *the 17th Annual Conference on Genetic and Evolutionary Computation (GECCO)*, Madrid, Spain, 2015. Multi-objective evolutionary

algorithms (MOEAs) have been efficiently applied to Search-Based Software Engineering (SBSE) problems. However, skilled software engineers waste significant effort designing such algorithms for a particular problem, adapting them, selecting operators and configuring parameters. Hyper-heuristics can help in these tasks by dynamically selecting or creating heuristics. Despite of such advantages, we observe a lack of works regarding this subject in the SBSE field. Considering this fact, this work introduces HITO, a Hyper-heuristic for the Integration and Test Order Problem. It includes a set of well-defined steps and is based on two selection functions (Choice Function and Multi-armed Bandit) to select the best low-level heuristic (combination of mutation and crossover operators) in each mating. To perform the selection, a quality measure is proposed to assess the performance of low-level heuristics throughout the evolutionary process. HITO was implemented using NSGA-II and evaluated to solve the integration and test order problem in seven systems. The introduced hyper-heuristic obtained the best results for all systems, when compared to a traditional algorithm. `http://dl.acm.org/citation.cfm?id=2754725`.

[550] Giovani Guizzo, Silvia R Vergilio, and Aurora TR Pozo. Evaluating a multi-objective hyper-heuristic for the integration and test order problem. In *2015 Brazilian Conference on Intelligent Systems (BRACIS)*, pages 1–6. IEEE, 2015. Multi-objective evolutionary algorithms (MOEAs) have been successfully applied for solving different software engineering problems. However, adapting and configuring these algorithms for a specific problem can demand significant effort from software engineers. Therefore, to help in this task, a hyper-heuristic, named HITO (Hyper-heuristic for the Integration and Test Order problem) was proposed to adaptively select search operators during the optimization process. HITO was successfully applied using NSGA-II for solving the integration and test order problem. HITO can use two hyper-heuristic selection methods: Choice Function and Multi-armed Bandit. However, a hypotheses behind this study is that HITO does not depend of NSGA-II and can be used with other MOEAs. To this aim, this paper presents results from evaluation experiments comparing the performance of HITO using two different MOEAs: NSGA-II and SPEA2. The results show that HITO is able to outperform both MOEAs. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7423906`.

[551] Aldy Gunawan, Mustafa Misir, and Hoong Chuin Lau. Designing a portfolio of parameter configurations for online algorithm selection. In *the 29th AAAI Conference on Artificial Intelligence: Workshop on Algorithm Configuration (AlgoConf)*, Austin/Texas, USA, 2015. Algorithm portfolios seek to determine an effective set of algorithms that can be used within an algorithm selection framework to solve problems. A limited number of these portfolio studies focus on generating different versions of a target algorithm using different parameter configurations. In this paper, we employ a Design of Experiments (DOE) approach to determine a promising range of values for each parameter of an

algorithm. These ranges are further processed to determine a portfolio of parameter configurations, which would be used within two online Algorithm Selection approaches for solving different instances of a given combinatorial optimization problem effectively. We apply our approach on a Simulated Annealing-Tabu Search (SA-TS) hybrid algorithm for solving the Quadratic Assignment Problem (QAP) as well as an Iterated Local Search (ILS) on the Travelling Salesman Problem (TSP). We also generate a portfolio of parameter configurations using best-of-breed parameter tuning approaches directly for the comparison purpose. Experimental results show that our approach lead to improvements over best-of-breed parameter tuning approaches. `https://mustafamisir.github.io/papers/gunawan2015designing-AAAI-AlgoConf.pdf`.

[552] Sean Harris, Travis Bueter, and Daniel R Tauritz. A comparison of genetic programming variants for hyper-heuristics. In *Proceedings of the 17th Annual Conference Companion on Genetic and Evolutionary Computation (GECCO)*, pages 1043–1050. ACM, 2015. General-purpose optimization algorithms are often not well suited for real-world scenarios where many instances of the same problem class need to be repeatedly and efficiently solved. Hyper-heuristics automate the design of algorithms for a particular scenario, making them a good match for real-world problem solving. For instance, hardware model checking induced Boolean Satisfiability Problem (SAT) instances have a very specific distribution which general SAT solvers are not necessarily well targeted to. Hyper-heuristics can automate the design of a SAT solver customized to a specific distribution of SAT instances. The first step in employing a hyper-heuristic is creating a set of algorithmic primitives appropriate for tackling a specific problem class. The second step is searching the associated algorithmic primitive space. Hyper-heuristics have typically employed Genetic Programming (GP) to execute the second step, but even in GP there are many alternatives. This paper reports on an investigation of the relationship between the choice of GP type and the performance obtained by a hyper-heuristic employing it. Results are presented on SAT, demonstrating the existence of problems for which there is a statistically significant performance differential between the use of different GP types. `http://dl.acm.org/citation.cfm?id=2768456`.

