CONFERENCE PROGRAM

Genetic and Evolutionary Computation Conference 2025 (GECCO 2025)

Málaga, Spain, July 14–18, 2025

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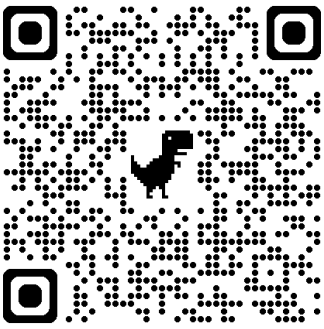

Association for Computing Machinery

Advancing Computing as a Science & Profession

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General Information

Welcome

Dear GECCO attendees,

Welcome to the Genetic and Evolutionary Computation Conference (GECCO). GECCO 2025 returns to Europe, to the vibrant city of Málaga in southern Spain. Bathed by the Mediterranean Sea, Málaga offers temperate sunny weather and a rich cultural life, with numerous historic monuments including the Roman Theatre, the Moorish Fortress, and the Cathedral. As the hometown of Pablo Ruiz Picasso, Málaga is also known as the City of Museums, with over 30 museums devoted to painting, sculpture, music, jewelry, and sports. This year's GECCO continues the hybrid mode to support participants across the globe.

GECCO is the largest peer-reviewed conference in the field of Evolutionary Computation, and the main conference of the Special Interest Group on Genetic and Evolutionary Computation (SIGEVO) of the Association for Computing Machinery (ACM). GECCO implements a rigorous review process to identify the most important and technically sound papers to publish. The technical program is divided into 14 tracks reflecting all aspects of our field. Each of these tracks was chaired by two domain experts who managed the review process and made the decisions about the papers in coordination with the Editor-in-Chief. GECCO 2025 received 501 papers and accepted 181, resulting in a 36.1 % acceptance rate. Those papers will be presented during the conference, either in person or remotely. 30 papers were nominated for the Best Paper Award and will be presented in dedicated sessions. We decided to continue the Outstanding Reviewer awards introduced at GECCO 2023; the 2025 awardees will be announced during the closing session. In addition, we accepted 40 Hot-off-the-Press (HOP) submissions, 13 Late Breaking Abstracts (LBA) and 218 posters that will be presented during the conference. GECCO 2025 also includes 35 tutorials, selected from among 58 proposals, as well as 19 workshops reflecting the most relevant topics in our field. They will take place during the first two days of the hybrid conference.

We are excited to welcome Maria Amparo Alonso Betanzos from the University of A Coruña and Javier Del Ser from the University of the Basque Country as keynote speakers. We are honored that Marc Schoenauer will give this year's SIGEVO keynote. We would like to thank all authors for submitting their work to GECCO 2025. Special thanks to the tutorial speakers, as well as the workshop and competition organizers.

Organizing a conference like GECCO is a tremendous task that relies on many people. We would like to thank all the chairs of our events: tracks, posters, workshops, student workshop, tutorials, competitions, LBA, and HOP. We also thank the organizers of Humies, Evolutionary Computation in Practice, Job Market, SIGEVO Summer School, and Women+@GECCO, as well as the members of our program committee.

Many other members of the organization team deserve recognition: the GECCO local chairs, local organization team, and dozens of student volunteers that help run the hybrid conference, as well as the chairs of all the different elements that hybrid GECCO is made of: Hybridization, Hybrid Scheduling, Proceedings, Student Affairs, Electronic Media, Publicity, Sponsorships, Sustainability, and SIGEVO Electronic Media Affairs. It is also worth mentioning Roxane Rose and Stephanie Matal of Executivevents for their hard work with the registrations and logistics, Leah Glick, Mark Montague, and Taylor Carr of the Linklings team for their support with the submission and review management system, Robert Mercado and Daniel Vogt from Whova for their assistance with the event management system, as well as Maribel Tineo, Diana Brantuas and John Otero of ACM for their organizational support. Finally, we also thank Anne Auger, Manuel López-Ibáñez, Markus Wagner, and Peter Bosman from SIGEVO for their valuable advice and guidance.

Enjoy the conference!

Bogdan Filipič
GECCO 2025 General Chair
Jožef Stefan Institute, Slovenia

Gabriela Ochoa
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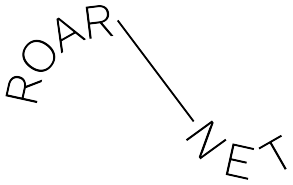

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Leonardo Vanneschi, *Universidade Nova de Lisboa, Portugal*
Swetha Varadarajan, *SASTRA University, India*
Denis Vargas, *Centro Federal de Educação Tecnológica de Minas Gerais, Brazil*
Danilo Vasconcellos Vargas, *Kyushu University and MiraiX, Japan*

Zdenek Vasicek, *Brno University of Technology, Czechia*
Vassilis Vassiliades, *CYENS Centre of Excellence, Cyprus*
Igor Vatolkin, *RWTH Aachen University, Germany*
Nadarajen Veerapen, *Université de Lille, France*
Sébastien Verel, *Université du Littoral Côte d'Opale, France*
Diederick Vermetten, *Sorbonne Université, France*
Ana Viana, *INESC TEC/Polytechnic of Porto, Portugal*
Petra Vidnerova, *Institute of Computer Science of ASCR, Czechia*
Adam Viktorin, *Tomas Bata University in Zlín, Czechia*
Esther Villar-Rodriguez, *Tecnalia Research & Innovation, Spain*
Vanessa Volz, *Centrum Wiskunde & Informatica, Netherlands*
Anya Vostinar, *Carleton College, USA*
Markus Wagner, *Monash University, Australia*
Stefan Wagner, *University of Applied Sciences Upper Austria, Austria*
David J. Walker, *University of Exeter, UK*
Sean Walton, *Swansea University, UK*
Handing Wang, *Xidian University, China*
Hao Wang, *Leiden University and Leiden Institute of Advanced Computer Science, Netherlands*
Shaolin Wang, *Zhejiang Geely Holding Group and Victoria University of Wellington, China*
Shuai Wang, *Sun Yat-sen University, China*
Rolf Wanka, *University of Erlangen-Nuremberg, Germany*
Elizabeth Wanner, *Aston University, Brazil*
John Alasdair Warwicker, *Karlsruhe Institute of Technology, Germany*
Thomas Weise, *Hefei University/Institute of Applied Optimization, China*
Bernhard Werth, *University of Applied Sciences Upper Austria and Johannes Kepler University Linz, Austria*
Simon Wessing, *Technische Universität Dortmund, Germany*
Marcel Wever, *Leibniz University Hannover and L3S Research Center, Germany*
Peter Alexander Whigham, *University of Otago, New Zealand*
Darrell Whitley, *Colorado State University, USA*
Simon Wietheger, *Vienna University of Technology, Austria*
Josh Wilkerson, *NAVAIR, USA*
Dennis Wilson, *Université de Toulouse, France*
Garnett Wilson, *Dalhousie University, Canada*
Stephan Winkler, *University of Applied Sciences Upper Austria and Johannes Kepler University Linz, Austria*
Carsten Witt, *Technical University of Denmark, Denmark*
Man Leung Wong, *Lingnan University, Hong Kong*
Yunshuang Xiao, *Université libre de Bruxellles, Belgium*
Huayang Xie, *Bastion Security Group, New Zealand*
Yu Xie, *Shanxi University, China*
Yue Xie, *University of Cambridge, UK*
Huanlai Xing, *Southwest Jiaotong University, China*
Ying Xu, *Hunan University, China*
Bing Xue, *Victoria University of Wellington, New Zealand*
Xingsi Xue, *Fujian University of Technology, China*
Yinxing Xue, *University of Science and Technology of China, China*
Yu Xue, *Nanjing University of Information Science and Technology, China*
Takeshi Yamada, *Kindai University, Japan*
Anil Yaman, *Vrije Universiteit Amsterdam, Netherlands*
Xiankun Yan, *University of Adelaide, Australia*
Kaifeng Yang, *Leiden University, Austria*
Qiang Yang, *Nanjing University of Information Science and Technology, China*
Estefania Yap, *Monash University, Australia*
Furong Ye, *Leiden University, Netherlands*
Iryna Yevseyeva, *De Montfort University, UK*
Wenjie Yi, *Shenzhen University, China*
Aisha Yousuf, *Raytheon BBN Technologies, USA*
Tian-Li Yu, *National Taiwan University, Taiwan*
Gonglin Yuan, *Victoria University of Wellington, New Zealand*
Martin Zaefferer, *DHBW Ravensburg, Germany*
Amelia Zafra, *University of Córdoba, Spain*
Daniela Zaharie, *West University of Timisoara, Romania*
Aleš Zamuda, *University of Maribor, Slovenia*
Saúl Zapotecas-Martínez, *Instituto Nacional de Astrofísica, Óptica y Electrónica, Mexico*
Ciprian Zavoianu, *Robert Gordon University, UK*
Hector Zenil, *Cambridge University, UK*
Zhi-Hui Zhan, *Nankai University, China*
Fangfang Zhang, *Victoria University of Wellington, New Zealand*
Mengjie Zhang, *Victoria University of Wellington, New Zealand*
Qingfu Zhang, *City University of Hong Kong, Hong Kong*
Xingyi Zhang, *Anhui Unversity, China*
Weijie Zheng, *Harbin Institute of Technology, China*
Huang Zhixing, *Victoria University of Wellington, New Zealand*
Jinghui Zhong, *South China University of Technology, Singapore*
Yan Zhou, *Shenyang Jianzhu University and Northeastern University, China*
Jason Paul Zutty, *Georgia Tech Research Institute, USA*

Schedules and Floor Plan

Schedule at a Glance

Monday, July 14	Tuesday, July 15	Wednesday, July 16	Thursday, July 17	Friday, July 18
Registration 08:30–19:00	**Registration** 08:30–19:00	**Registration** 08:30–19:00	**Registration** 09:30–19:00	**Registration** 09:30–13:00
Workshops and Tutorials 09:30–11:20	Workshops and Tutorials 09:30–11:20	Opening Session 09:45–10:30	Poster Session II **Online**: 09:30–10:30	Paper Sessions and HOP 10:00–11:30
		Invited Keynote **A. Alonso Betanzos** 10:30–11:30	Invited Keynote **Javier Del Ser** 10:30–11:30	
Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
Workshops, Tutorials and Competitions 11:40–13:30	Workshops and Tutorials 11:40–13:30	Paper Sessions, HOP and ECiP 12:00–13:30	Paper Sessions, HOP and Impact 12:00–13:30	SIGEVO Keynote **Marc Schoenauer** 12:00–13:00
Lunch (on your own) 13:30–15:00	Lunch (on your own) 13:30–15:00	Lunch (on your own) 13:30–15:30	Lunch (on your own) 13:30–15:30	Awards and Closing 13:10–14:30
Workshops, Tutorials and Competitions 15:00–16:50	Workshops and Tutorials 15:00–16:50	Paper Sessions and HOP 15:30–17:00	Paper Sessions and Job Market 15:30–17:00	
Coffee break	Coffee break	Coffee break	Coffee break	
Workshops and Tutorials 17:10–19:00	Workshops and Tutorials 17:10–19:00	Paper Sessions and HOP 17:30–19:00	Humies 17:30–19:00	
Women+@GECCO 19:10–21:10		Poster Session I **Online**: 19:30–20:30 **Onsite**: 19:30–22:00 Buffet Dinner (Patio Inglés) 20:00–21:00	Social Dinner (Baños del Carmen) 20:30–00:00	

- All sessions take place on Floor −1 (access next to reception), except those in Room Jábega (ground floor).
- Opening, Closing, Keynotes, Women+@GECCO, and Humies are in Arlequín + Tauromaquia.
- Poster Session I is in Patio Inglés.
- Both Poster Sessions include posters from tracks, late-breaking abstracts, and competitions.
- Coffee breaks are served in Patio Inglés.
- Lunch is on your own: outside food is not allowed in the hotel.

