Scanning the Issue

Two-Stage Scalable Air Traffic Flow Management Model Under Uncertainty

G. G. N. Sandamali, R. Su, K. L. K. Sudheera, Y. Zhang, and Y. Zhang

In order to efficiently balance the current and future air traffic demands with the system capacity, a proper air traffic flow management (ATFM) approach is required. The current focus of ATFM is generally on optimally utilizing the available airspace and airport capacities while maintaining the required safety separation between aircraft. Yet, only a minor focus is given to the inherent uncertainty in the air transportation system (ATS), especially to its adverse effect on safety and day-to-day operations. To this end, the authors propose an ATFM framework for scrutinizing the stochastic nature of ATS through a chance-constraint-based probabilistic approach. Moreover, anticipating the high volumes in air traffic in the future, the authors propose to split the model into two stages, in which the first stage scrutinizes the behavior of a set of flights as a flow, while the second stage transforms them into individual flight plans, enhancing scalability. The two models are formulated as an integer linear programming (ILP) problem, and a mixed-integer linear programming (MILP) problem at stages I and II, respectively. The NP-hard nature of the overall problem is minimized by transforming the problem into a maximum weighted independent set (MWIS) finding problem.

Learning From Naturalistic Driving Data for Human-Like Autonomous Highway Driving

D. Xu, Z. Ding, X. He, H. Zhao, M. Moze, F. Aioun, and F. Guillemard

The proposed method learns the cost parameters of a motion planner from the naturalistic data of human drivers, which is achieved by encouraging the selected trajectory to approximate human-driven ones under the same traffic situations. The designed cost function incorporates incentive of behavior decision like a human driver, so that both lane change decision and motion planning are coupled into one framework. Experiments are conducted on a dataset that is developed using naturalistic data on the motorways in Beijing. Promising results are demonstrated on both lane change decision and motion planning.

Memorable Maps: A Framework for Re-Defining Places in Visual Place Recognition

M. Zaffar, S. Ehsan, M. Milford, and K. D. McDonald-Maier

A cognition-inspired agnostic framework for building a map for visual place recognition is presented. This framework draws inspiration from human-memorability, utilizes the traditional image entropy concept, and computes the static content in an image, thereby presenting a threefold criteria to assess the "memorability" of an image for visual place recognition. A dataset, namely, "ESSEX3IN," is created, which is composed of highly confusing images from indoor, outdoor, and natural scenes for analysis. When used in conjunction with state-of-the-art visual place recognition methods, the proposed framework provides a significant performance boost to these techniques, as evidenced by results on ESSEX3IN1 and other public datasets.

Evaluating Special Event Transit Demand: A Robust Principal Component Analysis Approach

P. Kumar and A. Khani

Methods are proposed for detecting and evaluating transit demand for a special event. This includes an outlier detection method leveraging Mahalanobis distance to detect a special event in a large-scale time-series transit passenger flow data and a state-of-the-art dimensionality reduction technique known as robust principal component analysis (RPCA) to estimate a special event demand matrix. An application of these methods to evaluate the Minnesota State Fair demand on a bus rapid transit (BRT) route using automatic passenger count (APC) data from Twin Cities, MN, is presented. The methods are general and can be used to detect outliers in any type of transit or highway network data available with respect to time.

Continuous Road Network-Based Skyline Query for Moving Objects

Z. Cai, X. Cui, X. Su, L. Guo, Z. Liu, and Z. Ding

In skyline queries, the query areas have a great impact on the quality of the query results. However, current continuous skyline query approaches limit the area of the skyline query to a specific area in the road network, which causes many useful tuples to not be retrieved. To this end, an innovative continuous skyline query approach is proposed in this article, where multi-scale area divisions of the urban road network are provided. First, the dominant area of each intersection node is established. Then, all points of interest (POIs) are divided into the dominant area of each intersection node. After this, the intersection node aggregation algorithm (INAA), link remolding algorithm (LMA), and link fitting algorithm (LFA) are proposed to reduce the number of intersection nodes and increase the dominant area of the remaining intersection nodes. Finally, a better query scale by considering the efficiency and quality of the query is given.

Bi-Directional Dense Traffic Counting Based on Spatio-Temporal Counting Feature and Counting-LSTM Network

S. Li, F. Chang, and C. Liu

Machine vision-based vehicle counting and traffic flow estimation are challenging problems, especially for dense traffic scenarios. Avoiding the use of complex tracking methods, an LOI counting framework is proposed to address the

Digital Object Identifier 10.1109/TITS.2021.3128609

bidirectional LOI counting problem in dense scenarios. First, a novel spatio-temporal counting feature (STCF) is proposed for extracting bidirectional traffic flow features in dense traffic scenarios. Second, a counting network called the counting long short-term memory (cLSTM) network is proposed to do the analysis of the bidirectional STCF features and vehicle counting in successive video frames. Lastly, an estimation model is designed for estimating traffic flow parameters including speed, volume, and density. The experiments performed on the UA-DETRAC dataset and the captured videos show that the proposed vehicle counting method outperforms the tested representative LOI counting methods in both accuracy and speed.