[553] Yue Jia. Hyperheuristic search for sbst. In *Proceedings of the Eighth International Workshop on Search-Based Software Testing*, pages 15–16. IEEE Press, 2015. This paper argues that incorporating hyperheuristic techniques into existing SBST approaches could help to increase their applicability and generality. We propose a general two layer selective hyperheuristic approach for SBST and provide an example of its use for Combinatorial Interaction Testing (CIT). `http://dl.acm.org/citation.cfm?id=2821343`.

[554] Yue Jia, Myra B Cohen, Mark Harman, and Justyna Petke. Learning combinatorial interaction test generation strategies using hyperheuristic search. In *Proceedings of the 37th International Conference on Software Engineering-Volume*

1, pages 540–550. IEEE, 2015. The surge of search based software engineering research has been hampered by the need to develop customized search algorithms for different classes of the same problem. For instance, two decades of bespoke Combinatorial Interaction Testing (CIT) algorithm development, our exemplar problem, has left software engineers with a bewildering choice of CIT techniques, each specialized for a particular task. This paper proposes the use of a single hyperheuristic algorithm that learns search strategies across a broad range of problem instances, providing a single generalist approach. We have developed a Hyperheuristic algorithm for CIT, and report experiments that show that our algorithm competes with known best solutions across constrained and unconstrained problems: For all 26 real-world subjects, it equals or outperforms the best result previously reported in the literature. We also present evidence that our algorithm's strong generic performance results from its unsupervised learning. Hyperheuristic search is thus a promising way to relocate CIT design intelligence from human to machine. `http://dl.acm.org/citation.cfm?id=2818821`.

[555] Olacir R. Castro Jr. and Aurora Pozo. Using hyper-heuristic to select leader and archiving methods for many-objective problems. In *the 8th International Conference on Evolutionary Multi-Criterion Optimization (EMO)*, Guimaraes, Portugal, 2015. `http://link.springer.com/chapter/10.1007/978-3-319-15934-8_8`.

[556] Ahmed Kheiri and Ed Keedwell. A sequence-based selection hyper-heuristic utilising a hidden markov model. In *the 17th Annual Conference on Genetic and Evolutionary Computation (GECCO)*, Madrid, Spain, 2015. Selection hyper-heuristics are optimisation methods that operate at the level above traditional (meta-)heuristics. Their task is to evaluate low level heuristics and determine which of these to apply at a given point in the optimisation process. Traditionally this has been accomplished through the evaluation of individual or paired heuristics. In this work, we propose a hidden Markov model based method to analyse the performance of, and construct, longer sequences of low level heuristics to solve difficult problems. The proposed method is tested on the well known hyper-heuristic benchmark problems within the CHeSC 2011 competition and compared with a large number of algorithms in this domain. The empirical results show that the proposed hyper-heuristic is able to outperform the current best-in-class hyper-heuristic on these problems with minimal parameter tuning and so points the way to a new field of sequence-based selection hyper-heuristics. `http://dl.acm.org/citation.cfm?id=2754766`.

[557] Ahmed Kheiri, Edward Keedwell, Michael J Gibson, and Dragan Savic. Sequence analysis-based hyper-heuristics for water distribution network optimisation. *Procedia Engineering*, 119:1269–1277, 2015. Hyper-heuristics operate at the level above traditional (meta-)heuristics that 'optimise the optimiser'. These algorithms can combine low level heuristics to create bespoke algorithms for particular classes of problems. The lowlevel heuristics can be mutation operators or hill climbing algorithms and can include industry expertise. This paper inves-

tigates the use of a new hyper-heuristic basedon sequence analysis in the biosciences, to develop new optimisers that can outperform conventional evolutionary approaches. It demonstrates that the new algorithms develop high quality solutions on benchmark water distribution network optimisation problems efficiently, and can yield important information about the problem search space. http://www.sciencedirect.com/science/article/pii/S1877705815026636.