Parallel Sessions on Monday, July 14

	09:30–11:20	11:40–13:30	15:00–16:50	17:10–19:00
Arlequín & Tauromaquia		Competitions	Competitions	Student Workshop
Azul	*Miikkulainen, Risi, Ha, Tang*: Evolution of Neural Networks	10th Workshop on Industrial Applications of Metaheuristics	10th Workshop on Industrial Applications of Metaheuristics	*Sudholt, Squillero*: Theory and Practice of Population Diversity in Evolutionary Computation
Minotauro	Open Source Software for Evolutionary Computation	Good Benchmarking Practices for Evolutionary Computation	*Ishibuchi, Pang*: Fair Performance Comparison of Evolutionary Multi-Objective Algorithms	*Pillay*: Advances in Evolutionary Hyper-Heuristics
Malagueta	*Deb, Saxena, Mittal*: Machine Learning Assisted Evolutionary Multi- and Many-objective Optimization	*Shir*: Introductory Mathematical Programming for EC	*Li*: Combinatorial Optimisation Can be Different from Continuous Optimisation for MOEAs	*Kononova, van Stein*: Structural Bias in Optimisation Algorithms
Alborán	*Vermetten, Doerr, de Nobel, Bäck*: Benchmarking Single- and Multi-Objective Optimization Algorithms: How to Make Your Experimental Data More Valuable	*Jaszkiewicz, Zielniewicz*: Recent Developments in Data Structures and Algorithms for Evolutionary Multiobjective Optimization	*Moraglio, Chicano*: Introduction to Quantum Optimization	*Machado, Correia*: Evolutionary Art and Design in the Machine Learning Era
Mena	Evolutionary Computing and Explainable AI | Evolutionary Computation and Decision Making	28th International Workshop on Evolutionary Rule-based Machine Learning	28th International Workshop on Evolutionary Rule-based Machine Learning	*Whitley*: New, More Efficient Crossover and Local Search Operators for Recombination Lattices
Alcazaba	*Thierens, Bosman*: Model-Based Evolutionary Algorithms	*Cagnoni, Bi, Sun*: Evolutionary Computation and Evolutionary Deep Learning for Image Analysis, Signal Processing and Pattern Recognition	*Mei, Raidl*: Evolutionary Computation Meets Machine Learning for Combinatorial Optimization	*Couckuyt, Rojas Gonzalez, Branke*: Bayesian Optimization
Gibralfaro	*Xu, Li, Sun, Ye*: Intelligent Evolution Optimization: Guided from Deep Learning to Large Language Model	*Li*: Decomposition Multi-objective Optimization: What We Know from the Literature, and What We Are NOT Clear from a Data Science Perspective	*Doerr*: Tutorial: A Gentle Introduction to Theory (for Non-Theoreticians)	*Urbanowicz*: Automated Machine Learning Tools for Data Science, Modeling, and Algorithm Benchmarking
Jábega	*Lucas, Goodman, Tot*: Statistical Forward Planning Algorithms		*Rothlauf*: Representations for Evolutionary Algorithms	*Đurasević, Gil Gala, Jakobović, Mei*: Genetic Programming as a Hyper-Heuristic for Solving Combinatorial Optimisation Problems

Introductory Tutorial | Advanced Tutorial | Workshop | Competitions

Parallel Sessions on Tuesday, July 15

	09:30–11:20	11:40–13:30	15:00–16:50	17:10–19:00
Arlequín & Tauromaquia	Student Workshop			
Azul	*Cenikj, Nikolikj, Eftimov*: Recent Advances in Meta-features Used for Representing Black-box Single-objective Continuous Optimization	Workshop on Black Box Optimization Benchmarking 2025	Workshop on Black Box Optimization Benchmarking 2025	Neuroevolution at Work
Minotauro	Decomposition Techniques in Evolutionary Optimization	Graph-based Genetic Programming	Workshop on Quantum Optimization	Workshop on Quantum Optimization
Malagueta	Workshop on Surrogate-Assisted Evolutionary Optimisation	Workshop on Surrogate-Assisted Evolutionary Optimisation	Landscape-Aware Heuristic Search	Large Language Models for and with Evolutionary Computation Workshop
Alborán	*Neumann, Neumann, Singh*: Evolutionary Computation for Stochastic Problems	15th Workshop on Evolutionary Computation for the Automated Design of Algorithms	Evolving Self-Organisation	Evolving Self-Organisation
Mena	Analysing Algorithmic Behaviour of Optimisation Heuristics	Evolutionary Computing and Explainable AI	Symbolic Regression Workshop	Symbolic Regression Workshop
Alcazaba	*Qian*: Pareto Optimization for Subset Selection: Theories and Practical Algorithms	*Beyer*: What You Always Wanted to Know About Evolution Strategies, But Never Dared to Ask	Evolutionary Generative Models	*Banzhaf, Hu*: Linear Genetic Programming
Gibralfaro	*XUE, Zhang*: Evolutionary Computation for Feature Selection and Feature Construction	*Toutouh, O'Reilly*: Coevolutionary Computation for Adversarial Deep Learning	*Rook, López-Ibáñez*: Advanced Use of Automatic Algorithm Configuration: Single- and Multi-Objective Approaches	*Coello Coello*: Constraint-Handling Techniques used with Evolutionary Algorithms
Jábega	*Kalkreuth, Cussat-Blanc, Wilson*: Cartesian Genetic Programming: From Foundations to Recent Developments and Applications	*Flageat, Lim, Templier, Cully*: Evolutionary Reinforcement Learning		

Introductory Tutorial
Advanced Tutorial
Specialized Tutorial
Workshop

Parallel Sessions on Wednesday, July 16 – Friday, July 18

	Wednesday, July 16			Thursday, July 17		Friday, July 18
	12:00–13:30	15:30–17:00	17:30–19:00	12:00–13:30	15:30–17:00	10:00–11:30
Arlequín & Tauromaquia	HOP 1 (p. 91)	HOP 2 (p. 91)	HOP 3 (p. 92)	HOP 4 (p. 92)	Job Market (p. 99)	HOP 5 (p. 93)
Azul	EML 1 (p. 56)	EML 2 (p. 58)	ECOM 2 (p. 61)	ECOM 3 (p. 63)	EML 4 (p. 66)	EML 5 (p. 69)
Minotauro	★ RWA 1 (p. 56)	★ EMO 1 (p. 58)	★ GA 1 + SI 3 (p. 61)	★ + ☆ GP 3 + Impact (p. 63)	★ ECOM 4 (p. 66)	GP 4 (p. 69)
Malagueta	ECiP (p. 97)	RWA 2 (p. 59)	RWA 3 (p. 61)	RWA 4 (p. 64)	RWA 5 (p. 67)	RWA 6 (p. 69)
Alborán	GP 1 (p. 56)	GP 2 (p. 59)	EMO 2 (p. 62)	EMO 3 (p. 64)	EMO 4 (p. 67)	EMO 5 (p. 69)
Mena	★ BBSR 1 + ENUM 1 (p. 57)	★ GECH 1 + Theory 2 (p. 59)	★ EML 3 (p. 62)	★ CS 1 + NE 1 (p. 64)	★ L4EC 4 (p. 67)	ECOM 5 (p. 70)
Alcazaba	Theory 1 (p. 57)	ECOM 1 (p. 60)	GECH 2 (p. 62)	GECH 3 (p. 65)	ENUM 2 (p. 68)	ENUM 3 (p. 70)
Gibralfaro	SI 1 (p. 57)	SI 2 (p. 60)	BBSR 2 (p. 62)	BBSR 3 (p. 65)	NE 2 (p. 68)	NE 3 (p. 70)
Jábega	L4EC 1 (p. 58)	L4EC 2 (p. 60)	L4EC 3 (p. 63)	GA 2 (p. 65)	CS 2 (p. 68)	CS 3 (p. 71)

Paper Session

★ Session with Best Paper Nominees

Hot off the Press

Evolutionary Computation in Practice

Job Market

Abbreviations and Symbols

Abbreviations

BBSR	Benchmarking, Benchmarks, Software, and Reproducibility
CS	Complex Systems
ECiP	Evolutionary Computation in Practice
ECOM	Evolutionary Combinatorial Optimization and Metaheuristics
EML	Evolutionary Machine Learning
EMO	Evolutionary Multiobjective Optimization
ENUM	Evolutionary Numerical Optimization
GA	Genetic Algorithms
GECH	General Evolutionary Computation and Hybrids
GP	Genetic Programming
HOP	Hot Off the Press
L4EC	Learning for Evolutionary Computation
NE	Neuroevolution
RWA	Real World Applications
SI	Swarm Intelligence

Symbols

☆ SIGEVO Impact Award
★ Best Paper Award nominee
✶ Best Student Workshop Paper Award nominee

ACM Digital Library link

Onsite presentation
Online presentation
▶ Video presentation

Presentation will be recorded
Presentation will not be recorded

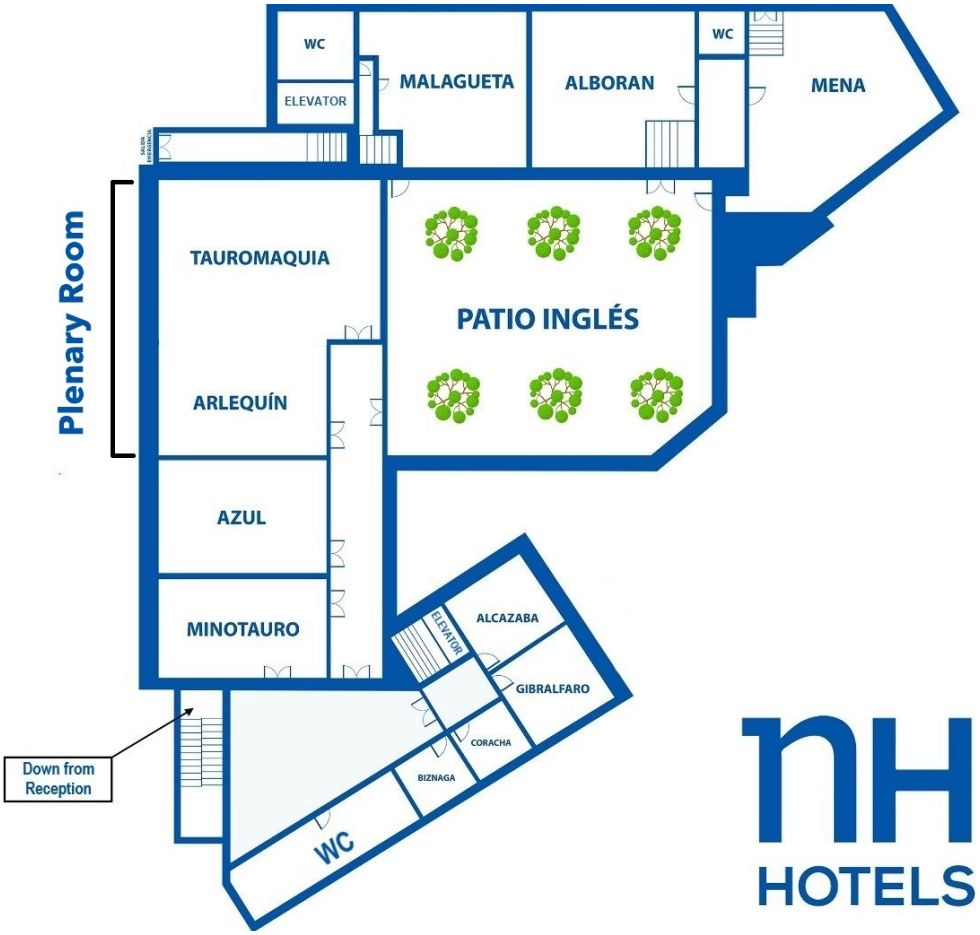
Time Zone

All times in this program are listed in CEST (UTC + 2 hours), Málaga's time zone during the conference. For convenience, time differences with respect to some major cities around the world are provided below:

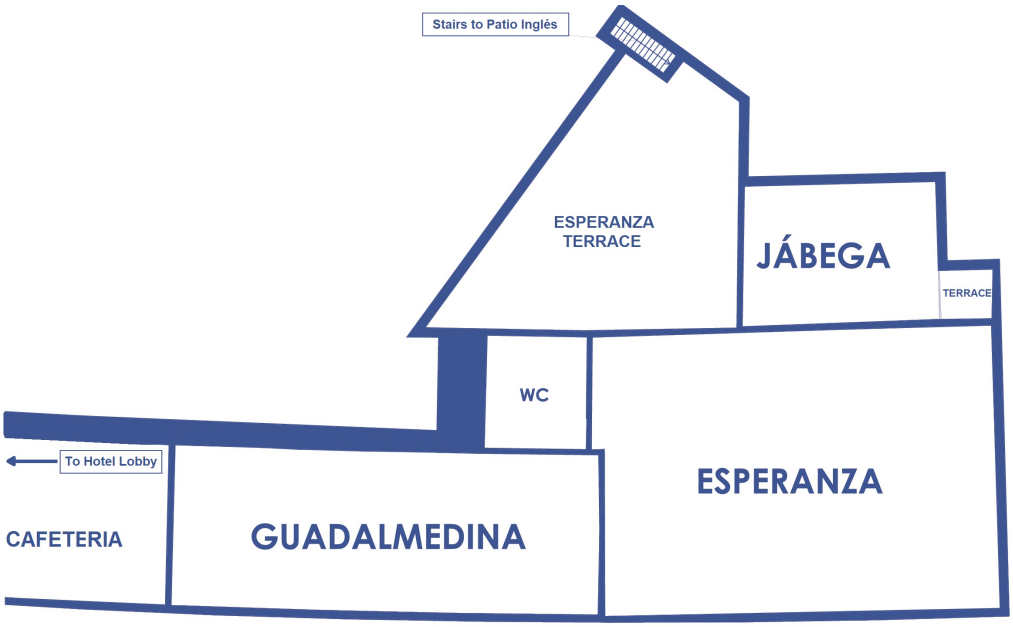
- For Los Angeles/San Francisco (USA), please subtract 9 hours.
- For Vancouver (Canada), please subtract 9 hours.
- For Mexico City (Mexico), please subtract 8 hours.
- For Chicago/Houston (USA), please subtract 7 hours.
- For New York (USA), please subtract 6 hours.
- For Toronto (Canada), please subtract 6 hours.
- For Santiago (Chile), please subtract 6 hours.
- For São Paulo/Rio de Janeiro (Brazil), please subtract 5 hours.
- For London (UK), please subtract 1 hour.
- For Lisbon (Portugal), please subtract 1 hour.
- For Athens (Greece), please add 1 hour.
- For Istanbul (Turkey), please add 1 hour.
- For Moscow (Russia), please add 1 hour.
- For New Delhi (India), please add 3.5 hours.
- For Shanghai/Beijing (China), please add 6 hours.
- For Taipei (Taiwan), please add 6 hours.
- For Tokyo (Japan), please add 7 hours.
- For Sydney/Melbourne (Australia), please add 8 hours.
- For Wellington (New Zealand), please add 10 hours.

Floor Plans

Floor -1



Ground Floor



Keynotes

GECCO Keynote

Rethinking Efficiency in Machine Learning

Wednesday, July 16, 10:30–11:30
Chair: Gabriela Ochoa

Maria Amparo Alonso Betanzos, *CITIC-University of A Coruña, Spain*

The success of Artificial Intelligence (AI) has so far relied on developing increasingly precise models. However, this has come at the cost of greater complexity, requiring a higher number of parameters to estimate. As a result, model transparency and explainability have diminished, while the energy demands for training and deployment have skyrocketed. It is estimated that by 2030, AI could account for more than 30% of the planet's total energy consumption.

In this context, green and responsible AI has emerged as a promising alternative, characterized by lower carbon footprints, reduced model sizes, decreased computational complexity, and improved transparency. Various strategies can help achieve these goals, such as improving data quality, developing more energy-efficient execution models, and optimizing energy efficiency in model training and inference. These innovation approaches highlight the potential of green AI to challenge the prevailing paradigm of ever-growing models.

Biosketch: Amparo Alonso Betanzos is a Full Professor in the area of Computer Science and Artificial Intelligence at CITIC-University of A Coruña (UDC), where she coordinates the LIDIA group (Artificial Intelligence R&D Laboratory). She is also a Professor II at the Department of Psychology, NTNU Tröndheim. Her research lines are the development of Scalable Machine Learning models, Reliable and Explainable Artificial Intelligence, and Green AI, among others.

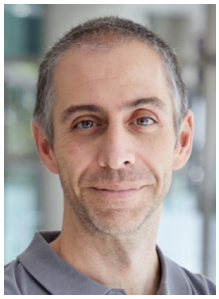
She was formerly President of the Spanish Association of Artificial Intelligence (2013–21). She is a Senior Member of IEEE and ACM and Royal Spanish Academy of Exact, Physical, and Natural Sciences. She has participated as a member of the Working Group on AI of the Spanish Ministry of Science, Innovation, and Universities, collaborating in drafting the Spanish R&D&I Strategy in Artificial Intelligence in 2018. She is currently a member of CAIA, the Advisory Council on Artificial Intelligence of the Ministry of Digital Transformation and Public Function of the Government of Spain, since 2020, as well as a Member of the Spanish Research Ethics Committee of the Ministry of Science, Innovation and Universities of the Government of Spain, since 2023.

GECCO Keynote

Evolutionary Computation as a Path to Safe, Trustworthy, and Responsible General-Purpose Artificial Intelligence

Thursday, July 17, 10:30–11:30
Chair: Carlos Cotta

Javier Del Ser, *TECNALIA, Basque Research & Technology Alliance, and University of the Basque Country, Spain*



As AI systems grow in capability and autonomy, concerns around safety, alignment, and trust have taken center stage. Issues such as goal misalignment, vulnerability to adversarial attacks, and the inability to generalize reliably in open-world settings are no longer theoretical: they are pressing challenges with real-world implications. At the same time, global regulatory efforts, including the EU AI Act and other emerging international frameworks, are setting strict expectations for transparency, robustness, and accountability in AI development. This keynote provides an accessible introduction to the key pillars of safe, trustworthy, responsible, and general-purpose AI, tailored for newcomers to the field. It highlights how evolutionary computation offers a powerful, underexplored toolkit for meeting safety and trustworthy requirements. With its emphasis on diversity, adaptability, and robustness, evolutionary computation can contribute to safer learning, better generalization, and more resilient systems. The talk will bridge technical concepts with regulatory perspectives, illustrating how evolutionary approaches can help meet both the ethical and legal requirements driving the future of responsible AI systems.

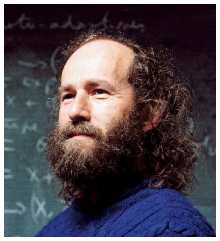
Biosketch: Javier (Javi) Del Ser holds a Telecommunications Engineering degree from the University of the Basque Country (2003), a Ph.D. in Control Engineering and Industrial Electronics from the University of Navarra (2006, Cum Laude), and a second Ph.D. in Information and Communication Technologies from the University of Alcalá de Henares (2013, Cum Laude and recipient of the Extraordinary PhD Award). He is a Principal Investigator in Applied Artificial Intelligence and Chief AI Scientist at TECNALIA. Additionally, he is a Distinguished Researcher at the Department of Mathematics of the University of the Basque Country (UPV/EHU), and a Visiting Professor at the University of Granada (Spain) and the University of Natural Resources and Life Sciences, Vienna (Austria). His research focuses on Artificial Intelligence, Machine Learning and Evolutionary Computation, with applications in practical modeling and optimization challenges across diverse sectors, including industry, healthcare, transportation, energy, and mobility. He has coauthored more than 450 scientific papers, edited 6 books, supervised 20 doctoral theses, and contributed to more than 60 research projects and industrial contracts. He has been included in the list of the top 2% most influential AI researchers worldwide by Stanford University, with a yearly rate of ca. 7,500 citations to his authored works (2024). He was also part of the team that developed the R&D&I strategy in Artificial Intelligence for the Government of Spain (2019). He is a Senior Member of IEEE and a recipient of several awards for his research trajectory, including the BRTA Award (among more than 3,000 researchers in the Basque R&D network) and the IJCNN 2024 Best Paper Award.

sigevo KEYNOTE

Evolutionary Computation: Back to the Future

Friday, July 18, 12:00–13:00
Chair: Peter A.N. Bosman

Marc Schoenauer, *Institut national de recherche en sciences et technologies du numérique (INRIA), France*



The evolution principles underlying Evolutionary Algorithms can be applied in any search space (i.e., to any representation), provided we are able to define meaningful variation operators with respect to the problem at hand. From the historical bitstring, continuous variables and Finite State Automata to advanced program or structure embeddings and beyond, EC has gradually, and sometimes painfully, earned its spurs, turning from confidential pocketknife to recognized Swiss Army Knife. I will try to illustrate this historical perspective with various examples gathered during my 35 (omg!) years of research in EC, and to demonstrate how a thorough exploitation of the past can provide useful hints for an efficient exploration of the future.

Biosketch: Marc Schoenauer is Principal Senior Researcher (Directeur de Recherche de Classe Exceptionnelle) with INRIA, Emeritus since May 2024. He graduated at Ecole Normale Supérieure (1975), then got a PhD in Applied Maths at Paris 6 U. (1980). He has been Junior Researcher (Chargé de Recherche) with CNRS (1980–2001), at CMAP (the Applied Maths Lab.) at Ecole Polytechnique. He then joined INRIA, and in 2003 founded the TAO team (Machine Learning and Optimization) at INRIA Saclay together with Michèle Sebag. He has been Head of Research of the Saclay Inria branch (2010–2016) and Deputy Research Director in charge of AI at INRIA (2020–2024).

Marc Schoenauer has been working since early 90s at the interface between Evolutionary Computation (EC) and Machine Learning (ML). He is author of more than 200 papers in journals and major conferences. He is or has been (co-)advisor of 42 PhD students. He has been Chair of SIGEVO (2015–2019); Founding President (2015–2021) of SPECIES, the Society for the Promotion of Evolutionary Computation In Europe and Surroundings that runs the EvoStar series of confeences; Founding president (1995–2002) of Evolution Artificielle, the French Society for Evolutionary Computation; And president of AFIA (2002–2004), the French Association for Artificial Intelligence.

He has been Editor in Chief of Evolutionary Computation Journal (2002–2009, now on the Advisory Board), is or has been in the Editorial Board of other prestigious journals in EC: IEEE Trans. on EC (1996–2004), TCS-C (2001–2006), GPEM (1999–2017), ASOC (2000–2014), and the recent (2019) ACM–TELO. He is Action Editor of Journal of Machine Learning Research (JMLR) since 2013. Last but not least, he seconded Cédric Villani in writing his report on the French Strategy for AI delivered to Pdt Macron in March 2018.