BCPPA: A Blockchain-Based Conditional Privacy-Preserving Authentication Protocol for Vehicular Ad Hoc Networks

C. Lin, D. He, X. Huang, N. Kumar, and K.-K. R. Choo

While vehicular ad-hoc networks (VANETs) can potentially improve driver safety and traffic management efficiency, security and privacy are two ongoing issues that need to be addressed. Blockchain-based conditional privacy-preserving authentication (BCPPA) protocols have been proposed to mitigate these security challenges; however, there still exist some intractabilities such as revoking private keys, or frequent interactions, or requiring an idea hardware. This article proposes a new BCPPA protocol based on Ethereum and ECDSA without these existing issues. Specifically, the authors combine the blockchain technology and a key derivation algorithm to realize an effective certificate management. This reduces the need for participating vehicles to store a large number of private keys. To reduce the verification time, the BCPPA supports replacing ECDSA with modified ECDSA for batch verification or directly adopting other PKI-based signatures with batch verification. The final security analysis and implementation results in Rinkeby, VanetMobiSim, and NS-2 have demonstrated the feasibility.

Adaptive Fault-Tolerant Pseudo-PID Sliding-Mode Control for High-Speed Train With Integral Quadratic Constraints and Actuator Saturation

X.-G. Guo and C. K. Ahn

An adaptive fault-tolerant pseudo-PID sliding-mode control scheme is proposed for a high-speed train (HST) subject to actuator faults, asymmetric nonlinear actuator saturation (ANAS), and integral quadratic constraints (IQCs). This scheme based on the the pseudo-PID-SMC surface does not require acceleration measurement. An adaptive saturation compensation system that makes no assumption, as in existing works, where nonlinear functions are used to describe the unsaturated region of ANAS as known and strictly monotonous, is developed to attenuate the adverse effects of ANAS.

Intelligent Prediction of Train Delay Changes and Propagation Using RVFLNs With Improved Transfer Learning and Ensemble Learning

P. Zhou, L. Chen, X. Dai, B. Li, and T. Chai

Intelligent prediction of train delay changes and propagation is studied using RVFLNs with improved transfer learning and ensemble learning. First, an improved stacking ensemble learning RVFLNs (SRN) algorithm is proposed for predicting the delay changes. Then, to ensure the classification accuracy of unlabeled and class-imbalanced train data, an improved transfer learning RVFLNs (ITRN) classifier is proposed to decide whether the initial delay will lead to associated delays, with the aid of the improved SMOTE algorithm for processing imbalanced data. If associated delays are identified by the ITRN classifier, the SRN will be further to predict the subsequent associated delays. The effectiveness and practicability of the proposed method are verified using two experiments against actual train data from different railway lines.

Controllability Analysis and Optimal Control of Mixed Traffic Flow With Human-Driven and Autonomous Vehicles

J. Wang, Y. Zheng, Q. Xu, J. Wang, and K. Li

Connected and automated vehicles (CAVs) have great potential to improve traffic efficiency in mixed-traffic systems, which has been demonstrated by multiple numerical simulations and field experiments. However, some fundamental properties of mixed-traffic flow, including controllability and stabilizability, have not been well understood. This article analyzes the controllability of mixed-traffic systems and designs a system-level optimal control strategy. The authors prove for the first time that a ring-road mixed-traffic system with one CAV and multiple heterogeneous human-driven vehicles is not completely controllable, but is stabilizable under a very mild condition. Also, the authors formulate the design of a system-level control strategy for the CAV as a structured optimal control problem, where the CAV's communication ability is explicitly considered. Extensive numerical experiments verify the effectiveness of the analytical results and the proposed control strategy.

Haze Removal of Railway Monitoring Images Using Multi-Scale Residual Network

Z. Cao, Y. Qin, L. Jia, Z. Xie, Q. Liu, X. Ma, and C. Yu

The article proposes an end-to-end multi-scale residual network (MSRN) which can achieve a remarkable dehazing effect on railway monitoring images. The method optimizes the image dehazing algorithm in three aspects: network structure, loss function, and hazy dataset. The extensive experimental results on both full reference image quality assessment and no reference image quality assessment of image restoration demonstrate that the proposed algorithm shows good performance. Moreover, the haze of railway monitoring images is removed under hazy weather, and the detection algorithm achieved higher detection accuracy on the images after dehazing.

Spatial Origin-Destination Flow Imputation Using Graph Convolutional Networks

X. Yao, Y. Gao, D. Zhu, E. Manley, J. Wang, and Y. Liu

The authors propose a spatial interaction graph convolutional network model for spatial origin–destination flow imputation. This model generates embedding vectors of geographical units related to their first-order and second-order similarities and maps the vectors to flow intensities using a bilinear transformation for flow prediction. A case study based on Beijing taxi trip data demonstrates that the proposed model can significantly improve the prediction accuracy compared with baselines. The impact of training data on the mode's performance and the predictability of origin-destination flows have also been discussed. The proposed model can be applied to estimate the missing flows and evaluate the spatial interaction potentials among regions.