[558] Yu Lei, Maoguo Gong, Licheng Jiao, and Yi Zuo. A memetic algorithm based on hyper-heuristics for examination timetabling problems. *International Journal of Intelligent Computing and Cybernetics*, 8(2), 2015. Purpose - The examination timetabling problem is an NP-hard problem. A large number of approaches for this problem are developed to find more appropriate search strategies. Hyper-heuristic is a kind of representative methods. In hyper-heuristic, the high-level search is executed to construct heuristic lists by traditional methods (such as Tabu search, variable neighborhoods and so on). The purpose of this paper is to apply the evolutionary strategy instead of traditional methods for high-level search to improve the capability of global search. Design/methodology/approach - This paper combines hyper-heuristic with evolutionary strategy to solve examination timetabling problems. First, four graph coloring heuristics are employed to construct heuristic lists. Within the evolutionary algorithm framework, the iterative initialization is utilized to improve the number of feasible solutions in the population; meanwhile, the crossover and mutation operators are applied to find potential heuristic lists in the heuristic space (high-level search). At last, two local search methods are combined to optimize the feasible solutions in the solution space (low-level search). Findings - Experimental results demonstrate that the proposed approach obtains competitive results and outperforms the compared approaches on some benchmark instances. Originality/value - The contribution of this paper is the development of a framework which combines evolutionary algorithm and hyper-heuristic for examination timetabling problems. http://www.emeraldinsight.com/doi/abs/10.1108/IJICC-02-2015-0005.

[559] Dongni Li, Miao Li, Xianwen Meng, and Yunna Tian. A hyperheuristic approach for intercell scheduling with single processing machines and batch processing machines. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 45(2), 2015. Intercell transfers in cellular manufacturing systems disrupt the philosophy of creating independent cells, but are essential for enterprises to reduce production costs. The problem of intercell scheduling with single processing machines and batch processing machines is considered in this paper, which involves an assignment subproblem, a sequencing subproblem, and a batch formation subproblem. An ant colony optimization (ACO)-based hyperheuristic (ABH) is developed in this paper, searching assignment rules for parts, sequencing rules for single processing machines, and batch formation rules for batch processing machines, simultaneously, and then using the obtained combinatorial rules to generate scheduling solutions. Computational re-

sults show that ABH is an effective and significantly efficient approach to provide near-optimum solutions even when CPLEX shows poor performance, and as compared to genetic algorithm that is widely used in hyperheuristics, ABH has better performance with respect to the problem addressed in this paper. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6871417`.

[560] Hong Li, Ying Wang, Shi Li, and Sujian Li. A column generation based hyper-heuristic to the bus driver scheduling problem. *Discrete Dynamics in Nature and Society*, 2015, 2015. `http://dx.doi.org/10.1155/2015/638104`.

[561] Jiawei Li and Graham Kendall. A hyper-heuristic methodology to generate adaptive strategies for games. *IEEE Transactions on Computational Intelligence and AI in Games*, 2015. Hyperheuristics have been successfully applied in solving a variety of computational search problems. In this paper, we investigate a hyperheuristic methodology to generate adaptive strategies for games. Based on a set of low-level heuristics (or strategies), a hyperheuristic game player can generate strategies which adapt to both the behavior of the co-players and the game dynamics. By using a simple heuristic selection mechanism, a number of existing heuristics for specialized games can be integrated into an automated game player. As examples, we develop hyperheuristic game players for three games: iterated prisoner's dilemma, repeated Goofspiel and the competitive traveling salesmen problem. The results demonstrate that a hyperheuristic game player outperforms the low-level heuristics, when used individually in game playing and it can generate adaptive strategies even if the low-level heuristics are deterministic. This methodology provides an efficient way to develop new strategies for games based on existing strategies. `http://ieeexplore.ieee.org/abstract/document/7017583/`.

[562] Nuno Lourenço, Francisco B Pereira, and Ernesto Costa. The optimization ability of evolved strategies. In *Portuguese Conference on Artificial Intelligence*, pages 226–237. Springer, 2015.