Tutorials

Introductory Tutorials

Evolution of Neural Networks
Risto Miikkulainen, Sebastian Risi, David Ha, Yujin Tang
Monday, July 14, 09:30–11:20
Azul

Machine Learning Assisted Evolutionary Multi- and Many-objective Optimization
Kalyanmoy Deb, Dhish Kumar Saxena, Sukrit Mittal
Monday, July 14, 09:30–11:20
Malagueta

Benchmarking Single- and Multi-Objective Optimization Algorithms: How to Make Your Experimental Data More Valuable
Diederick Vermetten, Carola Doerr, Jacob de Nobel, Thomas Bäck
Monday, July 14, 09:30–11:20
Alborán

Model-Based Evolutionary Algorithms
Dirk Thierens, Peter A.N. Bosman
Monday, July 14, 09:30–11:20
Alcazaba

Statistical Forward Planning Algorithms
Simon Lucas, James Goodman, Marko Tot
Monday, July 14, 09:30–11:20
Jábega

Introductory Mathematical Programming for EC
Ofer M. Shir
Monday, July 14, 11:40–13:30
Malagueta

Fair Performance Comparison of Evolutionary Multi-Objective Algorithms
Hisao Ishibuchi, Lie Meng Pang
Monday, July 14, 15:00–16:50
Minotauro

Combinatorial Optimisation Can be Different from Continuous Optimisation for MOEAs
Miqing Li
Monday, July 14, 15:00–16:50
Malagueta

Introduction to Quantum Optimization
Alberto Moraglio, Francisco Chicano
Monday, July 14, 15:00–16:50
Alborán

Tutorial: A Gentle Introduction to Theory (for Non-Theoreticians)
Benjamin Doerr
Monday, July 14, 15:00–16:50
Gibralfaro

Representations for Evolutionary Algorithms
Franz Rothlauf
Monday, July 14, 15:00–16:50
Jábega

Structural Bias in Optimisation Algorithms
Anna Kononova, Niki van Stein
Monday, July 14, 17:10–19:00
Malagueta

Evolutionary Art and Design in the Machine Learning Era
Penousal Machado, João Correia
Monday, July 14, 17:10–19:00
Alborán

Bayesian Optimization
Ivo Couckuyt, Sebastian Rojas Gonzalez, Juergen Branke
Monday, July 14, 17:10–19:00
Alcazaba

Automated Machine Learning Tools for Data Science, Modeling, and Algorithm Benchmarking
Ryan Urbanowicz
Monday, July 14, 17:10–19:00
Gibralfaro

Genetic Programming as a Hyper-Heuristic for Solving Combinatorial Optimisation Problems — Monday, July 14, 17:10–19:00, Jábega
Marko Đurasević, Francisco Javier Gil Gala, Domagoj Jakobović, Yi Mei

Evolutionary Computation for Feature Selection and Feature Construction — Tuesday, July 15, 09:30–11:20, Gibralfaro
Bing Xue, Mengjie Zhang

What You Always Wanted to Know About Evolution Strategies, But Never Dared to Ask — Tuesday, July 15, 11:40–13:30, Alcazaba
Hans-Georg Beyer

Evolutionary Reinforcement Learning — Tuesday, July 15, 11:40–13:30, Jábega
Manon Flageat, Bryan Lim, Paul Templier, Antoine Cully

Advanced Tutorials

Intelligent Evolution Optimization: Guided from Deep Learning to Large Language Model — Monday, July 14, 09:30–11:20, Gibralfaro
Hua Xu, Xiaodong Li, Yuan Sun, Huigen Ye

Recent Developments in Data Structures and Algorithms for Evolutionary Multiobjective Optimization — Monday, July 14, 11:40–13:30, Alborán
Andrzej Jaszkiewicz, Piotr Zielniewicz

Evolutionary Computation and Evolutionary Deep Learning for Image Analysis, Signal Processing and Pattern Recognition — Monday, July 14, 11:40–13:30, Alcazaba
Stefano Cagnoni, Ying Bi, Yanan Sun

Decomposition Multi-objective Optimization: What We Know from the Literature, and What We Are NOT Clear from a Data Science Perspective — Monday, July 14, 11:40–13:30, Gibralfaro
Ke Li

Evolutionary Computation Meets Machine Learning for Combinatorial Optimization — Monday, July 14, 15:00–16:50, Alcazaba
Yi Mei, Günther R. Raidl

Theory and Practice of Population Diversity in Evolutionary Computation — Monday, July 14, 17:10–19:00, Azul
Dirk Sudholt, Giovanni Squillero

Advances in Evolutionary Hyper-Heuristics — Monday, July 14, 17:10–19:00, Minotauro
Nelishia Pillay

New, More Efficient Crossover and Local Search Operators for Recombination Lattices — Monday, July 14, 17:10–19:00, Mena
Darrell Whitley

Recent Advances in Meta-features Used for Representing Black-box Single-objective Continuous Optimization — Tuesday, July 15, 09:30–11:20, Azul
Gjorgjina Cenikj, Ana Nikolikj, Tome Eftimov

Evolutionary Computation for Stochastic Problems — Tuesday, July 15, 09:30–11:20, Alborán
Frank Neumann, Aneta Neumann, Hemant Singh

Pareto Optimization for Subset Selection: Theories and Practical Algorithms — Tuesday, July 15, 09:30–11:20, Alcazaba
Chao Qian

Coevolutionary Computation for Adversarial Deep Learning — Tuesday, July 15, 11:40–13:30, Gibralfaro
Jamal Toutouh, Una-May O'Reilly

Advanced Use of Automatic Algorithm Configuration: Single- and Multi-Objective Approaches — Tuesday, July 15, 15:00–16:50, Gibralfaro
Jeroen Rook, Manuel López-Ibáñez

Specialized Tutorials

Cartesian Genetic Programming: From Foundations to Recent Developments and Applications — Tuesday, July 15, 09:30–11:20, Jábega
Roman Kalkreuth, Sylvain Cussat-Blanc, Dennis Wilson

Linear Genetic Programming — Tuesday, July 15, 17:10–19:00, Alcazaba
Wolfgang Banzhaf, Ting Hu

Constraint-Handling Techniques used with Evolutionary Algorithms — Tuesday, July 15, 17:10–19:00, Gibralfaro
Carlos A. Coello Coello

Workshops

10th Workshop on Industrial Applications of Metaheuristics

Organizers: Silvino Fernandez Alzueta, *ArcelorMittal, Spain*
Pablo Valledor, *ArcelorMittal, Spain*
Thomas Stützle, *Université Libre de Bruxelles, Belgium*

Time & location:
- Monday, July 14, 11:40–13:30, Azul
- Monday, July 14, 15:00–16:50, Azul

Monday, July 14, 11:40–13:30, Azul

Welcome to IAM 2025 11:40
Silvino Fernandez

A Hybrid Constrained Programming with Genetic Algorithm for the Job Shop Scheduling Problem 11:42
Alessandro Lorenzi, Stefano Genetti, Chiara Camilla Rambaldi Migliore, Marco Roveri, Giovanni Iacca

Multi-objective Optimisation of Floating Offshore Wind Farms based on a Real-World Case Study 12:05
Pawel L. Manikowski, David J. Walker, Matthew J. Craven

Efficient Scheduling of Transformer Neural Network Computation for Edge-AI Deployment 12:28
David Sedlák, Jan Klhufek, Vojtech Mrazek, Zdenek Vasicek

Memory-Assisted Genetic Algorithm for Signal Timing Optimization in Traffic Networks 12:51
Sahar Kianian, Edward Keedwell, Aidan Bennett

Grammatical Evolution for Temperature Prediction Models in Different Photovoltaic Technologies 13:04
Alexander Cortés-Llanos, Lucía Serrano-Lujan, Carlos Toledo, Antonio Urbina, Jose Manuel Colmenar

GRASP Metaheuristic for Energy-efficient Drone Coverage Path Planning 13:17
Bárbara Cristina Fonseca de Souza, Tarcísio Barroso Marques, Jose Elias Claudio Arroyo

Monday, July 14, 15:00–16:50, Azul

Evolutionary Adaptive Stress Testing for Collision Avoidance in Sustainable Maritime Transportation 15:00
Thomas Steenfeldt Laursen, Ole Jakob Mengshoel

Nested Multi-objective Model Updating for an Aircraft Wingtail Digital Twin 15:23
Jake Hollins, Kostantinos Agathos, Tinkle Chugh

Panel Discussion: Industrial Application on Metaheuristics 15:46
Carlos Alba, Kalyanmoy Deb, Manuel Iori, Manuel López-Ibáñez, Thomas Bäck

Conclusions 16:46

15th Workshop on Evolutionary Computation for the Automated Design of Algorithms

Organizers: Daniel R Tauritz, *Auburn University, USA*
Johm Woodward, *Loughborough University, UK*
Emma Hart, *Edinburgh Napier University, UK*

Time & location: Tuesday, July 15, 11:40–13:30, Alborán

Welcome & Opening 11:40
Workshop Organizers

Genetic Improvement of Dynamic Optimization Algorithms using PushGP 11:45
Vladimir Stanovov, Eugene Semenkin

How to Train Algorithm Selection Models: Insights from Black-box Continuous Optimization 12:05
Xiao He, Haopu Shang, Chao Qian

Learning the Particle Swarm Optimization Velocity Update via Genetic Programming 12:25
Frederico J.J.B. Santos, Andrea De Lorenzo, Luca Manzoni, Gloria Pietropolli

Keynote Introduction 12:45

Some few examples of automated design of algorithm 12:50
Thomas Stützle

Open discussion & Wrap up 13:20
Workshop Organizers

28th International Workshop on Evolutionary Rule-based Machine Learning

Organizers: Abubakar Siddique, *Wellington Institute of Technology, New Zealand*
Michael Heider, *Universität Augsburg, Germany*
Hiroki Shiraishi, *Yokohama National University, Japan*

Time & location:
- Monday, July 14, 11:40–13:30, Mena
- Monday, July 14, 15:00–16:50, Mena

Monday, July 14, 11:40–13:30, Mena

Welcome & Opening 11:40
Workshop Organizers

Evolutionary Optimization via Rule-based Learning 11:50
Masaya Nakata

Dimensionality Reduction for Enabling Visual Reinforcement Learning with a Classifier System 12:20
Connor Schönberner, Armin Mackensen, Sven Tomforde

Evolving Modular Abstractions through Lateralized Learning in Classifier Systems 12:45
Abubakar Siddique, Muhammad Iqbal, Will N. Browne, Gina M. Grimshaw

Why state differentiation in ACS2 is not enough in aliased environments 13:05
Mateusz Łabędzki, Olgierd Unold

Monday, July 14, 15:00–16:50, Mena

GPU-Accelerated Rule Evaluation and Evolution 15:00
Hormoz Shahrzad, Risto Miikkulainen

How to Design an LCS to Create Explainable AI Models for Real-World Applications 15:20
Michael Heider

A Proposal for a Leaner Narrative of Learning Classifier Systems 15:40
Pierluca Lanzi, Daniele Loiacono

Panel Discussion 16:05

Closing Remarks 16:40

Analysing Algorithmic Behaviour of Optimisation Heuristics

Organizers: Anna Kononova, *Leiden University, Netherlands*
Niki van Stein, *Leiden University, Netherlands*
Daniela Zaharie, *West University of Timisoara, Romania*
Fabio Caraffini, *Swansea University, UK*
Thomas Bäck, *Leiden University, Netherlands*

Time & location: Tuesday, July 15, 09:30–11:20, Mena

Welcome 09:30

It is Time for a Revision of COCO BBOB 09:33
Hans-Georg Beyer

Tracing Genome Influence in Multi-Objective Evolutionary Algorithms 10:18
Tobias Benecke, Sanaz Mostaghim

