

Eric Medvet  
Gisele Pappa  
Bing Xue (Eds.)

LNCS 13223

# Genetic Programming

25th European Conference, EuroGP 2022  
Held as Part of EvoStar 2022  
Madrid, Spain, April 20–22, 2022, Proceedings

evo 

 Springer

## Founding Editors

Gerhard Goos

*Karlsruhe Institute of Technology, Karlsruhe, Germany*

Juris Hartmanis

*Cornell University, Ithaca, NY, USA*


## Editorial Board Members

Elisa Bertino

*Purdue University, West Lafayette, IN, USA*

Wen Gao


*Peking University, Beijing, China*

Bernhard Steffen 

*TU Dortmund University, Dortmund, Germany*

Gerhard Woeginger 

*RWTH Aachen, Aachen, Germany*

Moti Yung 

*Columbia University, New York, NY, USA*

More information about this series at <https://link.springer.com/bookseries/558>

Eric Medvet · Gisele Pappa · Bing Xue (Eds.)

# Genetic Programming

25th European Conference, EuroGP 2022

Held as Part of EvoStar 2022

Madrid, Spain, April 20–22, 2022

Proceedings

*Editors*

Eric Medvet   
University of Trieste  
Trieste, Italy

Gisele Pappa   
Universidade Federal de Minas Gerais  
Belo Horizonte, Minas Gerais, Brazil

Bing Xue   
Victoria University of Wellington  
Wellington, New Zealand

ISSN 0302-9743                      ISSN 1611-3349 (electronic)  
Lecture Notes in Computer Science  
ISBN 978-3-031-02055-1              ISBN 978-3-031-02056-8 (eBook)  
<https://doi.org/10.1007/978-3-031-02056-8>

© The Editor(s) (if applicable) and The Author(s), under exclusive license  
to Springer Nature Switzerland AG 2022

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

The 25th European Conference on Genetic Programming (EuroGP 2022) took place at the Complutense University of Madrid, Madrid, Spain, during April 20–22, 2022. Due to the travel restrictions caused by the COVID-19 pandemic, the conference was held in a hybrid mode to allow both in-person and online attendance.

Genetic programming (GP) is a unique branch of evolutionary computation that has been developed to automatically solve design problems, in particular the computer program design, without requiring the user to know or specify the form or structure of the solution in advance. It uses the principles of Darwinian evolution to approach problems in the synthesis, improvement, and repair of computer programs. The universality of computer programs, and their importance in so many areas of our lives, means that the automation of these tasks is an exceptionally ambitious challenge with far-reaching implications. GP has attracted a significant number of researchers and a vast amount of theoretical and practical contributions are available, as shown by consulting the GP bibliography.<sup>1</sup>

Since the first EuroGP event in Paris in 1998, EuroGP has been the only conference exclusively devoted to the evolutionary design of computer programs and other computational structures. In fact, EuroGP represents the single largest venue at which GP results are published. It plays an important role in the success of the field, by serving as a forum for expressing new ideas, meeting fellow researchers, and initiating collaborations. It attracts scholars from all over the world. In a friendly and welcoming atmosphere authors present the latest advances in the field and GP-based solutions to complex real-world problems.

EuroGP 2022 received 35 submissions from around the world. The papers underwent a rigorous double-blind peer review process, each being reviewed by multiple members of an international Program Committee.

Among the papers presented in this volume, 12 were accepted for full-length oral presentation (34% acceptance rate) and seven as short talks. In 2022, papers submitted to EuroGP could also be assigned to the “Evolutionary Machine Learning Track”. Among the 35 submissions, the authors of eight papers indicated their papers fit the track, with two accepted for full-length oral presentation and four as short talks. Authors of both categories of papers also had the opportunity to present their work in poster sessions to promote the exchange of ideas in a carefree manner.

The wide range of topics in this volume reflects the current state of research in the field. The collection of papers covers interesting topics including developing new variants of GP algorithms, synthesizing computer programs with GP, and evolving neural networks using GP, as well as exploring GP-based explainable or interpretable methods and applying GP to address complex real-world problems.

