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Preface

Introduction to the special issue on evolutionary computer vision and image understanding

Genetic and Evolutionary Computation (GEC) is a recent research field in computer science which deals with adaptive systems and optimization techniques inspired by the rules of natural evolution. One of its goals is to endow computers with information-processing capabilities comparable to those found in nature (Holland, 1992; Poli and Cagnoni, 2003; Koza, 1992; Schwefel, 1981; Mitchell, 1996; Landon and Poli, 2002; Goldberg, 1989).

The general applicability of its methods makes it possible to use GEC to solve problems in a large number of applications. In particular, GEC methods can be applied effectively to those fields whose tasks require robust and flexible techniques to optimize performance in the many possible scenarios that characterize real-world problems (GECCO; CEC; PPSN; EuroGP). Among those fields, computer vision and image understanding (CVIU) represents one of the most challenging for the complexity of the tasks that are being solved in order to provide computers with human-like perception capabilities, allowing them to sense the environment, understand the sensed data, identify patterns, take appropriate actions and learn from experience to enhance future performance (CVPR; ICCV; ECCV; ICPR).

Real-world applications of CVIU presently include autonomous robot or vehicle navigation, inspection, quality control, surveillance, to mention but a few. To achieve these high-level tasks, lower-level problems need to be solved, such as feature extraction, 3D modeling, and object classification. These real-world tasks require to be robust and flexible to optimize performance in diverse scenarios encountered in a given application. CVIU is steadily gaining relevance within the large number of application fields of GEC techniques, thanks to the capability of the latter to explore huge search domains effectively, searching and often finding solutions that lie well far away from the rather limited region spanned by more traditional, hand-coded ones. A first benefit of studying GEC techniques within the computational CVIU framework is to mature the information-processing capabilities of artificial systems based on challenging real-world problems. A second benefit is the promise of advancing the CVIU techniques with a better understanding of complex images of real-world scenes. This last point should be accomplished with a carefully well designed evaluation function and problem representation, as well as a number of variation operators and adaptation strategies in order to achieve the desired visual emergent behavior.

The use of evolutionary algorithms in real-world CVIU tasks requires knowledge of the application domain and abstraction of the problem domain in terms of evolvable structures through the selection of appropriate representations. Therefore, the effective design of an evolutionary system needs to answer questions like what is being evolved (selection of a suitable representation), which are the mechanisms by which evolution takes place (selection of a suitable evolutionary paradigm), how an evolved structure can be evaluated (definition of a fitness function). The solutions evolved by GEC techniques must then be compared with those currently embedded in vision systems, to possibly substitute them or hybridize them with the original features that have emerged from evolution. This approach to the design of vision systems seems to be on its way to be accepted as a standard technique in computer vision research. We hope and believe that the work published in this special issue can enhance and speed up this process, which is already leading to wider and wider acceptance of GEC techniques within the CVIU community. This is also demonstrated by the steady growth in number and quality of submissions to EvoIASP, the European Workshop on Evolutionary Computation in Image Analysis and Signal Processing, born as the meeting of the homonimous working group of the European Network of Excellence in Evolutionary Computation (EvoNET) and heading towards its ninth edition in 2006 as the main worldwide forum in the field (EvoIASP). However, the work presented in a workshop cannot reach the depth and degree of maturity allowed by publication in archival publications like this journal.

A call for papers was posted to look for contributions to this special issue, inviting all previous participants of EvoIASP. This special issue includes also extended versions of the two best contributions (the papers by Dunn et al. and

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by de Croon et al.) of last EvoIASP edition. Scientists and engineers from around the world have submitted their most mature research for inclusion in this unified, high-quality venue. The goal of this special issue is to provide readers of Pattern Recognition Letters with samples of recent work which uses evolutionary CVIU techniques. Fourteen papers have been included in this special issue, which describe a variety of techniques in areas of human endeavor that matter. All papers have gone through several rounds of reviewing according to the guidelines and standards of Pattern Recognition Letters. The papers which have been selected cover a broad area of theory and applications of evolutionary CVIU. We hope that this special issue will further boost research in this field, by stimulating new ideas and attracting new adepts.