Correlated Geometric Mutations for Integer Evolution Strategies 10:38
Ofer M. Shir, Michael Emmerich

Evolving to Extinction: a Case Study in Heuristic Search Dynamics 10:58
James McDermott, Kostadin Dimanov Georgiev, Miguel Nicolau

Closing 11:18

Decomposition Techniques in Evolutionary Optimization

Organizers: Bilel Derbel, *University of Lille and Inria Lille, France*
Ke Li, *University of Exeter, UK*
Xiaodong Li, *RMIT University, Australia*
Saúl Zapotecas-Martínez, *Instituto Nacional de Astrofísica, Óptica y Electrónica, Mexico*
Qingfu Zhang, *City University of Hong Kong, Hong Kong*

Time & location: Tuesday, July 15, 09:30–11:20, Minotauro

The Pitfalls and Potentials of Adding Gene-invariance to Optimal Mixing 09:30
Anton Bouter, Dirk Thierens, Peter A.N. Bosman

Towards a Penalty Annealing Approach in MOEA/D for Constrained Multi-Objective Optimization 09:55
Miguel Ángel Jiménez-Domínguez, Néstor Andrés García-Rojas, Saúl Zapotecas-Martínez, Raquel Díaz-Hernández, Leopoldo Altamirano-Robles, Bilel Derbel

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Evolutionary Computing and Explainable AI

Organizers: Jaume Bacardit, *Newcastle University, UK*
Alexander Brownlee, *University of Stirling, UK*
Stefano Cagnoni, *University of Parma, Italy*
Giovanni Iacca, *University of Trento, Italy*
John McCall, *Robert Gordon University, UK*
David J. Walker, *University of Exeter, UK*

Time & location: Tuesday, July 15, 11:40–13:30, Mena

Welcome & Opening 11:40
Workshop Organizers

A Step towards Interpretable Multimodal AI Models with MultiFIX 11:45
Mafalda Malafaia, Thalea Schlender, Tanja Alderliesten, Peter A.N. Bosman

A Better Multi-Objective GP-GOMEA – But do we Need it? 12:05
Joe Harrison, Tanja Alderliesten, Peter A.N. Bosman

Evaluating a Novel Explainability Method for Metaheuristics via a User Study 12:25
GianCarlo Antonino Pasquale Ignazio Catalano, Alexander Brownlee, David Cairns, John McCall, Russell Ainslie

Local Optima Networks (LONs) and Search Trajectory Networks (STNs) for Noisy Combinatorial Problems 12:45
John Payne, Aishwaryaprajna, David J. Walker, Edward Keedwell

Open Discussion 13:05

Evolutionary Computing and Explainable AI | Evolutionary Computation and Decision Making

Organizers: Jaume Bacardit, *Newcastle University, UK*
Alexander Brownlee, *University of Stirling, UK*
Stefano Cagnoni, *University of Parma, Italy*
Giovanni Iacca, *University of Trento, Italy*
John McCall, *Robert Gordon University, UK*
David J. Walker, *University of Exeter, UK*
Tinkle Chugh, *University of Exeter, UK*
Richard Allmendinger, *University of Manchester, UK*
Ana Belen Ruiz, *Universidad de Málagaa, Spain*

Time & location: Monday, July 14, 09:30–11:20, Mena

Welcome & Opening 09:30
Workshop Organizers

Urban Transport Decision Making: Improving Traffic Prediction with Symbolic Regression, Transfer Learning and Deep Learning 09:35
Alina Patelli, John Rego Hamilton, Aniko Ekart

An introduction to the preference-based and interactive EMO algorithms 09:50
Mariano Luque

Interactive Evolutionary Optimization of Visual Explainable AI through Gestalt Principles with Human Feedback 10:20
Doina Bucur, Sara Miotto, Leonardo Lucio Custode, Chiara Camilla Rambaldi Migliore, Giovanni Iacca

Interpreting Machine Learning Pipelines Produced by Evolutionary AutoML for Biochemical Property Prediction 10:40
Alex G.C. de Sá, Gisele Lobo Pappa, Alex A. Freitas, David B. Ascher

Closing 11:00
Workshop Organizers

Evolutionary Generative Models

Organizers: João Correia, *University of Coimbra, Portugal*
Jamal Toutouh, *Universidad de Málaga and Massachusetts Institute of Technology, Spain*
Una-May O'Reilly, *Massachusetts Institute of Technology, USA*
Penousal Machado, *University of Coimbra, Portugal*
Erik Hemberg, *Massachusetts Institute of Technology, USA*

Time & location: Tuesday, July 15, 15:00–16:50, Alcazaba

Welcome & Opening 15:00
Workshop Organizers

Open-Ended Evolution of Artistic Styles in Diffusion Models via Island-Based Genetic Algorithms 15:05
Marcel Salvenmoser, Michael Affenzeller

A Voxel Representation Based Evolutionary Data Generator of Adversarial Objects for AI Agents 15:25
Akshay

Three-objective evolutionary search of the latent space of Generative Adversarial Networks for human face generation 15:45
Sergio Nesmachnow, Pedro Moreno

Multi-population GAN Training: Analyzing Co-Evolutionary Algorithms 16:05
Walter Casas, Jamal Toutouh

Panel Discussion 16:25

Closing 16:45
Workshop Organizers

Evolving Self-Organisation

Organizers: Eleni Nisioti, *IT University of Copenhagen, Denmark*
Sebastian Risi, *IT University of Copenhagen, Denmark*
Joachim Winther Pedersen, *IT University of Copenhagen, Denmark*
Ettore Randazzo, *Google Research in Zürich, Switzerland*
Alexander Mordvintsev, *Google Research in Zürich, Switzerland*
Eyvind Niklasson, *Google Research in Zürich, Switzerland*

Time & location:
- Tuesday, July 15, 15:00–16:50, Alborán
- Tuesday, July 15, 17:10–19:00, Alborán

Tuesday, July 15, 15:00–16:50, Alborán

Introductory Remarks 15:00

Surprising Synergies of Evolution and Self-Organization 15:05
Risto Miikkulainen

Tutorial 15:50
Workshop Organizers

Morphology-Adaptive Muscle-Driven Locomotion via Attention Mechanisms 16:35
Junior Rojas

Tuesday, July 15, 17:10–19:00, Alborán

A Path to Universal Neural Cellular Automata 17:10
Gabriel Béna, Maxence Faldor, Dan Goodman, Antoine Cully

Self-Organizing Models of Brain Wiring: Developmental Programs for Evolving Intelligence 17:25
Jamieson Warner, Risto Miikkulainen

Poster Session 17:40–18:25

On the Parallels Between Evolutionary Theory and the State of AI
Zeki Doruk Erden, Boi Faltings

Time-Modulated Hebbian Learning for Classic Control Tasks
Daniel García Núñez, Fergal Stapleton, Edgar Galván

A Study on Morphological and Behavioral Adaptations from Multi-Task Morphoevolution by Voxel-based Soft Robots
V. A. Ashwin, G. M. Harish, D. Jayadev, C. Shunmuga Velayutham

Self-organized Swarm Reinforcement Learning under Spontaneous Communications
Qihao Shan, Sanaz Mostaghim

Evolvability in Rule-Making: A Self-Amendment Game Among LLM Agents
Kazuya Horibe

Talk and Concluding Remarks 18:25
Workshop Organizers

Good Benchmarking Practices for Evolutionary Computation

Organizers: Vanessa Volz, *Centrum Wiskunde & Informatica, Netherlands*
Carola Doerr, *CNRS and Sorbonne University, France*
Boris Naujoks, *TH Köln, Germany*
Mike Preuss, *Universiteit Leiden, Netherlands*
Olaf Mersmann, *Hochschule des Bundes für öffentliche Verwaltung, Germany*
Pascal Kerschke, *TU Dresden and ScaDS.AI, Germany*

Time & location: Monday, July 14, 11:40–13:30, Minotauro

Revisiting COCO with automated benchmarking in mind 11:40
Nikolaus Hansen

Benchmarking through the lense of a Machine Learner and Roboticist 12:15
Antoine Cully

General Discussion 12:50

Graph-based Genetic Programming

Organizers: Roman Kalkreuth, *RWTH Aachen University, Germany*
Yuri Lavinas, *University of Toulouse, France*
Eric Medvet, *University of Trieste, Italy*
Giorgia Nadizar, *University of Trieste, Italy*
Giovanni Squillero, *Politecnico di Torino, Italy*
Alberto Tonda, *Université Paris-Saclay, France*
Dennis Wilson, *Université de Toulouse, France*

Time & location: Tuesday, July 15, 11:40–13:30, Minotauro

Everybody Wants to Rule the Benchmark: The Dangers of GP Leaderboard Chasing 11:40
Fabrício Olivetti de França

Linear Genetic Programming for Design Graph Neural Networks for Node Classification 12:10
Maciej Krzywda, Szymon Łukasik, Amir H. Gandomi

Towards Efficient Semantic Mutation in CGP: Enhancing SOMOk 12:30
Lukas Plevac, Zdenek Vasicek

Evolving Typed Token Processing Networks 12:50
Berfin Sakallioglu, Giorgia Nadizar, Luca Manzoni, Eric Medvet

On Chromosome Crossover in Multimodal Adaptive Graph Evolution 13:10
Camilo De La Torre, Sylvain Cussat-Blanc, Hervé Luga, Dennis Wilson, Yuri Lavinas

Landscape-Aware Heuristic Search

Organizers: Sarah L. Thomson, *Edinburgh Napier University, UK*
Nadarajen Veerapen, *Université de Lille, France*
Katherine Mary Malan, *University of South Africa, South Africa*
Arnaud Liefooghe, *Université du Littoral Côte d'Opale, France*
Sébastien Verel, *Université du Littoral Côte d'Opale, France*
Gabriela Ochoa, *University of Stirling, UK*

Time & location: Tuesday, July 15, 15:00–16:50, Malagueta

Welcome & Opening 15:00
Workshop Organizers

Towards Benchmarking Multi-Objective Optimization Algorithms Based on the Basin Connectivity 15:05
Ryosuke Ota, Likun Liu, Naoki Hamada, Takahiro Yamamoto, Shoichiro Tanaka, Daisuke Sakurai

Visualising Adam Oscillations in Neural Network Loss Landscapes 15:35
Henri van der Grijp, Anna Sergeevna Bosman, Katherine Mary Malan

Algorithm Explainability for Malware Evolution with Search Trajectory Networks 16:05
Kehinde Babaagba, Ritwik Murali, Sarah L. Thomson

Large Language Models for and with Evolutionary Computation Workshop

Organizers: Erik Hemberg, *Massachusetts Institute of Technology, USA*
Roman Senkerik, *Tomas Bata University in Zlín, Czechia*
Joel Lehman, *Uber AI Labs, USA*
Una-May O'Reilly, *Massachusetts Institute of Technology, USA*
Michal Pluháček, *AGH University of Krakow, Poland*
Niki van Stein, *Leiden University, Netherlands*
Pierluca Lanzi, *Politecnico di Milano, Italy*
Tome Eftimov, *Jožef Stefan Institute, Slovenia*

Time & location: Tuesday, July 15, 17:10–19:00, Malagueta

Welcome & Opening 17:10
Workshop Organizers

BLADE: Benchmark suite for LLM-driven Automated Design and Evolution of iterative optimisation heuristics 17:15
Niki van Stein, Anna Kononova, Haoran Yin, Thomas Bäck

Regarding Context Size in LLM-Based Metaheuristic Design 17:28
Adam Viktorin, Michal Pluháček, Jozef Kovac, Tomas Kadavy, Roman Senkerik