Together with three other co-located evolutionary computation conferences (EvoCOP 2022, EvoMUSART 2022, and EvoApplications 2022), EuroGP 2022 was part of

---

<sup>1</sup> <http://iinwww.ira.uka.de/bibliography/Ai/genetic.programming.html>.

the Evo\* 2022 event. This meeting could not have taken place without the help of many people. The EuroGP Organizing Committee is particularly grateful to the following:

- SPECIES, the Society for the Promotion of Evolutionary Computation in Europe and its Surroundings, which aims to promote evolutionary algorithmic thinking within Europe and wider, and more generally to promote inspiration of parallel algorithms derived from natural processes.
- The high-quality and diverse EuroGP 2022 Program Committee. Each year the members give freely of their time and expertise in order to maintain high standards in EuroGP, providing constructive feedback to help the authors to improve their papers.
- Nuno Lourenço (University of Coimbra, Portugal) for his dedicated work with the submission system.
- João Correia (University of Coimbra, Portugal), Ignacio Hidalgo (Universidad Complutense de Madrid, Spain), and Francisco Chicano (University of Málaga, Spain) for their great work on the Evo\* publicity, social media service, and website.
- Sérgio Rebelo (University of Coimbra, Portugal), João Correia (University of Coimbra, Portugal), and Tiago Martins (University of Coimbra, Portugal) for their important graphic design work.
- The local organizing team, in particular Iñaki Hidalgo (Universidad Complutense Madrid, Spain) for his proactivity in getting us a new venue for the conference. We also thank Federico Divina (Universidad Pablo de Olavide, Spain) as the original local organizing chair for Seville, Spain, but unfortunately the conference had to be moved due to the COVID-19 pandemic.
- Our invited speakers, Gabriela Ochoa and Pedro Larrañaga, who gave inspiring and enlightening keynote talks.
- Finally, we express our continued appreciation to Anna I. Esparcia-Alcázar (Universitat Politècnica de València, Spain), from SPECIES, whose considerable efforts in managing and coordinating Evo\* helped towards building a unique, vibrant, and friendly atmosphere.

April 2022

Eric Medvet  
Gisele Pappa  
Bing Xue

# Organization

## Program Co-chairs

Eric Medvet  
Gisele Pappa

University Degli Studi di Trieste, Italy  
Universidade Federal de Minas Gerais, Brazil

## Publication Chair

Bing Xue

Victoria University of Wellington, New Zealand

## Local Chair

Iñaki Hidalgo

Universidad Complutense Madrid, Spain

## Publicity Chair

João Correia

Victoria University of Wellington, New Zealand

## Conference Administration

Anna I. Esparcia-Alcazar

Evostar Coordinator

## Program Committee

Ignacio Arnaldo  
R. Muhammad Atif Azad  
Wolfgang Banzhaf  
Heder Bernardino  
Anthony Brabazon  
Stefano Cagnoni  
Mauro Castelli  
Ernesto Costa  
Antonio Della Cioppa  
Francisco Fernandez de Vega  
James Foster  
Jin-Kao Hao  
Erik Hemberg  
Malcolm Heywood  
Ting Hu

Massachusetts Institute of Technology, USA  
Birmingham City University, UK  
Michigan State University, USA  
Federal University of Juiz de Fora, Brazil  
University College Dublin, Ireland  
University of Parma, Italy  
Universidade Nova de Lisboa, Portugal  
University of Coimbra, Portugal  
University of Salerno, Italy  
Universidad de Extremadura, Spain  
University of Idaho, USA  
University of Angers, France  
Massachusetts Institute of Technology, USA  
Dalhousie University, Canada  
Memorial University, Canada



Domagoj Jakobović	University of Zagreb, Croatia
Krzysztof Krawiec	Poznan University of Technology, Poland
Andrew Lensen	Victoria University of Wellington, New Zealand
Nuno Lourenço	University of Coimbra, Portugal
Penousal Machado	University of Coimbra, Portugal
James McDermott	University College Dublin, Ireland
Julian Miller	University of York, UK
Julio Cesar Nievola	Pontificia Universidade Catolica do Parana, Brazil
Michael O'Neill	University College Dublin, Ireland
Una-May O'Reilly	Massachusetts Institute of Technology, USA
Tomasz Pawlak	Poznan University of Technology, Poland
Stjepan Picek	Delft University of Technology, The Netherlands
Clara Pizzuti	ICAR-CNR, Italy
Peter Rockett	University of Sheffield, UK
Lukas Sekanina	Brno University of Technology, Czech Republic
Sara Silva	University of Lisbon, Portugal
Moshe Sipper	Ben-Gurion University, Israel
Lee Spector	Hampshire College, USA
Jerry Swan	University of York, UK
Ivan Tanev	Doshisha University, Japan
Ernesto Tarantino	ICAR-CNR, Italy
Leonardo Trujillo	Instituto Tecnológico de Tijuana, Mexico
Leonardo Vanneschi	Universidade Nova de Lisboa, Portugal
Marco Virgolin	Centrum Wiskunde & Informatica, The Netherlands
Man Leung Wong	Lingnan University, Hong Kong, SAR China
Bing Xue	Victoria University of Wellington, New Zealand
Mengjie Zhang	Victoria University of Wellington, New Zealand