Exploratory Investigation of Disengagements and Crashes in Autonomous Vehicles Under Mixed Traffic: An Endogenous Switching Regime Framework

Z. H. Khattak, M. D. Fontaine, and B. L. Smith

Autonomous vehicles (AVs) not only have a large potential to improve traffic safety but also pose some critical challenges. While AVs may help reduce crashes caused by human error, they still may experience failures of technologies and sensing, as well as decision-making errors in a mixed-traffic environment. Disengagement refers to an AV transitioning control from autonomous systems to the trained test driver. This study analyzes both crashes and disengagements from real-world AV driving in California to fill the knowledge gap regarding the relationship between disengagements and crashes in a mixed traffic environment. Endogenous switching regime and nested logit models were calibrated to draw distinctions between the relationship of disengagements and crashes while accounting for endogeneity effects. AV systems (such as software failures) and other roadway participants were observed to increase the propensity of disengagement without a crash. Furthermore, AVs were observed to disengage less often (8% decrease) as the technology matured over time.

Channel State Information-Based Cryptographic Key Generation for Intelligent Transportation Systems

S. Ribouh, K. Phan, A. V. Malawade, Y. Elhillali, A. Rivenq, and M. A. Al Faruque

As nature is open access, distributed keys are more vulnerable to attacks in the vehicular environment. Physical layer key generation methods using wireless channel characteristics show promise in preventing such attacks. In this article, a novel key generation approach in a real vehicular environment based on channel state information (CSI) is presented, including a new algorithm for key bit extraction. The algorithm is implemented using USRP B210 software-defined radios (SDR) and the industry-standard V2X communication protocol: IEEE 802.11p. The proposed approach uses the CSI values as a source of randomness, from which bits are extracted using a new QAM demodulator quantizer (QAM-Dem-Quan). This technique is compared to state-of-the-art received signal strength (RSS)-based approaches, which shows that it achieves better performance. Moreover, it reached a min-entropy of approximately 70% and a key generation rate of less than 150 μs/key for key lengths ranging from 16 to 128 bits.

Improved S-AF and S-DF Relaying Schemes Using Machine Learning Based Power Allocation Over Cascaded Rayleigh Fading Channels

Y. Alghorani, A. S. Chekkouri, D. A. Chekired, and S. Pierre

This study investigates the performance of a dual-hop inter-vehicular communications (IVC) system with relay selection strategy. A machine learning-based power allocation scheme is proposed to improve the link reliability in IVC. The statistical analysis shows that machine learning plays a key role in selecting the best relay and allocation of transmission power over cascaded Rayleigh fading channels. The results indicate that transmit power allocation optimization is required for IVC systems when the cascading order $n \leq 2$. Plus, the time required to find the optimal relay is greatly reduced when the cascading order n decreases. Of course, this study will help automakers deploy a dynamic IVC network that can significantly improve safety and operational efficiency.

The Flying Warehouse Delivery System: A Quantitative Approach for the Optimal Operation Policy of Airborne Fulfillment Center

H. Y. Jeong, B. D. Song, and S. Lee

The flying warehouse delivery system operates based on the collaboration of the airborne fulfillment center (AFC), UAV, and shuttle. AFC remains and moves at a high altitude, and UAVs are deployed from the AFC to deliver items to customers. Smaller airships (shuttle) are used to replenish inbound and outbound items of AFC. To operate the system, a quantitative operation methodology needs to be developed with considerations on regulations and consumable replenishment. In this study, mixed-integer linear programming is developed to simultaneously derive optimal operation schedules for AFC, UAVs, and shuttles. The proposed model can be used in real-time to address system changes and derive new operation schedules. The effects of system components are analyzed via a numerical experiment to provide managerial guidelines for the implementation of the AFC delivery system. Furthermore, the cooperation between the new AFC delivery system and the existing stationary UAV delivery service was investigated.

Location-Allocation Model for the Design of Guidance Signage Systems for Pedestrian Wayfinding in Public Spaces

Z. Zhang, L. Jia, and Y. Qin

A pedestrian-friendly design method for guidance signage systems in public spaces is proposed. A guidance graph (GG) method is proposed to find the potential guidance demand and sign location sites. In order to realize consistent guidance, the distance between adjacent nodes in the GG is shorter than the expected guidance distance which is measured by the memory duration and walking speed of pedestrians. The multifeature fusion-based interaction (MFI) model is proposed to determine the guidance relationship between pedestrians and signs. The field of view of pedestrians, the orientation, arrow type, and letter size of signs, and the obstacles are considered in MFI. Therefore, the proposed design model can suggest the optimal orientation of each sign in addition to the location plan and the optimal number of signs. The experimental results demonstrate the utility of the proposed model.

A Vision-Based Pipeline for Vehicle Counting, Speed Estimation, and Classification

C. Liu, D. Q. Huynh, Y. Sun, M. Reynolds, and S. Atkinson

Cameras have been widely used in traffic operations. While many technologically smart camera solutions in the market can be integrated into intelligent transport systems (ITS) for automated detection, monitoring, and data generation, many network operation (also known as traffic control) centers still use legacy camera systems as manual surveillance devices. In this article, the authors demonstrate effective use of these older assets by applying computer vision techniques to extract traffic data from videos captured by legacy cameras. In the proposed vision-based pipeline, the authors adopt recent state-of-the-art object detectors and transfer-learning to detect vehicles, pedestrians, and cyclists from monocular videos. By weakly calibrating the camera, the authors demonstrate a novel application of the image-to-world homography which gives the monocular vision system the efficacy of counting vehicles by lane and estimating vehicle length and speed in real-world units. The authors' pipeline also includes a module which combines a convolutional neural network (CNN) classifier with projective geometry information to classify vehicles. The authors have tested it on videos captured at several sites with different traffic flow conditions and compared the results with the data collected by piezoelectric sensors. The experimental results show that the proposed pipeline can process 60 frames per second for prerecorded videos and yield high-quality metadata for further traffic analysis.