LLM-Guided Evolution: An Autonomous Model Optimization for Object Detection 17:41
YiMing Yu, Jason Paul Zutty

Optimizing Photonic Structures with Large Language Model Driven Algorithm Discovery 17:54
Haoran Yin, Anna Kononova, Thomas Bäck, Niki van Stein

Giving Simulated Cells a Voice: Evolving Prompt-to-Intervention Models for Cellular Control 18:07
Nam Le, Patrick Erickson, Zhang Yanbo, Michael Levin, Josh Bongard

LEAR: LLM-Driven Evolution of Agent-Based Rules 18:20
Can Gurkan, Narasimha Karthik Jwalapuram, Kevin Wang, Rudy Danda, Leif Rasmussen, John Chen, Uri Wilensky

Panel Discussion 18:33

Closing 18:58
Workshop Organizers

Neuroevolution at Work

Organizers: Ernesto Tarantino, *National Research Council of Italy, Italy*
Ivanoe De Falco, *National Research Council of Italy, Italy*
Antonio Della Cioppa, *University of Salerno and National Research Council of Italy, Italy*
Edgar Galván, *Maynooth University, Ireland*
Mengjie Zhang, *Victoria University of Wellington, New Zealand*

Time & location: Tuesday, July 15, 17:10–19:00, Azul

Welcome & Opening 17:10
Workshop Organizers

Low Rank Factorizations are Indirect Encodings for Deep Neuroevolution 17:15
Jack Garbus, Jordan Pollack

Evaluating Encoding of Neuron Configuration and Position in Neuroevolution of Liquid State Machines 17:45
Carlos-Alberto López-Herrera, Héctor-Gabriel Acosta-Mesa, Efrén Mezura-Montes

Unveiling the Search Space of Simple Contrastive Graph Clustering with Cartesian Genetic Programming 18:15
Maciej Krzywda, Yue Liu, Szymon Łukasik, Amir H. Gandomi

Open Source Software for Evolutionary Computation

Organizers: Stefan Wagner, *University of Applied Sciences Upper Austria, Austria*
Michael Affenzeller, *University of Applied Sciences Upper Austria and Johannes Keppler University Linz, Austria*

Time & location: Monday, July 14, 09:30–11:20, Minotauro

Welcome & Opening 09:30
Workshop Organizers

SEvoBench: A C++ Framework For Evolutionary Single-Objective Optimization Benchmarking 09:40
Yongkang Yang, Jian Zhao, Tengfei Yang

logicGP – A Framework for Literal Based Classification with a Focus on Software Architecture and Open Source Implementation 10:00
Robin Nunkesser

pyHMS: A Python Library for Hierarchic Memetic Strategy 10:20
Wojciech Achtelik, Hubert Guzowski, Maciej Smołka

Design, Containerization and Performance of Distributed Evolutionary Computation 10:40
Jan Zenisek, Florian Bachinger, Christian Haider, Florian Holzinger, Philipp Neuhauser, Erik Pitzer, Stefan Wagner, Michael Affenzeller

Slim_gsgp: A Python Library for Non-Bloating GSGP 11:00
Liah Rosenfeld, Davide Farinati, Diogo Rasteiro, Gloria Pietropolli, Karina Brotto Rebuli, Sara Silva, Leonardo Vanneschi

Closing 11:10
Workshop Organizers

Student Workshop

Organizers: Alexander Brownlee, *University of Stirling, UK*

Time & location:
- Monday, July 14, 17:10–19:00, Arlequín & Tauromaquia
- Tuesday, July 15, 09:30–11:20, Arlequín & Tauromaquia

Monday, July 14, 17:10–19:00, Arlequín & Tauromaquia

Welcome & Opening by the Workshop Organisers 17:10

✶ The Specificity vs. Expense Trade-Off of Multiagent Credit 17:15
Raghav Thakar, Kagan Tumer

✶ School Bus Routing for Pupils with Special Needs Under Uncertainty: An Averaging Approach 17:35
Ozioma Paul, Julia Handl, Manuel López-Ibáñez

✶ Evaluation of Sensitivity Analysis of Penalty Weights in QUBO 17:55
Jiajie Liu, Alberto Moraglio

✶ Noise Resilient Quantum Circuit Design by Multi-Objective Genetic Algorithm 18:15
Christian Wood, Alberto Moraglio

Tuesday, July 15, 09:30–11:20, Arlequín & Tauromaquia

Automated Generation of Trajectory-based Metaheuristics for Capacitated Vehicle Routing 09:30
Pablo Contreras Estrada, Thomas Stützle, Leslie Pérez Cáceres

Efficient Pretrained Model for Surrogate-assisted High-Dimensional Expensive Multi-objective Optimization 09:50
Jiajun Li, Shuwei Zhu, Wei Fang

LLM-aided Evolutionary Algorithms for Haiku Generation 10:10
Vedant Jobanputra, Basam Thilaknath Reddy, Sri Ganesh Bhojanapalli, S.V.S Krishna Aditya, Bagavathi Chandrasekara, Ritwik Murali

Towards Automated and Interpretable Decision Support Systems for Precision Livestock Farming Using Evolutionary Computing 10:30
Elisabeth Mayrhuber, Stephan Winkler

Efficient Waste Collection Routing Using F-CVRP and Dynamic Parameter Optimization via Q-Learning 10:50
Yogesh Kumar, Prakhar Gupta, Karuna Panwar, Kusum Deep

Closing by Workshop Organisers 11:10

Symbolic Regression Workshop

Organizers: Gabriel Kronberger, *University of Applied Sciences Upper Austria, Austria*
Fabrício Olivetti de França, *Universidade Federal do ABC, Brazil*
William G. La Cava, *Boston Children's Hospital and Harvard Medical School, USA*
Steven Gustafson, *Nooum, Inc., USA*

Time & location:
- Tuesday, July 15, 15:00–16:50, Mena
- Tuesday, July 15, 17:10–19:00, Mena

Tuesday, July 15, 15:00–16:50, Mena

Welcome & Opening 15:00
Workshop Organizers

SCRBenchmark: A Benchmarking Library for Shape-Constrained Regression 15:05
Florian Bachinger, Bernhard Werth, Jan Zenisek, Christian Haider, Fabrício Olivetti de França

A Hierarchical Multiview Symbolic Regression Method for Decoding Oceanic Metabolism 15:25
Hernan Lira, Luis Martí, Nayat Sanchez-Pi

Can Synthetic Data Improve Symbolic Regression Extrapolation Performance? 15:45
Fitria Wulandari Ramlan, Colm O'Riordan, Gabriel Kronberger, James McDermott

When Data Transformations Mislead Symbolic Regression: Deceptive Search Spaces in System Identification 16:05
Alberto Tonda, Hengzhe Zhang, Qi Chen, Bing Xue, Mengjie Zhang, Evelyne Lutton

On the use of Hinge Loss as a Surrogate Fitness Function with Grammatical Evolution for Parkinson's Disease Classification 16:25
Jiajun Duan, Miguel Nicolau, Michael O'Neill

Discussion 16:45

Tuesday, July 15, 17:10–19:00, Mena

Continuous Pruning for Symbolic Regression 17:10
Bernhard Werth, Michael Affenzeller

Model Recovery in Symbolic Regression: Theory, Conjectures, and Open Questions 17:30
Erik-Jan Senn

Call for Action: towards the next generation of symbolic regression benchmark 17:50
Guilherme S. Imai Aldeia, Hengzhe Zhang, Geoffrey Bomarito, Miles Cranmer, Alcides Fonseca, Bogdan Burlacu, William G. La Cava, Fabrício Olivetti de França

Rewarding Model Smoothness and Simplicity via Alternating Objectives in Symbolic Regression 18:10
Nathan Haut, Mark Kotanchek

Panel Discussion and Closing 18:30
Workshop Organizers

Workshop on Black Box Optimization Benchmarking 2025

Organizers: Anne Auger, *Inria and Ecole Polytechnique, France*
Dimo Brockhoff, *Inria and Ecole Polytechnique, France*
Tobias Glasmachers, *Ruhr-University Bochum, Germany*
Nikolaus Hansen, *Inria and Ecole Polytechnique, France*
Olaf Mersmann, *Hochschule des Bundes für öffentliche Verwaltung, Germany*
Tea Tušar, *Jožef Stefan Institute, Slovenia*

Time & location:
- Tuesday, July 15, 11:40–13:30, Azul
- Tuesday, July 15, 15:00–16:50, Azul

Tuesday, July 15, 11:40–13:30, Azul

Blackbox Optimization Benchmarking with COCO – Fundamentals and Recent Developments 11:40
The BBOBies

On the Robustness of BFGS to Positive and Negative Noise Outliers on the BBOB Test Suite 12:00
Alexandre Chotard, Anne Auger

On the Robustness of Nelder-Mead to Positive and Negative Noise Outliers with Heavy-Tails on the BBOB Test Suite 12:10
Alexandre Chotard, Anne Auger

Benchmarking Powell's Legacy: Performance of Five Derivative-Free Solvers in pdfo on the bbob Test Suite 12:20
Dimo Brockhoff, Tanguy Villain

How Robust is UOBYQA to Worsening, Frozen Noise? Investigations on the bbob Test Suite With Outliers 12:30
Dimo Brockhoff, Tanguy Villain

Benchmarking CMA-ES under Additive and Subtractive Noise on the BBOB Testbed 12:40
Oskar Girardin

Benchmarking Improved Variants of CMA-ES-PDM on the bbob-mixint Testbed 13:00
Duc Manh Nguyen

Session Wrap Up 13:20
The BBOBies

Tuesday, July 15, 15:00–16:50, Azul

Cascading CMA-ES Instances for Generating Input-diverse Solution Batches 15:00
Maria Laura Santoni, Christoph Dürr, Carola Doerr, Mike Preuss, Elena Raponi

BEACON: Continuous Bi-objective Benchmark problems with Explicit Adjustable COrrelatioN control 15:20
Samuel Tebbet, George De Ath, Tinkle Chugh

Benchmarking Seven Multi-objective Optimization Methods from the PlatEMO Platform on the bbob-biobj Test Suite 15:40
David Ibehej, Jakub Kudela

Benchmarking the (1+1) Limited Memory Matrix Adaptation Evolution Strategy on the bbob-largescale Testbed 16:00
Tobias Glasmachers

General Discussion 16:20
The BBOBies

Workshop on Quantum Optimization

Organizers: Alberto Moraglio, *University of Exeter, UK*
Mayowa Ayodele, *D-Wave Quantum Inc, UK*
Francisco Chicano, *University of Málaga, Spain*
Ofer M. Shir, *Tel-Hai College and The Galilee Research Institute – Migal, Israel*
Lee Spector, *Amherst College, University of Massachusetts Amherst and Hampshire College, USA*
Matthieu Parizy, *Fujitsu, Japan*

Time & location:
- Tuesday, July 15, 15:00–16:50, Minotauro
- Tuesday, July 15, 17:10–19:00, Minotauro

Tuesday, July 15, 15:00–16:50, Minotauro

Welcome & Opening 15:00
Workshop Organizers

Optimization Strategies for Variational Quantum Algorithms 15:05
Hao Wang

On "Solving The Travelling Salesman Problem Using A Single Qubit" vs. Quantum Genetic Optimization: Are we there? 15:50
Hamza Baniata

A Variational Quantum Algorithm for the Permutation Flow Shop Scheduling Problem 16:05
Marco Baioletti, Fabrizio Fagiolo, Angelo Oddi, Riccardo Rasconi