# Contents

## Long Presentations

Evolving Adaptive Neural Network Optimizers for Image Classification . . . . .	3
<i>Pedro Carvalho, Nuno Lourenço, and Penousal Machado</i>	
Combining Geometric Semantic GP with Gradient-Descent Optimization . . . . .	19
<i>Gloria Pietropolli, Luca Manzoni, Alessia Paoletti, and Mauro Castelli</i>	
One-Shot Learning of Ensembles of Temporal Logic Formulas for Anomaly Detection in Cyber-Physical Systems . . . . .	34
<i>Patrick Indri, Alberto Bartoli, Eric Medvet, and Laura Lenzi</i>	
Multi-objective Genetic Programming with the Adaptive Weighted Splines Representation for Symbolic Regression . . . . .	51
<i>Christian Raymond, Qi Chen, Bing Xue, and Mengjie Zhang</i>	
SLUG: Feature Selection Using Genetic Algorithms and Genetic Programming . . . . .	68
<i>Nuno M. Rodrigues, João E. Batista, William La Cava, Leonardo Vanneschi, and Sara Silva</i>	
Evolutionary Design of Reduced Precision Levodopa-Induced Dyskinesia Classifiers . . . . .	85
<i>Martin Hurta, Michaela Drahosova, Lukas Sekanina, Stephen L. Smith, and Jane E. Alty</i>	
Using Denoising Autoencoder Genetic Programming to Control Exploration and Exploitation in Search . . . . .	102
<i>David Wittenberg</i>	
Program Synthesis with Genetic Programming: The Influence of Batch Sizes . . . . .	118
<i>Dominik Sobania and Franz Rothlauf</i>	
Genetic Programming-Based Inverse Kinematics for Robotic Manipulators . . . .	130
<i>Julia Reuter, Christoph Steup, and Sanaz Mostaghim</i>	
On the Schedule for Morphological Development of Evolved Modular Soft Robots . . . . .	146
<i>Giorgia Nadizar, Eric Medvet, and Karine Miras</i>	

An Investigation of Multitask Linear Genetic Programming for Dynamic Job Shop Scheduling ..... 162  
*Zhixing Huang, Fangfang Zhang, Yi Mei, and Mengjie Zhang*

Cooperative Co-evolution and Adaptive Team Composition for a Multi-rover Resource Allocation Problem ..... 179  
*Nicolas Fontbonne, Nicolas Maudet, and Nicolas Bredeche*

**Short Presentations**

Synthesizing Programs from Program Pieces Using Genetic Programming and Refinement Type Checking ..... 197  
*Sabrina Tseng, Erik Hemberg, and Una-May O’Reilly*

Creating Diverse Ensembles for Classification with Genetic Programming and Neuro-MAP-Elites ..... 212  
*Kyle Nickerson, Antonina Kolokolova, and Ting Hu*

Evolving Monotone Conjunctions in Regimes Beyond Proved Convergence .... 228  
*Pantia-Marina Alchirch, Dimitrios I. Diochnos, and Katia Papakonstantinopoulou*

Accurate and Interpretable Representations of Environments with Anticipatory Learning Classifier Systems ..... 245  
*Romain Orhand, Anne Jeannin-Girardon, Pierre Parrend, and Pierre Collet*

Exploiting Knowledge from Code to Guide Program Search ..... 262  
*Dirk Schweim, Erik Hemberg, Dominik Sobania, and Una-May O’Reilly*

Multi-objective Genetic Programming for Explainable Reinforcement Learning ..... 278  
*Mathurin Videau, Alessandro Leite, Olivier Teytaud, and Marc Schoenauer*

Permutation-Invariant Representation of Neural Networks with Neuron Embeddings ..... 294  
*Ryan Zhou, Christian Muise, and Ting Hu*

**Author Index** ..... 309