

Guest Editorial

Special Issue on Evolutionary Computer Vision

EVOLUTIONARY Computer Vision (ECV) is at the intersection of two major research fields of artificial intelligence: 1) computer vision (CV) and 2) evolutionary computation (EC). This special issue brings an overview of state-of-the-art contributions to the latest research and development in the discipline. CV includes methods for acquiring, processing, analyzing, and understanding images. The aim is to design computational models of human and animal perception. ECV is an interdisciplinary research area where analytical methods combined with powerful stochastic optimization and metaheuristic approaches produced human-competitive results. From an engineering standpoint, ECV aims to design software and hardware solutions useful for solving challenging CV problems. From a scientific viewpoint, the goal is to enhance our current understanding of visual processing in nature and replicate this within a seeing machine. ECV is a well-established research discipline as evolutionary algorithms are more efficient than classical optimization approaches for the discontinuous, nondifferentiable, multimodal, and noisy search, optimization, and learning problems arising in many CV tasks. EC has also demonstrated its ability as a robust approach to cope with the fundamental steps of image processing, image analysis, and image understanding included in the CV pipeline (e.g., restoration, segmentation, registration, classification, reconstruction, or tracking).

We received 21 papers for this special issue. After a strict review process involving at least three reviewers, two papers were accepted [A1], [A2]. In order to complete the special issue, we invited, with the Editor-in-Chief's approval, two more papers matching the scope of the special issue that were submitted as regular papers and whose authors accepted to be part of this ECV special issue [A3], [A4]. Next, you will find a brief review of the four articles contained within this special issue.

The first paper in this special issue [A1] by Bi et al. provides a comprehensive survey of existing EC approaches for CV and image analysis. The survey aims to give an updated introduction of ECV while recognizing historical contributions to shed light on how and why we can use such evolutionary algorithms for CV tasks. The second paper [A2] by Peng et al. proposes an evolutionary-based neural architecture search strategy called PRE-NAS that outperforms current state-of-the-art methods. The new methodology offers high-fidelity weight inheritance over generations, which are topologically

homogeneous, circumvents bias, and leads to more accurate predictions for image classification problems. The authors perform an extensive experimentation over the NAS-Bench-201 and DARTS search spaces showing the high performance of PRE-NAS by including a large set of benchmarking methods. In the third paper [A3], Wan et al. proposed an accurate multiobjective low-rank and sparse denoising framework for hyperspectral images. The manuscript describes a subfitness strategy to achieve effective optimization by comparing the objective function values corresponding to each band for each solution. The authors developed an extensive experimental study with both simulated and real noisy images showing the effectiveness of the proposed methodology in comparison with several traditional and advanced techniques. The last paper [A4] by Bigdoli et al. presents a study of EC to efficiently process hyperdimensional digitized biopsy samples. The authors considered large-scale evolutionary multiobjective feature selection to derive a compact representation (deep embedding) useful for exploiting deep learning to accelerate image analysis and facilitate the visualization and interpretability of pathology results in a post-pandemic world. The proposal includes a novel multicriteria decision space to assist the decision maker in the Pareto set selection. Also, the method considers a patch-level visualization approach to increase the interpretability of deep features. The authors validate the complete methodology on the TCGA repository, which is the largest publicly available histopathology dataset.

The authors publishing in this special issue, and the guest editors who had the privilege of assembling this collection of papers, would like to express our gratitude to Dr. Carlos A. Coello, the Editor-in-Chief of IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION (IEEE TEVC), by approving us to compile the documents featured in this special issue, and for his constant and prompt support throughout all phases of the editorial process. Furthermore, we wish to acknowledge the invaluable assistance of Dr. Gregorio Toscano with all technical matters.

Additionally, we are grateful to all reviewers who assessed the quality of the submitted articles and took time from their busy schedules to provide constructive feedback and suggestions to the authors. We appreciate the efforts that the authors have made in preparing the manuscripts and responding to the recommendations of the reviewers and guest editors in making their work more understandable to the readership of IEEE TEVC.

We thank all of you for your help in this important milestone for the ECV community and hope that the readers will enjoy this IEEE TEVC special issue on ECV.

