Introduction to the Special Issue on Evolutionary Computer Vision and Image Understanding

Genetic and Evolutionary Computation (GEC) is considered a new field of research characterized by the simulation of the adaptive behavior of biological organisms. One of its goals is to endow computers with information-processing capabilities comparable to those found in nature. On the other hand, the goal of computer vision is the construction of explicit meaningful descriptions of physical objects from images, while the goal of image understanding is to derive the descriptions useful in tasks such as recognition, manipulation, and thinking about objects.

Computer vision is a well established discipline whose goal is to provide computers with human-like perception capabilities so that they can sense the environment, understand the sense data, identify patterns, take appropriate actions, and learn from this experience in order to enhance future performance. In general, computer vision uses statistical methods to disentangle data using models constructed with the aid of geometry, physics and learning theory. Nowadays, computer vision is currently challenged with real-world applications, such as autonomous navigation, feature extraction, 3D modeling, and object classification to mention but a few. These real-world tasks require to be robust and flexible to optimize performance in diverse scenarios encountered in a given application.

Computer vision and image understanding (CVIU) is steadily gaining relevance within the large number of application fields to which genetic and evolutionary computation techniques are applied. 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 effective usage of evolutionary algorithms in real-world computer vision problems requires understanding the domain of application, abstraction of the domain problem in terms of evolutionary computation, and the selection of appropriate representations. In this way, an evolutionary system has to clearly demonstrate and answer the questions like what is being evolved, how it is evolved, what it is used to evaluate the evolved structure, how well and how efficient is the evolutionary system, how the evolutionary system improves the performance of the vision system over the standard approaches using current evaluation criteria for the task at hand. Experimental results and the details to achieve the experiments are essential elements if we want to develop new approaches based on evolutionary algorithms. These new algorithms will be hopefully standard in computer vision research.

Our goal in designing these new algorithms should be the acceptance of the proposed approaches within the computer vision literature. We believe that, the works published in this special issue of Pattern Recognition Letters represent a significant contribution, which demonstrates the growing interest in the research and application of evolutionary computer vision and image understanding. Today a working group of the European Network of Excellence in Evolutionary Computation, entirely devoted to the applications of evolutionary algorithms to image analysis and signal processing is steadily growing.

This year the European Workshop on Evolutionary Computation in Image and Signal Processing has arrived to its Eight edition. This event gives European and non-European researchers, as well as people from industry, an opportunity to present their latest research, discuss current developments and applications, besides fostering closer interaction between members of the GEC, image analysis, and signal processing scientific communities. Therefore, the work presented there can never have the depth allowed by more substantial and mature archival publications such as this journal.

This special issue represents a piece of evidence that GEC are finding an active research field in CVIU. Scientists and engineers from around the world have submitted their best mature research for inclusion in this unified, high-quality venue. The goal of this special issue is to provide to the Pattern Recognition Letters readers with samples of recent developments that use evolutionary computer vision and image understanding approaches. The special issue has 13 papers. These papers explain 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 the Pattern Recognition Letters. The papers cover a broad area of theory and applications of evolutionary computer vision and image understanding. We hope that the special issue will contribute with the boost that this new field of research deserve.

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 help 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 two borders at 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 *Evolutionary 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 minimal 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 presumed 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 show 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 design photogrammetric networks incurring in only a fraction of the computattional 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 dramatic improvement of almost 30 times reduction in execution time compared with a canonical evolutionary algorithm.

The seventh paper by Ebner, entitled *Evolving color constancy*, proposes 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 set of functions was described by simple arithmetic operators used to exchange local information. Comparison with other algorithms was made and experiments were performed using an object recognition task.

The next two 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-optimal 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 next three papers use genetic programming to approach object classification and recognition. The tenth paper, by Zhang and Smart, entitled *Using Gaussian distribution to construct fitness functions in genetic programming for multiclass object classification*, proposes to handle the problem of building different regions based on Gaussian distributions. The proposed strategy uses multiple programs rather than using the best evolved program using a voting strategy to perform classification. Experimental results tested on three multiclass 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 by low flying aircraft. Performance and quality of the detectors are reported to illustrate the effectiveness of the approach.

The twelveth 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 the 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

The field of evolutionary computer vision and image understanding is just emerging. We believe that in the future the number of CVIU systems incorporating the evolutionary adaptation paradigm will be increased, as well as the number of researchers embracing one of the most intriguing and powerful mechanism of nature. The quality of the advances depends on the interaction between researchers of evolutionary computation and computer vision. The ability to build an autonomous seeing machine represents probably the biggest challenging frontier in computer vision, and the fact that adaptation could play a major role is a fair claim.

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8. Proceedings of the Genetic and Evolutionary Computation Conference (GECCO). GECCO is the largest conference in the field.
9. Proceedings of the Congress on Evolutionary Computation (CEC). CEC is a large conference under the patronage of IEEE.
10. Proceedings of Parallel Problem Solving from Nature (PPSN). This is a large biannual European conference probably the oldest of its kind in Europe.
11. Proceedings of the European Conference on Genetic Programming (EuroGP). This is the largest event worlwide solely devoted to GP.
12. Proceedings of Computer Vision and Pattern recognition (CVPR). This is a large American conference hosted by IEEE with a worlwide scope.
13. Proceedings of the International Conference on Computer Vision (ICCV). This is the largest event in the discipline of computer vision.
14. Proceedings of the European Conference on Computer Vision (ECCV). This is the largest European conference of its kind.
15. Proceedings of the International Conference on Pattern Recognition (ICPR). This is the largest biannual conference on pattern recognition.
16. Proceedings of the European Workshop on Evolutionary Computation in Image Analysis and Signal Processing (EvoIASP). This is the only event worlwide uniquely devoted to the research topics covered by this special issue.