Resilient UAV Traffic Congestion Control Using Fluid Queuing Models

J. Zhou, L. Jin, X. Wang, and D. Sun

In this article, the issue of congestion in future unmanned aerial vehicle (UAV) traffic systems in uncertain weather is addressed. The traffic of UAVs is treated as fluid queues, and models for traffic dynamics at three basic traffic components are introduced. The impact of weather uncertainty is captured as fluctuation of the saturation rate of fluid queue discharge (capacity). The uncertainty is assumed to follow a continuous-time Markov process. The resilience of the UAV traffic system is defined as the long-run stability of the traffic queues and the optimal throughput strategy under uncertainties. The necessary and sufficient conditions for the stabilities of the traffic queues in the three basic traffic components are derived. Both conditions can be easily verified in practice. The optimal throughput can be calculated via the stability conditions. The results offer a strong insight and tools for designing flows in the UAV traffic system that is resilient against weather uncertainty.

Quiet Route Planning for Pedestrians in Traffic Noise Polluted Environments

Z. Wang, T. Novack, Y. Yan, and A. Zipf

This article addresses the issue of finding quiet routes for pedestrians in traffic noise polluted areas of cities. The authors develop a set of machine learning-based models to perform traffic volume estimations and employ an existing traffic noise model to derive the noise polluted areas. A new routing algorithm is proposed based on the Dijkstra algorithm to generate quiet routes. It minimizes the exposure of pedestrians to traffic noise pollution while taking into account the route distance constraint. The authors apply their quiet routing approach to the city of Heidelberg (Germany). The application results demonstrate the efficacy of the approach in the generation of quiet routes customized for pedestrians.

Learning a Deep Cascaded Neural Network for Multiple Motion Commands Prediction in Autonomous Driving

X. Hu, B. Tang, L. Chen, S. Song, and X. Tong

A deep cascaded neural network consisting of a shared CNN and three independent LSTMs is proposed to simultaneously predict multiple motion commands for autonomous driving, and a new network training algorithm is developed to train the proposed network, where three independent loss functions are designed to separately update the weights of three LSTMs and the shared CNN in order to balance the errors among different outputs and improve the overall prediction accuracy. The proposed network is also a general structure for other multiple commands prediction in motion planning. The simulation results demonstrate the proposed network can achieve better accuracy performance than other existing methods.

Multiple Lane Detection via Combining Complementary Structural Constraints

S. Luo, X. Zhang, J. Hu, and J. Xu

Lane detection is an essential technology for unmanned vehicles, autonomous navigation, departure warning, cruise control, and so on. However, it remains challenging because of the lack of lane marking clarity, altered and worn lane markings after new markings are added, tire skid marks, poor visibility due to bad weather, illumination, light reflection, heavy shadows, lane-pattern varieties, and road-based instructions. Sufficient research has been conducted on single-lane detection, but multiple lane detection is conducive to solving these problems. This article proposes a novel and robust multiple lane detection algorithm based on the road structure information, which contains five complementary constraints. This strategy can effectively deal with combination complexity and interference introduced by multiple lane detection.

Integrated Resource Assignment and Scheduling Optimization With Limited Critical Equipment Constraints at an Automated Container Terminal

H. Li, J. Peng, X. Wang, and J. Wan

This article presents a new mixed-integer programming model for analyzing the integrated problem of assigning resources and scheduling, which also considers that the quantity of critical equipment is limited. To solve the integrated optimization model, a genetic algorithm (GA) is developed. Because critical equipment, such as yard cranes, are limited, and thus, restrict the efficiency of terminals, a sharing policy is proposed to improve the GA to shorten the operation time of both the loading and unloading processes. Experiments show that the improved GA proposed in this article can obtain the optimal/near-optimal solutions in short CPU times; therefore, it is efficient in solving the integrated equipment assignment and scheduling problem. The results obtained from the sharing policy are superior to those obtained from a nonsharing approach.