APPENDIX: RELATED ARTICLES

- [A1] Y. Bi, B. Xue, P. Mesejo, S. Cagnoni, and M. Zhang, "A survey on evolutionary computation for computer vision and image analysis: Past, present, and future trends," *IEEE Trans. Evol. Comput.*, early access, Nov. 9, 2022, doi: [10.1109/TEVC.2022.3220747](https://doi.org/10.1109/TEVC.2022.3220747).
- [A2] Y. Peng, A. Song, V. Ciesielski, H. M. Fayek, and X. Chang, "PRE-NAS: Evolutionary neural architecture search with predictor," *IEEE Trans. Evol. Comput.*, early access, Dec. 8, 2022, doi: [10.1109/TEVC.2022.3227562](https://doi.org/10.1109/TEVC.2022.3227562).
- [A3] Y. Wan, A. Ma, W. He, and Y. Zhong, "Accurate multi-objective low-rank and sparse model for hyperspectral image denoising method," *IEEE Trans. Evol. Comput.*, early access, May 10, 2021, doi: [10.1109/TEVC.2021.3078478](https://doi.org/10.1109/TEVC.2021.3078478).
- [A4] A. A. Bidgoli, S. Rahnamayan, T. Dehkharghanian, A. Riasatian, and H. R. Tizhoosh, "Evolutionary computation in action: Hyperdimensional deep embedding spaces of gigapixel pathology images," *IEEE Trans. Evol. Comput.*, early access, May 26, 2022, doi: [10.1109/TEVC.2022.3178299](https://doi.org/10.1109/TEVC.2022.3178299).

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Gustavo Olague (Senior Member, IEEE) was born in Chihuahua, Mexico, in 1969. He received the B.S. and M.S. degrees (with Hons.) in industrial and electronics engineering from the Instituto Tecnológico de Chihuahua, Chihuahua, in 1992 and 1995, respectively, and the Ph.D. degree in computer vision, graphics, and robotics from the Institut Polytechnique de Grenoble, Grenoble, France, and the Institut National de Recherche en Informatique et Automatique (INRIA), Grenoble Rhône-Alpes, France, in 1998.

He is a Professor with the Department of Computer Science, Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, Mexico, where he is the Director of EvoVisión Research Team. He was also an Adjunct Professor of Engineering with the Universidad Autónoma de Chihuahua, Chihuahua. He is the author of the book *Evolutionary Computer Vision* published by Springer in the Natural Computing Series. He has authored over 150 conference proceedings papers and journal articles, he co-edited special issues in *Pattern Recognition Letters*, *Evolutionary Computation* (MIT Press), and *Applied Optics*. His main research interests are evolutionary

computing and computer vision.

Prof. Olague has received numerous distinctions, among them the Talbert Abrams Award presented by the American Society for Photogrammetry and Remote Sensing for authorship and recording of current and historical engineering and scientific developments in photogrammetry; Outstanding Associate Editor of IEEE ACCESS in 2021; Best Paper Awards at major conferences, such as GECCO, European Workshop on Evolutionary Computation in Image Analysis, Signal Processing, and Pattern Recognition, and European Workshop on Evolutionary Hardware Optimization; and twice the Bronze Medal at the Humies (GECCO Award for human-competitive results produced by genetic and evolutionary computation). His research received numerous national and international grants from CONACyT, UC MEXUS, Junta de Extremadura Spain, Laboratoire Franco-Mexicain d'Informatique, INRIA (Marie Curie International Research Staff) France, and the European Union. Stanford University and Elsevier recognize him as part of the Top 2% scientists in the world in Artificial Intelligence, Image Processing, and Information Technologies (source: "Ranking of the World Scientists: World's Top 2% Scientists," University of Stanford–Elsevier). He served as the Co-Chair of the Real-World Applications Track at the leading international evolutionary computing conference, GECCO (ACM SIGEVO Genetic and Evolutionary Computation Conference). He is an Associate Editor of *Axioms*, *Engineering Applications of Artificial Intelligence*, *Neural Computing and Applications*, and IEEE ACCESS.



Mario Köppen received the master's degree in solid-state physics from the Humboldt University of Berlin, Berlin, Germany, in 1991, and the Doctoral degree (with Hons.) from the Technical University of Berlin, Berlin, in 2005, with his thesis on "Development of an Intelligent Image Processing System by Using Soft Computing."