[563] Nuno António Marques Lourenço. Enhancing grammar-based approaches for the automatic design of algorithms, 2015. Evolutionary Algorithms (EA) are stochastic computational methods loosely inspired by the principles of natural selection and genetics. They have been successfully used to solve complex problems in the domains of learning, design and optimization. When using an EA practitioners have to define its main components such as the variation operators, the selection and replacement mechanisms. The performance of an EA can be greatly enhanced if the components are tailored to the specific situation being addressed. These modifications are usually done manually and require a reasonable degree of expertise. In order to ease the use of EAs some researchers have developed methods to automatically design this type of algorithms. Usually, these methods rely on an (meta-) algorithm that combine components and parameters, in order to learn the one that is most suited for the problem being addressed. The area

of Hyper-Heuristics (HH) emerges in this context focusing on the development of efficient meta-algorithms. Genetic Programming (GP), specifically the grammar based variants, are commonly used as HH. In this work, we study and analyze the conditions in which Grammatical Evolution (GE) can be enhanced to automatically design EAs. The main contributions can be divided in three aspects. Firstly, we propose an HH framework that relies on GE as the search algorithm. The proposed framework is divided in two complementary phases: Learning and Validation. In Learning the GE engine is used to combine low level components that are specified in a Context Free Grammar. In the second phase, Validation, the best algorithms learned are selected to be applied to scenarios different from the learning, in order to evaluate their generalization capacity. Secondly we study the impact that the learning conditions have in the final structure of the algorithms that are being learned. Moreover, we analyze the relationship between the quality exhibited by the algorithms during learning and their effective optimization ability when used in unseen scenarios. In concrete we analyze if the best strategies discover in learning still have the same good behavior in validation. Our final contribution addresses some of the limitations exhibited by Grammatical Evolution. The result is a novel representation with an enhanced performance. https://estudogeral.sib.uc.pt/jspui/handle/10316/29450.

[564] Mashael Maashi, Graham Kendall, and Ender Ozcan. Choice function based hyper-heuristics for multi-objective optimization. *Applied Soft Computing*, 28, 2015. http://www.cs.nott.ac.uk/~exo/docs/publications/CF_GD_LA.pdf.

[565] Richard Marshall, Mark Johnston, and Mengjie Zhang. Hyper-heuristic operator selection and acceptance criteria. In *the 15th European Conference on Evolutionary Computation in Combinatorial Optimisation (EvoCOP15)*, Copenhagen, Denmark, 2015. Earlier research has shown that an adaptive hyper-heuristic can be a successful approach to solving combinatorial optimisation problems. By using a pairing of an operator (low-level heuristic) selection vector and a solution acceptance criterion, an adaptive hyper-heuristic can manage development of a "good" solution within an unseen low-level problem domain in a commercially realistic computational time. However not all selection vectors and solution acceptance criteria pairings deliver competitive results when faced with differing problem instance features and computational time limits. We evaluate pairings of six different operator selection vectors and eight solution acceptance criteria, and monitor the performance of the adaptive hyper-heuristic when applying each pairing to a set of Capacitated Vehicle Routing Problem instances of the same size but with different features. The results show that a few pairings of operator selection vector and acceptance criterion perform consistently well, while others require a longer computational time to deliver competitive results. We also investigate some of the features of a problem instance that may influence the performance of the selection vector and acceptance criterion pairings. http://link.springer.com/chapter/10.1007/978-3-319-16468-7_9.