Vehicle Re-Identification With Image Processing and Car-Following Model Using Multiple Surveillance Cameras From Urban Arterials

Z. Xiong, M. Li, Y. Ma, and X. Wu

In this article, a vehicle Re-ID framework that integrates an image processing and traffic flow model is developed. First, the CNN network is applied for vehicle detection and tracking and extracting attribute recognition. Particularly, attributes including vehicle color, type, make, and Re-ID feature are extracted to derive a similarity matrix between upstream and downstream vehicles. However, solely using these features could not achieve satisfaction matching accuracy. The testing only shows a moderate accuracy of around 72.3%. To further improve the Re-ID rate, this article integrates visual information with the well-known IDM car-following model. In this framework, IDM is first used to estimate the arrival time window for each upstream vehicle and then, with this time window, derive a filter matrix which set the similarity as 0 for the matching vehicles outside the time window. Combining similarity matrix and filter matrix, the newly developed Re-ID framework improves the matching rate to 95.7%. Furthermore, the proposed framework can even help identify vehicles that may have changed lanes, overtaken vehicles, or driven on a sideroad. Such information is certainly valuable for future research on performance measures, traffic control, and congestion mitigation. Considering the significance of the trajectory data to nowadays traffic control and management and popularity of today's surveillance cameras, this research certainly will contribute to the improvement of arterial traffic performance measure and efficient control.

Evaluating the Effects of Switching Period of Communication Topologies and Delays on Electric Connected Vehicles Stream With Car-Following Theory

H. Zhao, Y. Li, W. Hao, S. Peeta, and Y. Wang

Unstable vehicle-to-vehicle (V2V) communication connections are a vital phenomenon in connected vehicle (CV) environments which lead to the change of communication topologies and delays among electric connected vehicles (ECVs). This article aims to evaluate the effects of the switching period of communication topology and delay on the dynamic performance and energy consumption of an ECV traffic stream considering the characteristics of the car-following (CF) theory. To this end, a communication topology characterization method is developed using the beacon transmission mechanism, graph theory, and probability theory. Then, a new CF model incorporating the effects of the communication topologies and delays is proposed to capture the interactions under a CV environment. The stability of the proposed model is analyzed using the perturbation method. Finally, extensive simulations are implemented to be separately discussed by considering the effects of different switching periods of communication topologies and delays.

STNN: A Spatio-Temporal Neural Network for Traffic Predictions

Z. He, C.-Y. Chow, and J.-D. Zhang

A new traffic prediction model, the spatio-temporal neural network (STNN) based on an encoder-decoder architecture, is proposed. It can model the complex factors in the road network, including dynamic spatio-temporal dependencies and external factors (e.g., road type and nearby points of interest). STNN first develops two spatial models into LSTM as the encoder to learn the dynamic spatio-temporal dependencies from three perspectives of links, regions, and road networks. Then, STNN integrates a temporal attention model into LSTM as the decoder to capture the long-term dependencies and fuses external factors in the road network to improve network-wide traffic predictions. The experimental results show the effectiveness of the proposed STNN in traffic predictions.

Pre-Estimating Self-Localization Error of NDT-Based Map-Matching From Map Only

E. Javanmardi, M. Javanmardi, Y. Gu, and S. Kamijo

Map-matching based on light detection and ranging (LiDAR) is a promising method for accurate self-localization and recently has gained a wider focus due to the availability of high definition (HD) maps and price-down of LiDARs. In this method, the input scan of the LiDAR is matched to the prebuilt map to get a centimeter-level accuracy position of the vehicle. However, in some places of the map, due to the lack of features, the presence of the repetitive features, the layout of the features, and other factors, the map-matching error might exceed the required bound for autonomous driving. In the authors' previous work, four criteria for evaluation of the features of the map were introduced and it is shown that, by examining the corresponding factors for each criterion, the map-matching error can be modeled. In this work, one of the map criteria called local similarity is further investigated and in order to quantify the fulfillment of this criterion, three new factors, namely, pfh_similarity, pfh_entropy, and Battacharya_similarity are introduced. In addition to this, a framework for pre-estimation of the map-matching error considering these four criteria based on random forest regression is proposed. To evaluate the accuracy of the framework, experiments were conducted for 3.6 km in Shinjuku, Tokyo. The experimental results show that using the proposed framework, in 64.1% of the cases, the localization error can be estimated with less than 2.5 cm of the estimation error.

Travel Time Prediction for Congested Freeways With a Dynamic Linear Model

S. Kwak and N. Geroliminis

Accurate prediction of travel time is an essential feature to support intelligent transportation systems (ITSs). The non-linearity of traffic states, however, makes this prediction a challenging task. Here, the authors propose to use dynamic linear models (DLMs) to approximate the non-linear traffic states. Unlike a static linear regression model, the DLMs assume that their parameters are changing across time. The authors design a DLM with model parameters defined at each time unit to describe the spatio-temporal characteristics of time-series traffic data. Based on the DLM and its model parameters analytically trained using historical data, the authors suggest an optimal linear predictor in the minimum mean square error (MMSE) sense. The authors compare their prediction accuracy of travel time for freeways in California (I210-E and I5-S) under highly congested traffic conditions with those of other methods: the instantaneous travel time, k-nearest neighbor, support vector regression, and artificial neural network. The authors show significant improvements in accuracy, especially for short-term prediction.

Improved iSAM Based on Flexible Re-Linearization Threshold and Error Learning Model for AUV in Large Scale Areas

J. Guo and B. He

Considering the GPS-denied underwater environment and its complexity, underwater localization of autonomous underwater vehicles puts a high demand on navigation performance. This article proposed an algorithm to improve the accuracy and efficiency of navigation for autonomous underwater vehicles. The effectiveness of the proposed approach is demonstrated by the simulation experiment and real datasets.