1. Papers in this special issue

The first three papers in this special issue take inspiration from robot vision to demonstrate how biologically-inspired techniques can be used to solve problems like path planning, obstacle avoidance, and gaze control. The first paper entitled *An agent based evolutionary approach to path detection for off-road vehicle guidance*, by Broggi and Cattani describes an ant colony optimization (ACO) algorithm used to detect road-borders on the Terramax autonomous vehicle specifically developed for the DARPA Grand Challenge 2004. The basic ACO has been adapted and improved with new features in order to track the two borders at the two sides of the road using a digital camera mounted on the vehicle. Real experiments are provided to show the robustness of the evolutionary system.

The second paper by Martin, entitled *Evolving visual sonar: Depth from monocular images*, presents a system based on genetic programming (GP) that finds algorithms for obstacle detection. The goal is to achieve a visual sonar, which returns the location of the nearest obstacle in a given direction. The system has been tested in an office environment, colliding only with obstacles outside of the robot's field of view and requiring minimum human intervention.

In *A situated model for sensory-motor coordination in gaze control*, de Croon et al. attack the problem of gaze control coordination using a situated model to approach a gender recognition task. This paper outlines how a closed-loop coordination agent could be implemented using evolutionary algorithms to approach classification problems by determining fixation locations that depend on the expected class and on specific image properties.

The next three papers (fourth, fifth, and sixth papers in this special issue) deal with 3D modeling and reconstruction. The fourth paper, by Cordón et al., entitled *A fast and accurate approach for 3D image registration using the scatter search evolutionary algorithm*, proposes a feature-based approach to find a near-optimal geometric transformation using an efficient stochastic optimization technique, named scatter search, embedded within an evolutionary algorithm. The successful application incorporates concepts such as diversification, local improvement, subset generation, and solution combination. Experiments are shown to validate the quality of the solution.

The fifth paper entitled *Pre-registration of arbitrarily oriented 3D surfaces using a genetic algorithm*, by Lomonosov et al., addresses also the problem of image registration. Genetic optimization is applied in order to achieve pre-registration of arbitrarily oriented surfaces. This step is combined with an iterative closest point algorithm to obtain final precision and robustness. Experiments are presented to describe a fully automatic 3D data alignment system.

The sixth paper, by Dunn et al., entitled *Parisian camera placement for vision metrology*, presents an individual strategy that efficiently designs photogrammetric networks incurring in only a fraction of the computation cost. Novel aspects are described within the genetic search process such as: partial encoding, individual aggregation, local and global fitness, and population diversity preservation. Results reported in this paper show a dramatic improvement, as a 30-fold reduction in execution is achieved, compared with a canonical implementation of the evolutionary algorithm.

The seventh paper by Ebner, entitled *Evolving color constancy*, uses genetic programming to evolve an algorithm for color constancy using a parallel architecture. Color constancy is a term used to express the ability to recognize the color of objects irrespective of the illumination. This paper describes the theory of color image formation in order to introduce how to evolve an algorithm for color constancy. The function set comprises simple arithmetic operators used to process local information. Comparison with other experiments has been made, and experiments have been performed using an object recognition task.

The next three papers deal with image segmentation. The eighth paper, by Melkemi et al., entitled *A multi-agent system approach for image segmentation using genetic algorithms and extremal optimization heuristics*, proposes a distributed algorithm structured as a multi-agent system. Several agents perform the iterated conditional modes method to obtain sub-optimally segmented images. The coordinator agent drives the evolution using genetic operators along with local search optimization. Experimental results on both synthetic and real images have been used to assess the validity and performance of the approach.

The ninth paper, entitled *Improving image segmentation quality through effective region merging using a hierarchical social meta-heuristic*, by Duarte et al., proposes to improve an initial over-segmentation approach through the power of competition and cooperation among different groups of regions based on a hierarchical top-down region-based decomposition. Experimental results have shown that the proposed evolutionary algorithm provides an effective region merging method for achieving a high-quality segmentation.