[566] Richard J. Marshall. Adapting a hyper-heuristic to respond to scalability issues in combinatorial optimisation, 2015. The development of a heuristic to solve an optimisation problem in a new domain, or a specific variation of an existing problem domain, is often beyond the means of many smaller businesses. This is largely due to the task normally needing to be assigned to a human expert, and such experts tend to be scarce and expensive. One of the aims of hyper-heuristic research is to automate all or part of the heuristic development process and thereby bring the generation of new heuristics within the means of more organisations. A second aim of hyper-heuristic research is to ensure that the process by which a domain specific heuristic is developed is itself independent of the problem domain. This enables a hyper-heuristic to exist and operate above the combinatorial optimisation problem "domain barrier" and generalise across different problem domains. A common issue with heuristic development is that a heuristic is often designed or evolved using small size problem instances and then assumed to perform well on larger problem instances. The goal of this thesis is to extend current hyper-heuristic research towards answering the question: How can a hyper-heuristic efficiently and effectively adapt the selection, generation and manipulation of domain specific heuristics as you move from small size and/or narrow domain problems to larger size and/or wider domain problems? In other words, how can different hyperheuristics respond to scalability issues? Each hyper-heuristic has its own strengths and weaknesses. In the context of hyper-heuristic research, this thesis contributes towards understanding scalability issues by firstly developing a compact and effective heuristic that can be applied to other problem instances of differing sizes in a compatible problem domain. We construct a hyper-heuristic for the Capacitated Vehicle Routing Problem domain to establish whether a heuristic for a specific problem domain can be developed which is compact and easy to interpret. The results show that generation of a simple but effective heuristic is possible. Secondly we develop two different types of hyper-heuristic and compare their performance across different combinatorial optimisation problem domains. We construct and compare simplified versions of two existing hyper-heuristics (adaptive and grammar-based), and analyse how each handles the trade-off between computation speed and quality of the solution. The performance of the two hyper-heuristics are tested on seven different problem domains compatible with the HyFlex (Hyper-heuristic Flexible) framework. The results indicate that the adaptive hyper-heuristic is able to deliver solutions of a pre-defined quality in a shorter computational time than the grammar-based hyper-heuristic. Thirdly we investigate how the adaptive hyper-heuristic developed in the second stage of this thesis can respond to problem instances of the same size, but containing different features and complexity. We investigate how, with minimal knowledge about the problem domain and features of the instance being worked on, a hyper-heuristic can modify its processes to respond to problem instances containing different features and problem domains of different complexity. In this stage we allow the adaptive hyper-heuristic to select alternative vectors for the selection of problem domain operators, and acceptance criteria used to determine whether solutions

should be retained or discarded. We identify a consistent difference between the best performing pairings of selection vector and acceptance criteria, and those pairings which perform poorly. This thesis shows that hyper-heuristics can respond to scalability issues, although not all do so with equal ease. The flexibility of an adaptive hyper-heuristic enables it to perform faster than the more rigid grammar-based hyper-heuristic, but at the expense of losing a reusable heuristic. `http://researcharchive.vuw.ac.nz/handle/10063/4242?show=full`.

[567] Matthew A Martin and Daniel R Tauritz. Hyper-heuristics: A study on increasing primitive-space. In *Proceedings of the 17th Annual Conference Companion on Genetic and Evolutionary Computation (GECCO)*, pages 1051–1058. ACM, 2015. Practitioners often need to solve real world problems for which no custom search algorithms exist. In these cases they tend to use general-purpose solvers that have no guarantee to perform well on their specific problem. The relatively new field of hyper-heuristics provides an alternative to the potential pit-falls of general-purpose solvers, by allowing practitioners to generate a custom algorithm optimized for their problem of interest. Hyper-heuristics are meta-heuristics operating on algorithm space employing targeted primitives to compose algorithms. This paper explores the advantages and disadvantages of expanding a hyper-heuristic's primitive-space with additional primitives. This should allow for an increase in quality of evolved algorithms. However, increasing the search space of a meta-heuristic almost always results in longer time to convergence and lower quality results for the same amount of computational time, but also all too often lower quality results at convergence, potentially making a problem impractical to solve for a practitioner. This paper explores the scalability of hyper-heuristics as the primitive-space is increased, demonstrating significantly increased quality solutions at convergence with a corresponding increase in convergence time. Additionally, this paper explores the impact that the nature of the added primitives have on the performance of the hyper-heuristic. `http://dl.acm.org/citation.cfm?id=2768457`.

[568] Mustafa Misir, Daniel Handoko, and Hoong Chuin Lau. Oscar: Online selection of algorithm portfolios with case study on memetic algorithms. In *the 9th Learning and Intelligent OptimizatioN Conference (LION)*, volume 8994 of *LNCS*, pages 59–73, Lille, France, 2015. This paper introduces an automated approach called OSCAR that combines algorithm portfolios and online algorithm selection. The goal of algorithm portfolios is to construct a subset of algorithms with diverse problem solving capabilities. The portfolio is then used to select algorithms from for solving a particular (set of) instance(s). Traditionally, algorithm selection is usually performed in an offline manner and requires the need of domain knowledge about the target problem; while online algorithm selection techniques tend not to pay much attention to a careful construction of algorithm portfolios. By combining algorithm portfolios and online selection, our hope is to design a problem-independent hybrid strategy

with diverse problem solving capability. We apply OSCAR to design a portfolio of memetic operator combinations, each including one crossover, one mutation and one local search rather than single operator selection. An empirical analysis is performed on the Quadratic Assignment and Flowshop Scheduling problems to verify the feasibility, efficacy, and robustness of our proposed approach. http://link.springer.com/chapter/10.1007/978-3-319-19084-6_6.