Adversarial Training-Based Hard Example Mining for Pedestrian Detection in Fish-Eye Images

Y. Qian, M. Yang, H. Li, C. Wang, and B. Wang

In this article, a distortion generation network is proposed, which automatically generates generous fish-eye images using only small samples. Moreover, the adversarial distortion generation network is proposed to mine hard examples via adversarial training. These hard examples benefit detectors to be more robust to seriously distorted objects in fish-eye images. Experiments with the ETH, the KITTI, the GM-ATCI, and real fish-eye datasets demonstrate that the proposed methods achieve higher accuracy than conventional methods in pedestrian detection in fish-eye images.

Pseudo-Image and Sparse Points: Vehicle Detection With 2D LiDAR Revisited by Deep Learning-Based Methods

G. Chen, F. Wang, S. Qu, K. Chen, J. Yu, X. Liu, L. Xiong, and A. Knoll

Detecting and locating surrounding vehicles robustly and efficiently are essential capabilities for autonomous vehicles. Existing solutions often rely on vision-based methods or 3-D LiDAR-based methods. These methods are either too expensive in both sensor pricing (3D LiDAR) and computation (camera and 3-D LiDAR) or less robust in resisting harsh environment changes (camera). In this work, the authors revisit the LiDAR-based approaches for vehicle detection with a less expensive 2-D LiDAR by utilizing modern deep learning approaches. The authors aim at filling in the gap as few previous works conclude an efficient and robust vehicle detection solution in a deep learning way in 2-D. To this end, the authors propose a learning-based method with the input of pseudo-images, named cascade pyramid region proposal convolution neural network (Cascade Pyramid RCNN), and a hybrid learning method with the input of sparse points, named Hybrid Resnet Lite. The experiments are conducted with the new 2-D LiDAR vehicle dataset recorded in complex traffic environments. The results demonstrate that the Cascade Pyramid RCNN outperforms state-of-the-art methods in accuracy while the proposed Hybrid Resnet Lite provides a superior performance of the speed and lightweight model by hybridizing learning-based and non-learning-based modules. As few previous works conclude an efficient and robust vehicle detection solution with 2D LiDAR, the research fills in this gap and illustrates that even with limited sensing information from a 2-D LiDAR, detecting obstacles like vehicles efficiently and robustly are still achievable.

A Hierarchical Model-Based Optimization Control Approach for Cooperative Merging by Connected Automated Vehicles

N. Chen, B. van Arem, T. Alkim, and M. Wang

A novel hierarchical model-based optimization control approach to plan vehicular trajectories for connected automated vehicles (CAVs) near on-ramps is proposed. Optimal merging sequences are established by a tactical layer controller which utilizes a second-order multi-regime model with a car-following mode and a cooperative merging mode to predict CAVs' future dynamics in the merging process and is formulated as an optimization problem constructed using predicted vehicular trajectories. Vehicular acceleration trajectories are regulated by an operational layer controller which is designed based on model predictive control. The experimental results show the superiority of the proposed control approach compared with a benchmark on-ramp merging method, using a first-in-first-out rule to determine merging sequences, under 135 scenarios with different initial conditions, desired time gap settings, and numbers of on-ramp vehicles.

Decentralized Emergency Service Vehicle Pre-Emption System Using RF Communication and GNSS-Based Geo-Fencing

P. Rosayyan, S. Subramaniam, and S. I. Ganesan

This article presents a new solution for emergency service vehicle pre-emption (EVP) using RF (radio frequency) and GNSS (global navigation satellite system) based geo-fencing technique. This decentralized solution gives a green signal to the emergency vehicles on their approaches automatically without any human intervention. The main features of the proposed system are automatic pre-emption, smooth operation on curved roads, enabling direction filter, no false triggering, faster response time, flexible route selection, low installation cost, and compatibility with all traffic signal controllers with Hurry Call (HC) facility. The proposed system was field trailed in one of the junctions in Thiruvananthapuram, India. The pre- and post-implementation travel time was analyzed, and the average travel time was reduced approximately by 48% after implementing this proposed system.

Vehicular Localization Based on CSI-Fingerprint and Vector Match

J. Zhang and Y. Zhang

In this article, in order to complement the accuracy and latency gaps of GPS in WAVE-based vehicle environment, an IEEE 802.11p module driver is modified to provide channel state information (CSI), and then a CSI-fingerprint is proposed to provide a fast and accurate short-distance vehicle localization system. Data transmission and vehicle localization use the same signals, thus saving dedicated localization infrastructure. The multipath effect was mitigated through signal processing, the common hardware errors were offset through the position feature, and the traffic noises were filtered out through the reference point filters. The effect of low-variability CSI fingerprint was alleviated through similarity degrees. The tests confirmed high accuracy and low latency, and ignorable influence of grid size, speed, traffic, and weather.