The 10th paper, entitled *Automatic Video Segmentation using Genetic Algorithms*, by Kim et al., presents an unsupervised video sequence segmentation method based on genetic algorithms that can automatically extract and track moving

objects. The proposed method achieves spatial segmentation with a distributed genetic algorithm, while adaptive thresholding is employed for temporal segmentation. Experimental results have shown the performance of the proposed method in comparison with other segmentation algorithms using several natural and synthetic video sequences.

The next three papers use genetic programming to approach object classification and recognition. The eleventh paper, by Zhang and Smart, entitled *Using Gaussian distribution to construct fitness functions in genetic programming for multi-class object classification*, proposes to handle the problem of region-based segmentation using Gaussian distributions. The proposed method uses multiple programs and a weighted voting strategy rather than using just the best program to perform segmentation. Experimental results tested on three multi-class object classification problems have shown that the new approach is more efficient and effective than the basic GP approach.

In *Pragmatic genetic programming strategy for the problem of vehicle detection in airborne reconnaissance*, Howard et al., address the problem of discovering a class of objects of interest. A detector is evolved using a multi-stage genetic programming approach to recognize vehicles on images obtained from low-flying aircrafts. Performance and quality of the detectors are reported to illustrate the effectiveness of the approach.

The 13th paper, by Yu and Bhanu, entitled *Evolutionary feature synthesis for facial expression recognition*, describes a feature learning method based on genetic programming to recognize facial expressions. Feature expression primitives are synthesized using Gabor wavelet and linear/nonlinear operators. Features are used to train a support vector machine classifier in order to recognize facial expressions. Experimental results show that the accuracy and number of features used by the GP approach are similar in quality to a number of standard approaches.

The last paper, by Blansché et al., entitled *MACLAW: A modular approach for clustering with local attribute weighting*, describes a collaborative clustering approach to classify complex objects described by a large set of features. Coevolution is used to combine several clusters using different feature weights. Experimental results have been performed on several datasets to show the validity of the approach.

2. The future

We believe that, in the future, the number of CVIU systems incorporating the evolutionary adaptation paradigm will increase, as well as the number of researchers embedding one of the most intriguing and powerful mechanisms of nature in computer systems. The quality of advances will depend on the closeness of interaction between researchers in evolutionary computation and in computer vision. The ability to build machines that can see is one of the greatest challenges in computer science, and the fact that evolutionary adaptation can play a major role in meeting it is a fair claim.

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Proc. Genetic and Evolutionary Computation Conf. (GECCO) (This is the largest conference in the field.).

Proc. Congress on Evolutionary Computation (CEC) (This is a large conference under the patronage of IEEE.).

Proc. Parallel Problem Solving from Nature (PPSN) (This is a large biannual European conference probably the oldest of its kind in Europe.).

Proc. European Conf. on Genetic Programming (EuroGP) (This is the largest event worldwide solely devoted to GP.).

Proc. Computer Vision and Pattern Recognition (CVPR) (This is a large American conference hosted by IEEE with a worldwide scope.).

Proc. Internat. Conf. on Computer Vision (ICCV) (This is the largest event in the discipline of computer vision.).

Proc. European Conf. on Computer Vision (ECCV) (This is the largest European conference of its kind.).

Proc. Internat. Conf. on Pattern Recognition (ICPR) (This is the largest biannual conference on pattern recognition.).

Proc. European Workshop on Evolutionary Comput. in Image Analysis and Signal Process. (EvoIASP) (This is the only event worldwide uniquely devoted to the research topics covered by this special issue.).

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Gustavo Olague
CICESE Research Center,
División de Física Aplicada,
EvoVisión Laboratory,
Km 107 carretera Tijuana-Ensenada,
22860, Ensenada, BC,
México
Tel.: +1 526461750500; fax: +1 526461750593
E-mail address: olague@cicese.mx

Stefano Cagnoni
Evelyne Lutton

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