[569] Mustafa Misir, Pieter Smet, and Greet Vanden Berghe. An analysis of generalised heuristics for vehicle routing and personnel rostering problems. *Journal of the Operational Research Society*, 66(5), 2015. http://www.palgrave-journals.com/jors/journal/vaop/ncurrent/full/jors201411a.html.

[570] Rahimeh Neamatian Monemi, Kassem Danach, Wissam Khalil, Shahin Gelareh, Francisco C. Lima Jr., and Dario Jose Aloise. Solution methods for scheduling of heterogeneous parallel machines applied to the workover rig problem. *Expert Systems with Applications*, 42(9), 2015. http://www.sciencedirect.com/science/article/pii/S0957417415000615.

[571] Mitra Montazeri, Mahdieh Soleymani Baghshah, and Ahmad Enhesari. Hyper-heuristic algorithm for finding efficient features in diagnose of lung cancer disease. *arXiv preprint arXiv:1512.04652*, 2015. Background: Lung cancer was known as primary cancers and the survival rate of cancer is about 15%. Early detection of lung cancer is the leading factor in survival rate. All symptoms (features) of lung cancer do not appear until the cancer spreads to other areas. It needs an accurate early detection of lung cancer, for increasing the survival rate. For accurate detection, it need characterizes efficient features and delete redundancy features among all features. Feature selection is the problem of selecting informative features among all features. Materials and Methods: Lung cancer database consist of 32 patient records with 57 features. This database collected by Hong and Youngand indexed in the University of California Irvine repository. Experimental contents include the extracted from the clinical data and X-ray data, etc. The data described 3 types of pathological lung cancers and all features are taking an integer value 0-3. In our study, new method is proposed for identify efficient features of lung cancer. It is based on Hyper-Heuristic. Results: We obtained an accuracy of 80.63% using reduced 11 feature set. The proposed method compare to the accuracy of 5 machine learning feature selections. The accuracy of these 5 methods are 60.94, 57.81, 68.75, 60.94 and 68.75. Conclusions: The proposed method has better performance with the highest level of accuracy. Therefore, the proposed model is recommended for identifying an efficient symptom of Disease. These finding are very important in health research, particularly in allocation of medical resources for patients who predicted as high-risks. http://arxiv.org/abs/1512.04652.

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France, 2015. A simple model shows how a reasonable update scheme for the probability vector by which a hyper-heuristic chooses the next heuristic leads to neglecting useful mutation heuristics. Empirical evidence supports this on the MaxSat, TravelingSalesman, PermutationFlowshop and VehicleRoutingProblem problems. A new approach to hyper-heuristics is proposed that addresses this problem by modeling and learning hyper-heuristics by means of a hidden Markov Model. Experiments show that this is a feasible and promising approach. http://link.springer.com/chapter/10.1007/978-3-319-19084-6_7.

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to automatically generate the acceptance criterion for each problem instance, instead of using human-designed criteria. Two well-known, and very different, combinatorial optimization problems, one static (exam timetabling) and one dynamic (dynamic vehicle routing) are used to demonstrate the generality of the proposed framework. Compared with state-of-the-art hyper-heuristics and other bespoke methods, empirical results demonstrate that the proposed framework is able to generalize well across both domains. We obtain competitive, if not better results, when compared to the best known results obtained from other methods that have been presented in the scientific literature. We also compare our approach against the recently released hyper-heuristic competition test suite. We again demonstrate the generality of our approach when we compare against other methods that have utilized the same six benchmark datasets from this test suite. `http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6824192`.

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efficiently. The proposed approach consists of two phases: a math phase and a hyper-heuristic phase. In the math phase, the problem is decomposed into sub-problems which are solved independently using the column generation algorithm. The solutions for these sub-problems are combined and then improved by the hyper-heuristic phase. Benchmark instances of large-scale vehicle routing problems with time windows were used for evaluation. The results show the effectiveness of the math phase. More importantly the proposed method achieved better solutions in comparison with two state of the art methods on all instances. The computational cost of the proposed method is also lower than that of other methods. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7256977`.