In-Vehicle Object-Level 3D Reconstruction of Traffic Scenes

Q. Rao and S. Chakraborty

Emerging automotive applications require a comprehensive understanding of the vehicle's 3-D surroundings represented as an object-level environmental model. A combination of 3-D object detection and 3-D surface reconstruction techniques, referred to as object-level 3-D reconstruction, is fundamental to building such environmental models. However, constrained by cost and resource associated with the automotive domain, the possibilities to incorporate this technique in a car have not been sufficiently explored. In this article, the authors address these constraints by proposing implementations of in-vehicle object-level 3-D reconstruction in two specific use cases: 1) augmented reality and 2) automated parking. The crux of the proposed approaches lies in the use of a latent shape space where various 3-D shapes are represented using only two parameters. As a result, highly complex 3-D shapes can now be transmitted using a low- to medium-bandwidth in-vehicle communication infrastructure in a cost-effective manner.

Intelligent Charging Management of Electric Vehicles Considering Dynamic User Behavior and Renewable Energy: A Stochastic Game Approach

H.-M. Chung, S. Maharjan, Y. Zhang, and F. Eliassen

Uncoordinated charging of a rapidly growing number of electric vehicles (EVs) and the uncertainty associated with renewable energy resources may constitute a critical issue for electric mobility (E-Mobility) in the transportation system, especially during peak hours. To overcome this dire scenario, the authors introduce a stochastic game to study the complex interactions between the power grid and charging stations. In this context, existing studies have not taken into account the dynamics of customers' preferences on charging parameters. In reality, however, the choice of the charging parameters may vary over time, as the customers may change their charging preferences. The authors model this behavior of customers with another stochastic game. Moreover, the authors define a QoS index to reflect how the charging process influences customers' choices on charging parameters. The authors also develop an online algorithm to reach the Nash equilibria for both stochastic games. Then, the authors utilize real data from the California Independent System Operator (CAISO) to evaluate the performance of the proposed algorithm. The results reveal that the electricity cost with the proposed method can result in a saving of about 20% compared to the benchmark method while also yielding a higher QoS in terms of charging and waiting time. The results can be employed as guidelines for charging service providers to make efficient decisions under uncertainty relative to the power generation of renewable energy.

A Vehicle Simulation Model and Automated Driving Features Validation for Low-Speed High Automation Applications

J. A. Matute-Peaspan, A. Zubizarreta-Pico, and S. E. Diaz-Briceno

In this study, a two-step validation methodology is proposed: First, an open-loop test set attempts to tune the required vehicle simulation models using experimental data considering also the dynamics of the actuation devices required for vehicle automation. Second, a closed-loop test strives to validate the selected automated driving functionality based on test plans, also improving the vehicle dynamics response. To illustrate the methodology, a study case is proposed using an automated Renault Twizy. The results demonstrate that the proposed methodology is capable not only to tune vehicle simulation models for automated driving development purposes but also to validate low-speed high automation functionalities.

Truck and Trailer Classification With Deep Learning Based Geometric Features

P. He, A. Wu, X. Huang, J. Scott, A. Rangarajan, and S. Ranka

The authors present a novel and effective approach to truck and trailer classification, which integrates deep learning models and conventional image processing and computer vision techniques. The developed method groups trucks into subcategories by carefully examining the truck classes and identifying key geometric features for discriminating truck and trailer types. The authors also present three discriminating features that involve shape, texture, and semantic information to identify trailer types. The experimental results demonstrate that the developed hybrid approach can achieve high accuracy with limited training data, whereas the vanilla deep learning approaches show moderate performance due to over-fitting and poor generalization. In addition, the models generated are human-understandable.

Optimal Eco-Driving of a Heavy-Duty Vehicle Behind a Leading Heavy-Duty Vehicle

N. K. Sharma, A. Hamednia, N. Murgovski, E. R. Gelso, and J. Sjöberg

The authors propose an eco-driving technique for a heavy-duty ego vehicle that drives behind a leading heavy-duty vehicle. By observing a decrease in speed of the leading vehicle when driving uphill, its power capability is estimated and its future speed is predicted within a look-ahead horizon.

The predicted speed is utilized in a model predictive controller (MPC) to plan the optimal speed of the ego vehicle such that its fuel consumption is minimized while keeping a safe distance to the leading vehicle and reducing the need for braking. The effectiveness of the proposed technique is analyzed in two case studies on real road topographies. Using the leading vehicle observer, fuel savings are achieved up to 8% compared to the case where the preceding vehicle is assumed to have a constant speed within the look-ahead horizon.

Solving Multi-Agent Routing Problems Using Deep Attention Mechanisms

G. Bono, J. S. Dibangoye, O. Simonin, L. Matignon, and F. Pereyron

This article introduces a multi-agent reinforcement learning model called sequential MMDP to address rich dynamic and stochastic vehicle routing problems. It also proposes a variation of attention model, a deep neural network architecture called MARDAM designed as a modular policy that can learn to represent various configurations of the problem and output online decision rules for any vehicle in the fleet, adapted to the latest information available. The approach is evaluated on large batches of artificially generated benchmarks and shows promising results in terms of generalization, robustness, and adaptability.