The Quantum Approximate Optimization Algorithm Can Require Exponential Time to Optimize Linear Functions 16:20
Francisco Chicano, Zakaria Abdelmoiz Dahi, Gabriel Luque

Manual vs. Automated QUBO Formulations for Flow Shop Scheduling: A Comparative Study on D-Wave and InfinityQ 16:35
Yousra Farhani, Taha Arbaoui, Karima Benatchba

Tuesday, July 15, 17:10–19:00, Minotauro

In the quest for quantum advantage in variational quantum algorithm with landscape analysis 17:10
Xavier Bonet-Monroig

Encoding Binary Comparison Constraints in QUBO for Quantum Annealing 17:20
Philippe Codognet

Steiner Traveling Salesman Problem with Quantum Annealing 17:30
Alessia Ciacco, Francesca Guerriero, Eneko Osaba

Lookalike Clustering for Customer Segmentation: a Comparative Study of Quantum Annealing and Classical Algorithms 17:45
Benedetta Ferrari, Giuseppe Gnocchi, Manuel Iori, Simone Mascaro, Mirko Mucciarini, Luca Rinaldi, Gianluigi Salerno, Vittorio Tartarini, Andrea Vezzani

Quantum Annealing for Bi-objective Weighted Portfolio Optimization in Real-world Financial Markets 18:00
Shu-Yu Kuo, Kun-Lin Lee, Yao-Hsin Chou, Jyun-Yi Shen, Sy-Yen Kuo

Comparative Analysis of Classical and Quantum-Inspired Solvers: A Preliminary Study on the Weighted Max-Cut Problem 18:15
Aitor Morais, Eneko Osaba, Iker Pastor, Izaskun Oregi

Panel Discussion 18:30

Workshop on Surrogate-Assisted Evolutionary Optimisation

Organizers: Alma Rahat, *Swansea University, UK*
Richard Everson, *University of Exeter, UK*
Jonathan Fieldsend, *University of Exeter, UK*
Handing Wang, *Xidian University, China*
Yaochu Jin, *Westlake University, China*
Tinkle Chugh, *University of Exeter, UK*

Time & location:
- Tuesday, July 15, 09:30–11:20, Malagueta
- Tuesday, July 15, 11:40–13:30, Malagueta

Tuesday, July 15, 09:30–11:20, Malagueta
Methodological Advances in Surrogate-Assisted Optimisation

Welcome Note, Workshop Introduction, and Session Overview 09:30

Transfer Learning of Surrogate Models: Integrating Domain Warping and Affine Transformations 09:40
Shuaiqun Pan, Diederick Vermetten, Manuel López-Ibáñez, Thomas Bäck, Hao Wang

Performance Benchmarking of Multi-Objective Surrogate-Assisted Evolutionary Algorithms on a Novel Computational Fluid Dynamics Test Case 10:05
Benjamin Moore, Andrew Roberts, Daniel Jarman, Alma Rahat, Jonathan Fieldsend, Gavin Tabor

Surrogate Model-Based Multi-Objective Optimization Using Desirability Functions 10:30
Thomas Bartz-Beielstein

Automated Prediction of Compressor Performance Maps: Surrogate-Based Optimization with RNNs for Enhanced Extrapolation and Interpolation 10:55
Richard Schulz, Alexander Hinterleitner, Noah Christoph Pütz, Jens Uwe Brandt, Matthias Müller, Thomas Bartz-Beielstein

Tuesday, July 15, 11:40–13:30, Malagueta
Surrogate-Assisted Optimisation: Insights, Innovations, and the Road Ahead

Welcome Note, and Session Overview 11:40

From 'How Good?' to 'Is it Better?': Classification-Based Surrogate Models for JADE 11:45
Konrad Krawczyk, Jarosław Arabas

A Novel Mesh Deformation Methodology for Computational Aerodynamic Shape Optimisation 11:57
Joelle Salamoun, Ben Hickling Smith, Ben Evans, Sean Walton

Panel Discussion: Surrogate-Assisted Optimisation – Past, Present, and Future 12:09
Jonathan Fieldsend, Richard Allmendinger, Juergen Branke, Vanessa Volz

Competitions

Competitions

Organizers: Hemant Singh, *University of New South Wales, Australia*
Yuri Lavinas, *University of Toulouse, France*

Time & location:
- Monday, July 14, 11:40–13:30, Arlequín & Tauromaquia
- Monday, July 14, 15:00–16:50, Arlequín & Tauromaquia

Monday, July 14, 11:40–13:30, Arlequín & Tauromaquia

2025 Competition on Evolutionary Computation in the Energy Domain: Summer Finals of the Risk-based Energy Scheduling 11:40
José Almeida, Fernando Lezaman, Joao Soares, Bruno Canizes, Filipe Sousa, Zita Vale

Numerical Global Optimization Competition on GNBG-II generated Test Suite 11:55
Amir H. Gandomi, Kalyanmoy Deb, Rohit Salgotra

Competition on LLM-designed Evolutionary Algorithms 12:10
Adam Viktorin, Roman Senkerik, Michal Pluháček, Niki van Stein, Lars Kotthoff

Planet Wars AI Challenge 12:25
Simon Lucas

Benchmarking Niching Methods for Multimodal Optimization 12:40
Ali Ahrari, Jonathan Fieldsend, Mike Preuss, Xiaodong Li, Michael G. Epitropakis

Anytime Algorithms for Many-affine BBOB Functions 12:55
Diederick Vermetten, Carola Doerr, Thomas Bäck, Jacob de Nobel

Monday, July 14, 15:00–16:50, Arlequín & Tauromaquia

Evolutionary Submodular Optimisation 15:00
Aneta Neumann, Saba Sadeghi Ahouei, Jacob de Nobel, Diederick Vermetten, Thomas Bäck, Frank Neumann

Dynamic Stacking Optimization in Uncertain Environments 15:15
Johannes Karder, Stefan Wagner, Sebastian Leitner

Interpretable Control Competition 15:30
Giorgia Nadizar, Luigi Rovito, Dennis Wilson, Eric Medvet

Evolutionary Algorithms for the Large-scale Earth Observation Satellite Scheduling Problem 15:45
Alex Vasegaard, Jonathan Guerra

Automated Design Competition 16:00
Maciej Komosinski, Konrad Miazga, Agnieszka Mensfelt

Papers

SIGEVO Impact Award

Established in 2009, the SIGEVO Impact award recognizes up to three papers a year that were published in the GECCO conference 10 years earlier and which are both highly cited and deemed to be seminal by the SIGEVO Executive Committee.

This year, the SIGEVO Impact Award goes to:

☆ **General Program Synthesis Benchmark Suite** — Thursday, July 17, 13:00–13:20, Minotauro
Thomas Helmuth, Lee Spector

Best Paper Award

Voting Instructions

Beware: Each GECCO attendee has only one vote and can vote for only one Best Paper Session. Attendees can decide which session to vote for after attending multiple Best Paper Sessions (see below).

Procedure: There will be one award per Best Paper Session. Papers competing for the same award are presented in the same Best Paper Session. Nominees from small tracks are grouped together into the same session. Votes are nominative and cannot be delegated to another attendee.

More detailed instructions on the voting procedure will be sent by email to all participants at the beginning of the conference.

Nominated Papers

Benchmarking, Benchmarks, Software, and Reproducibility (BBSR)

★ **Why We Should be Benchmarking Evolutionary Algorithms on Neural Network Training Tasks** — Wednesday, July 16, 12:00–12:20, Mena
Katherine Mary Malan, Mario Andrés Muñoz

★ **When Does Neuroevolution Outcompete Reinforcement Learning in Transfer Learning Tasks?** — Wednesday, July 16, 12:20–12:40, Mena
Eleni Nisioti, Erwan Plantec, Milton Llera Montero, Joachim Winther Pedersen, Sebastian Risi

Complex Systems (CS)

★ **Extract-QD Framework: A Generic Approach for Quality-Diversity in Noisy, Stochastic or Uncertain Domains** — Thursday, July 17, 12:40–13:00, Mena
Manon Flageat, Johann Huber, François Helenon, Stéphane Doncieux, Antoine Cully

Evolutionary Combinatorial Optimization and Metaheuristics (ECOM)

★ **To Repair or Not to Repair? Investigating the Importance of AB-Cycles for the State-of-the-Art TSP Heuristic EAX** — Thursday, July 17, 15:30–15:50, Minotauro
Jonathan Heins, Darrell Whitley, Pascal Kerschke

★ **On Revealing the Hidden Problem Structure in Real-World and Theoretical Problems Using Walsh Coefficient Influence** — Thursday, July 17, 15:50–16:10, Minotauro
Michal Witold Przewozniczek, Francisco Chicano, Renato Tinós, Jakub Nalepa, Bogdan Ruszczak, Agata Maria Wijata

★ **Large Neighborhood Search for Capacitated Facility Location with Customer Incompatibilities** Thursday, July 17, 16:10–16:30 Minotauro
Ida Gjergji, Lucas Kletzander, Nysret Musliu, Andrea Schaerf

Evolutionary Machine Learning (EML)

★ **Evolution of Inherently Interpretable Visual Control Policies** Wednesday, July 16, 17:30–17:50 Mena
Camilo De La Torre, Giorgia Nadizar, Yuri Lavinas, Hervé Luga, Dennis Wilson, Sylvain Cussat-Blanc

★ **Dynamic Influence For Coevolutionary Agents** Wednesday, July 16, 17:50–18:10 Mena
Everardo Gonzalez, Gaurav Dixit, Kagan Tumer

★ **Evolutionary Quadtree Pooling for Convolutional Neural Networks** Wednesday, July 16, 18:10–18:30 Mena
Po-Wei Harn, Bo Hui, Libo Sun, Wei-Shinn Ku

Evolutionary Multiobjective Optimization (EMO)

★ **R2 Indicator Analysis using the Optimal Distributions of Solutions for R2 and Other Indicators** Wednesday, July 16, 15:30–15:50 Minotauro
Yang Nan, Hisao Ishibuchi, Tianye Shu, Ke Shang

★ **Exploring Phase-Specific Configuration of Interactive Evolutionary Multiobjective Optimization Methods** Wednesday, July 16, 15:50–16:10 Minotauro
Giomara Larraga, Kaisa Miettinen

Evolutionary Numerical Optimization (ENUM)

★ **CatCMA with Margin: Stochastic Optimization for Continuous, Integer, and Categorical Variables** Wednesday, July 16, 12:40–13:00 Mena
Ryoki Hamano, Masahiro Nomura, Shota Saito, Kento Uchida, Shinichi Shirakawa

★ **Challenges of Interaction in Optimizing Mixed Categorical-Continuous Variables** Wednesday, July 16, 13:00–13:20 Mena
Youhei Akimoto, Xilin Gao, Ze Kai Ng, Daiki Morinaga

Genetic Algorithms (GA)

★ **Empirical Linkage Learning Provably Builds Truthful Models on Concatenated Traps and H-IFF** Wednesday, July 16, 17:30–17:50 Minotauro
Marcus Schmidbauer, Dirk Sudholt

General Evolutionary Computation and Hybrids (GECH)

★ **Augmented Decision Spaces for Stackelberg Security Games: Sparse evolution begets scalability** Wednesday, July 16, 15:30–15:50 Mena
Adam Żychowski, Abhishek Gupta, Yew-Soon Ong, Jacek Mańdziuk

Genetic Programming (GP)

★ An Online Genetic Programming Approach to Dynamic Production Scheduling
Binh Tran, Su Nguyen
Thursday, July 17, 12:00–12:20
Minotauro

★ Quality Diversity Genetic Programming for Learning Scheduling Heuristics
Meng Xu, Frank Neumann, Aneta Neumann, Yew-Soon Ong
Thursday, July 17, 12:20–12:40
Minotauro