He worked as a Scientific Assistant with the Central Institute for Cybernetics and Information Processing, Berlin, and changed his main research interests to image processing and neural networks. From 1992 to 2006, he was working with the Fraunhofer Institute for Production Systems and Design Technology, Berlin. He continued his works on the industrial applications of image processing, pattern recognition, and soft computing, especially, evolutionary computation. In 2006, he became a JSPS Fellow with the Kyushu Institute of Technology, Kitakyushu, Japan. He was a Professor with the Network Design and Research Center (NDRC) in 2008 and the Graduate School of Creative Informatics in 2013, Kyushu Institute of Technology, where he is currently conducting research in the fields of soft computing, especially for multiobjective and

relational optimization, digital convergence, and human-centered computing. He has published more than 150 peer-reviewed papers in conference proceedings, journals, and books.

Dr. Köppen was active in the organization of various conferences as the Chair or a member of the Program Committee, including the WSC Online Conference Series on Soft Computing in Industrial Applications, and the HIS Conference Series on Hybrid Intelligent Systems. He is a Founding Member of the World Federation of Soft Computing, and since 2016, he has been the Editor-in-Chief of *Applied Soft Computing* (Elsevier).



Oscar Cordon (Fellow, IEEE) received the B.S., M.S., and Ph.D. degrees in computer science from the University of Granada (UGR), Granada, Spain, in 1992, 1994, and 1997, respectively.

He was the Founder and a Leader of the Virtual Learning Center from 2001 to 2005 and the Vice President of Digital University from 2015 to 2019 with UGR. He was one of the founding researchers with the European Centre for Soft Computing, Mieres, Spain, from 2006 to 2011, being contracted as a Distinguished Affiliated Researcher until December 2015. He is currently a Professor with UGR. He has been, for over 25 years, an internationally recognized contributor to Research and Development Programs in fundamentals and real-world applications of computational intelligence. He has published over 400 peer-reviewed scientific publications, including a research book on *Genetic Fuzzy Systems* (with around 1500 citations in Google Scholar) and 121 JCR-SCI-indexed journal papers (73 in Q1 and 43 in D1), advised 20 Ph.D. dissertations, and coordinated 41 research projects and contracts (with an overall amount of > 10M€). He also has a granted international patent on an intelligent system for forensic identification commercialized

in Mexico and South Africa. He is included in the 1% of most-cited researchers in the world (source: Web of Science, with 5885 citations and H-index=41) and in the Top 2% of the most-cited researchers in the world in Artificial Intelligence (source: "Ranking of the World Scientists: World's Top 2% Scientists," University of Stanford-Elsevier). His publications had also received 15 905 citations, with H-index=62 in Google Scholar. His current research lines are on AI for forensic identification (with the UGR Physical Anthropology Lab and several international forensic labs and security forces) and agent-based modeling and social network analysis for marketing (with ROD Brand Consultants in projects for CAPSA, Mercedes, Jaguar-Land Rover, El Corte Inglés, Telefónica, Samsung, Coca Cola Europe, Cola Cao, and WiZink).

Dr. Cordon received the UGR Young Researcher Career Award in 2004, the IEEE Computational Intelligence Society (CIS) Outstanding Early Career Award in 2011 (the first such award conferred), the IFSA Award for Outstanding Applications of Fuzzy Technology in 2011, the National Award on Computer Science ARITMEL by the Spanish Computer Science Scientific Society in 2014, the IFSA Fellowship in 2019, the Recognition of the Spanish Artificial Intelligence (AI) Association (AEPIA) for his Scientific Career and the Promotion of AI in 2020, and the IX ICT Spanish Association of Universities (CRUE TIC) IT Professional Career Award in 2022, among other recognitions. He is currently or was an associate editor of 19 international journals. He was a member of the High-Level Expert Group that developed the Spanish R&D Strategy for AI by the Spanish Ministry of Science, Innovation and Universities from 2018 to 2019. He was recognized as an Outstanding Associate Editor of IEEE TRANSACTIONS ON FUZZY SYSTEMS in 2008 and IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION in 2019 and 2021. Since 2004, he has taken many different representative positions with EUSFLAT and the IEEE CIS.