Personalised Controller Strategies for Next Generation Intelligent Adaptive Electric Bicycles

L. Stilo, H. Lugo, D. Segura Velandia, P. P. Conway, and A. A. West

The current state of the world made the authors rethink the way of navigating through cities or commuting. The welcomed new attention to environmental impacts and personal protection made bicycles and electric bicycles the fastest growing segment in the transportation market. This article looks at the current state-of-the-art e-bike and its limitations due to the lack of personalization, in particular, for the way it delivers assistance in various circumstances. Through a performance study that involved 30 participants, this article analyzes the way a human interacts with a bicycle while cycling. Based on these findings, this article suggests three innovative motor controller strategies that can improve the interaction between human and vehicle for a more intelligent and adaptive way to use electric bicycles.

Indirect Shared Control for Cooperative Driving Between Driver and Automation in Steer-by-Wire Vehicles

R. Li, Y. Li, S. E. Li, C. Zhang, E. Burdet, and B. Cheng

It is widely acknowledged that drivers should remain in the control loop before automated vehicles completely meet real-world operational conditions. This article presents an “indirect shared control” framework for steer-by-wire vehicles, which allows the control authority to be continuously shared between the driver and automation through a weighted-input-summation method. A “best-response” driver steering model based on model predictive control (MPC) for indirect shared control is proposed. Unlike any conventional driver model for manual driving, this model assumes that drivers can learn and incorporate the controller strategy into their internal model for predictive path following. The analytic solution to the driver model is provided to enable off-line simulations. A driving-simulator experiment was conducted to demonstrate the advantages of the indirect shared control system in a highway lane-keeping task. The result showed that the proposed indirect shared control method was effective to improve the subjects' lane-keeping performance and reduce steering control effort. The proposed driver steering model was also validated by the experiment data, which produced a smaller prediction error than the conventional MPC driver model.

Eco-Driving System for Connected Automated Vehicles: Multi-Objective Trajectory Optimization

X. T. Yang, K. Huang, Z. Zhang, Z. A. Zhang, and F. Lin

A multi-objective control framework for eco-driving of connected automated vehicle (CAV) platoons is developed. Following a two-stage control logic, the first stage, at the planning level, aims at producing optimal trajectories of CAVs that can concurrently reduce freeway total travel time and CAV fuel consumption. Then, the second optimization is used to generate optimal CAV trajectories in compliance with the obtained speed profile and local driving environment. The results show the effectiveness of the proposed framework with reduced traffic time and fuel consumption for CAV platoons.

Two-Slope Path Loss Model for Curved-Tunnel Environment With Concept of Break Point

S. K. Kalyankar, Y. H. Lee, and Y. S. Meng

The curvature of tunnels introduces an extra loss in the wave propagation. A simulation and measurement study are performed on the straight and curved tunnels to investigate the extra loss in the curved tunnels in comparison with the straight tunnels at a frequency of 2.4 GHz. This study suggests the existence of two wave propagation mechanisms in the curved tunnel: an enhanced waveguiding mechanism induced by rich multipath components from the curved tunnels and a degraded waveguiding mechanism due to the blockage from the curved tunnel walls. For efficient radio planning, a new propagation model with curvature dependent breakpoint is proposed. The proposed breakpoint indicates the end of the enhanced waveguiding mechanism and the beginning of the degraded waveguiding mechanism. A two-slope radio wave propagation model is then proposed for radio communications inside curved tunnels using the determined breakpoint, with performance evaluation.

The Bionics and Its Application in Energy Management Strategy of Plug-In Hybrid Electric Vehicle Formation

C.-Z. Liu, L. Li, J.-W. Yong, F. Muhammad, S. Cheng, X.-Y. Wang, and W.-B. Li

A novel distributed cooperative formation control method inspired by the aggregate behaviors of fish groups is proposed for plug-in hybrid electric vehicle (PHEV) formation. First, a hierarchical control architecture is established for formation keeping with fuel consumption (FC) optimization simultaneously. The top layer is to generate a leader with the optimal performance based on the nonlinear model predictive control (MPC) technique. A fish swarm optimization (FSO) algorithm is proposed to solve the nonlinear MPC problem by imitating the predation behaviors of the fish swarm. The middle layer is a decentralized intelligent cruise control (ICC) for follower vehicles to track their leader imitating the behaviors of a fish swarm, and some design criteria are presented based on the Lyapunov stability theory. The under layer achieves a satisfying performance for the hybrid powertrain systems of followers. Finally, the bioinspired method applied for PHEV formation is verified with satisfying robustness, fuel economy, car-following, and also real-time processing performances. According to the results, the PHEV formation using the proposed method represents a better car-following performance compared with the normal adaptive cruise control (ACC) method and a 21.26% improvement of FC compared with the rule-based energy management strategy (EMS). The computational burden is also reduced by the bio-inspired method.

Optimizing Extensibility of CAN FD for Automotive Cyber-Physical Systems

Y. Xie, G. Zeng, R. Kurachi, F. Xiao, and H. Takada

The tradeoff between bandwidth utilization and extensibility is explored for the CAN FD-based E/E architecture of automotive cyber-physical systems. It first proposes a new extensibility model and the related evaluation metric, and then two optimization algorithms, namely, the mixed-integer linear programming approach and the simulated annealing-based heuristic approach, are proposed to resolve the tradeoff problem for mid-sized and industry sized signal sets, respectively. The efficiency of the proposed extensibility metric and the optimization algorithms is verified by comparing with the state-of-the-art algorithm.

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