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Grid resources scheduling has become a challenge in the computational Grid. The mapping of the jobs to appropriate resources for execution of the application in Grid computing is an NP-Complete problem. So there is no best solution for all grid computing system. Job and resource scheduling in grid environment is one of the key research area in grid environment. The comparison of the heuristic has been shown and experimental result shows that the hyper-heuristics can be of significance importance in Grid scheduling. Over the time, heuristics and meta-heuristics have proved to provide an optimum solution for the combinatorial optimization problems. In this paper, a survey of scheduling algorithms and heuristic approaches is done. `https://pdfs.semanticscholar.org/3a50/4a90fdbd2ca984cc2008d4d38fb68fa6e547.pdf`.

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a search method or a learning mechanism that controls a set of low level heuristics or combines different heuristic components to generate heuristics for solving a given computationally hard problem. In this study, we investigate into a novel apprenticeship-learning-based approach which is used to automatically generate a hyper-heuristic for vehicle routing. This approach itself can be considered as a hyper-heuristic which operates in a train and test fashion. A state-of-the-art hyper-heuristic is chosen as an expert which is the winner of a previous hyper-heuristic competition. Trained on small vehicle routing instances, the learning approach yields various classifiers, each capturing different actions that the expert hyper-heuristic performs during the search process. Those classifiers are then used to produce a hyper-heuristic which is potentially capable of generalizing the actions of the expert hyper-heuristic while solving the unseen instances. The experimental results on vehicle routing using the Hyper-heuristic Flexible (HyFlex) framework shows that the apprenticeship-learning-based hyper-heuristic delivers an outstanding performance when compared to the expert and some other previously proposed hyper-heuristics. `https://ieeexplore.ieee.org/abstract/document/7009505/`.

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that develop good solutions. Through a series of experiments we expand and refine the technique, achieving good quality results on 40 well known Capacitated Vehicle Routing Problem instances. `http://link.springer.com/chapter/10.1007/978-3-319-13563-2_56`.

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paper, the tip of the iceberg is reviewed; recent hyper-heuristic frameworks are surveyed and the overall context of the field is presented. We believe its content complements recent reviews and offers another perspective of this important and developing field to the research community. Some hyper-heuristic frameworks tend to be largely constrained and prevent the state-of-the-art algorithms being obtained. We suggest in addition to relaxing constraints together with analysis of the evolved algorithms may lead to human-competitive results. `http://www.cartesiangp.co.uk/papers/aisb2014-ryser-welch.pdf`.

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is plenty of room to improve the performance of these algorithms, especially by using heuristic scheduling. As such, this paper presents a novel heuristic scheduling algorithm, called hyper-heuristic scheduling algorithm (HHSA), to find better scheduling solutions for cloud computing systems. The diversity detection and improvement detection operators are employed by the proposed algorithm to dynamically determine which low-level heuristic is to be used in finding better candidate solutions. To evaluate the performance of the proposed method, this study compares the proposed method with several state-of-the-art scheduling algorithms, by having all of them implemented on CloudSim (a simulator) and Hadoop (a real system). The results show that HHSA can significantly reduce the makespan of task scheduling compared with the other scheduling algorithms evaluated in this paper, on both CloudSim and Hadoop. `http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6784130`.

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hand is a very hard problem. Most solutions proposed in the literature are based on meta-learning, and use meta-data about the problem to recommend an effective algorithm to solve the task. This paper proposes a new approach to this problem: to build an algorithm tailored to the application problem at hand. More specifically, we propose an evolutionary algorithm (EA) to automatically evolve Bayesian Network Classifiers (BNCs). The method receives as input a list of the main components of BNC algorithms, and uses an EA to encode these components. Given an input dataset, the method tests different combinations of components to that specific application domain. The method was tested in 10 UCI datasets, and compared to three classical BNCs and a greedy search algorithm. Results show that the current algorithms can indeed be improved, but that the EA is currently outperformed by the greedy search. `http://dl.acm.org/citation.cfm?id=2482729`.

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on other challenging combinatorial optimisation problems under different empirical conditions. The computational results indicate that GIHH is effective in solving the target instances from distinct problem domains. Additionally, GIHH won the first international cross domain heuristic search challenge 2011 against 19 high-level algorithms developed by the other academic competitors. The winning hyper-heuristic was then used to investigate the performance and contribution of low-level heuristics while simultaneously solving three problems with routing and rostering characteristics. This completely new application of a hyper-heuristic offers promising perspectives for supporting dedicated heuristic development. https://lirias.kuleuven.be/handle/123456789/358430.

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