★ Transformer Semantic Genetic Programming for Symbolic Regression
Philipp Anthes, Dominik Sobania, Franz Rothlauf
Thursday, July 17, 12:40–13:00
Minotauro

Learning for Evolutionary Computation (L4EC)

★ Deep reinforcement learning for instance-specific algorithm configuration
Elias Schede, Moritz Vinzent Seiler, Kevin Tierney, Heike Trautmann
Thursday, July 17, 15:30–15:50
Mena

★ The Pitfalls of Benchmarking in Algorithm Selection: What We Are Getting Wrong
Gašper Petelin, Gjorgjina Cenikj
Thursday, July 17, 15:50–16:10
Mena

★ On the Importance of Reward Design in Reinforcement Learning-based Dynamic Algorithm Configuration: A Case Study on OneMax with (1+(λ,λ))-GA
Tai Nguyen, Phong Le, André Biedenkapp, Carola Doerr, Nguyen Dang
Thursday, July 17, 16:10–16:30
Mena

Neuroevolution (NE)

★ Competition and Attraction Improve Model Fusion
João Abrantes, Robert Tjarko Lange, Yujin Tang
Thursday, July 17, 12:00–12:20
Mena

★ Evolving Comprehensive Proxies for Zero-Shot Neural Architecture Search
Junhao Huang, Bing Xue, Yanan Sun, Mengjie Zhang
Thursday, July 17, 12:20–12:40
Mena

★ Visualizing the Dynamics of Neuroevolution with Genetic Distance Projections
Evan Hayden Patterson, Joshua Karns, Zimeng Lyu, Travis Desell
Thursday, July 17, 13:00–13:20
Mena

Real World Applications (RWA)

★ Sequence Optimization of Multispacecraft Multitarget Rendezvous Missions with a Coevolutionary Algorithm
Yu Zhang, Yuehe Zhu, Jiacheng Zhang, Yazhong Luo
Wednesday, July 16, 12:00–12:20
Minotauro

★ Tomographic Reconstruction with Real-time a priori Acquistion
Muhammad Wishal Khan, Hooman Oroojeni, Bal Sanghera, Tim Blackwell, Mohammad Majid al-Rifaie
Wednesday, July 16, 12:20–12:40
Minotauro

★ **Differential Evolution for Infeasible Circumstances in Network-Assisted Full-Duplex Cell-Free Massive MIMO**
Trinh Van Chien, Bui Trong Duc, Mohammadali Mohammadi, Hien Quoc Ngo, Michail Matthaiou
Wednesday, July 16, 12:40–13:00
Minotauro

Swarm Intelligence (SI)

★ **Congestion-Aware Multi-Agent Path Planning for Pick-Up and Delivery Tasks**
Mehrdad Asadi, Ann Nowé, Javad Ghofrani
Wednesday, July 16, 17:50–18:10
Minotauro

Theory

★ **Improved Runtime Analysis of a Multi-Valued Compact Genetic Algorithm on Two Generalized OneMax Problems**
Sumit Adak, Carsten Witt
Wednesday, July 16, 15:50–16:10
Mena

★ **Why Dominance Is Not Enough: Lessons from Practical Evolutionary Multi-Objective Algorithms**
Duc-Cuong Dang, Andre Opris, Dirk Sudholt
Wednesday, July 16, 16:10–16:30
Mena

Papers Schedule

Wednesday, July 16, 12:00–13:30

EML 1

Wednesday, July 16, 12:00–13:20

Chair: Kalyanmoy Deb, *Michigan State University, USA*

Azul

LAOS: Large Language Model-Driven Adaptive Operator Selection for Evolutionary Algorithms 12:00
Yisong Zhang, Guoxing Yi

PropNEAT – Efficient GPU-Compatible Backpropagation over NeuroEvolutionary Augmenting Topology Networks 12:20
Michael Merry, Patricia Riddle, James Warren

Interpretable Non-linear Survival Analysis with Evolutionary Symbolic Regression 12:40
Luigi Rovito, Marco Virgolin

Machine Learning-Assisted Constraint Handling Under Variable Uncertainty for Preference-based Multi-Objective Optimization 13:00
Deepanshu Yadav, Palaniappan Ramu, Kalyanmoy Deb

RWA 1

Wednesday, July 16, 12:00–13:00

Chair: Günter Rudolph, *TU Dortmund University, Germany*

Minotauro

★ **Sequence Optimization of Multispacecraft Multitarget Rendezvous Missions with a Coevolutionary Algorithm** 12:00
Yu Zhang, Yuehe Zhu, Jiacheng Zhang, Yazhong Luo

★ **Tomographic Reconstruction with Real-time a priori Acquistion** 12:20
Muhammad Wishal Khan, Hooman Oroojeni, Bal Sanghera, Tim Blackwell, Mohammad Majid al-Rifaie

★ **Differential Evolution for Infeasible Circumstances in Network-Assisted Full-Duplex Cell-Free Massive MIMO** 12:40
Trinh Van Chien, Bui Trong Duc, Mohammadali Mohammadi, Hien Quoc Ngo, Michail Matthaiou

GP 1

Wednesday, July 16, 12:00–13:20

Chair: Penousal Machado, *University of Coimbra, Portugal*

Alborán

Multi-Objective Genetic Programming for Imbalanced Classification with Adaptive Thresholds and a New Fitness Function 12:00
Minghui Bai, Xiaoying Gao, Jiaxin Niu, Jianbin Ma

How Neutrality Shapes Evolution: Simplicity Bias and Search 12:20
Ting Hu, Wolfgang Banzhaf, Gabriela Ochoa

A comparison of tournament and lexicase selection paradigms in regression problems: error-based fitness versus correlation fitness 12:40
Illya Bakurov, Aidan Murphy, Charles Ofria, Wolfgang Banzhaf

Desire-Driven Selection: An Epigenetic Experiment in Genetic Programming 13:00
José Maria Simões, Penousal Machado, Nuno Lourenço

BBSR 1 + ENUM 1

Wednesday, July 16, 12:00–13:20

Chair: Tobias Glasmachers, *Ruhr-University Bochum, Germany* — Mena

★ **Why We Should be Benchmarking Evolutionary Algorithms on Neural Network Training Tasks** 12:00
Katherine Mary Malan, Mario Andrés Muñoz

★ **When Does Neuroevolution Outcompete Reinforcement Learning in Transfer Learning Tasks?** 12:20
Eleni Nisioti, Erwan Plantec, Milton Llera Montero, Joachim Winther Pedersen, Sebastian Risi

★ **CatCMA with Margin: Stochastic Optimization for Continuous, Integer, and Categorical Variables** 12:40
Ryoki Hamano, Masahiro Nomura, Shota Saito, Kento Uchida, Shinichi Shirakawa

★ **Challenges of Interaction in Optimizing Mixed Categorical-Continuous Variables** 13:00
Youhei Akimoto, Xilin Gao, Ze Kai Ng, Daiki Morinaga

Theory 1

Wednesday, July 16, 12:00–13:20

Chair: Christine Zarges, *Aberystwyth University, UK* — Alcazaba

A Royal Road Function for Permutation Spaces: an Example Where Order Crossover is Provably Essential 12:00
Andre Opris, Sebastian Sonntag, Dirk Sudholt

Runtime Analysis of Evolutionary Multitasking for Classical Benchmark Problems 12:20
Johannes Lengler, Aneta Neumann, Frank Neumann

A General Upper Bound for the Runtime of a Coevolutionary Algorithm on Impartial Combinatorial Games 12:40
Alistair Benford, Per Kristian Lehre

Random Gradient Hyper-heuristics Can Learn to Escape Local Optima in Multimodal Optimisation 13:00
Yuxuan Ma, Pietro S. Oliveto, John Alasdair Warwicker

SI 1

Wednesday, July 16, 12:00–13:20

Chair: Edward Keedwell, *University of Exeter, UK* — Gibralfaro

Evolving Neural Controllers for Adaptive Visual Pattern Formation by a Swarm of Robots 12:00
Alessia Loi, Nicolas Bredeche

Lifelong Evolution of Swarms 12:20
Lorenzo Leuzzi, Davide Bacciu, Sabine Hauert, Simon Jones, Andrea Cossu

Minimalist exploration strategies for robot swarms at the edge of chaos 12:40
Vinicius Sartorio, Luigi Feola, Vito Trianni, Jonata Tyska Carvalho

HSEPSO: A Hierarchical Self-Evolutionary PSO Approach for UAV Path Planning 13:00
Jie Wei, Yuhui Zhang, Wenhong Wei

L4EC 1

Wednesday, July 16, 12:00–13:20

Chair: Nadarajen Veerapen, *Université de Lille, France*

Jábega

Residual Learning Inspired Crossover Operator and Strategy Enhancements for Evolutionary Multitasking 12:00
Ruilin Wang, Xiang Feng, Huiqun Yu, Edmund M-K Lai

Learning Graph Configuration Spaces to Support Road Network Design Optimisation 12:20
Michael Mittermaier, Takfarinas Saber, Goetz Botterweck

Automatic Design of Specialized Variation Operators for the Multi-Objective Quadratic Assignment Problem 12:40
Adrián Isaí Morales-Paredes, Julio Juárez, Jesús Guillermo Falcón-Cardona, Hugo Terashima-Marín, Carlos A. Coello Coello

Greedy Restart Schedules: A Baseline for Dynamic Algorithm Selection on Numerical Black-box Optimization Problems 13:00
Lennart Schäpermeier

Wednesday, July 16, 15:30–17:00

EML 2

Wednesday, July 16, 15:30–16:50

Chair: Thomas Bäck, *Leiden University, Netherlands*

Azul

Transformers as Surrogate Models for Genetic Programming in AutoML Tasks 15:30
Matheus Cândido Teixeira, Gisele Lobo Pappa

Enhancing XCS with Dual-Stream Identification for Perceptual Aliasing in Multi-Step Decision-Making 15:50
Fumito Uwano, Will N. Browne

Adversarial attacks to image classification systems using evolutionary algorithms 16:10
Sergio Nesmachnow, Jamal Toutouh

Evolving Hard Maximum Cut Instances for Quantum Approximate Optimization Algorithms 16:30
Shuaiqun Pan, Yash J. Patel, Aneta Neumann, Frank Neumann, Thomas Bäck, Hao Wang

EMO 1

Wednesday, July 16, 15:30–16:10

Chair: Tapabrata Ray, *University of New South Wales, Australia*

Minotauro

★ **R2 Indicator Analysis using the Optimal Distributions of Solutions for R2 and Other Indicators** 15:30
Yang Nan, Hisao Ishibuchi, Tianye Shu, Ke Shang

★ **Exploring Phase-Specific Configuration of Interactive Evolutionary Multiobjective Optimization Methods** 15:50
Giomara Larraga, Kaisa Miettinen

RWA 2

Wednesday, July 16, 15:30–16:50

Chair: Roman Kalkreuth, *RWTH Aachen University, Germany*

Malagueta

Navigating Path-Influenced Environments using Evolutionary Multi-Objective Optimization 15:30
Carlo Nübel, Malte Florim Speidel, Sanaz Mostaghim

Optimization of Unequal-Area Facility Layouts for Mass-Customization Assembly Systems with AGV Material Handling 15:50
Thomas Seidelmann, Sanaz Mostaghim

Exploring the Expressive Space of an Articulatory Vocal Modal using Quality-Diversity Optimization with Multimodal Embeddings 16:10
Joris Grouwels, Nicolas Jonason, Bob L. T. Sturm

Orthogonal Genetic Algorithm for Efficient Delivery Route Planning in TSP-D 16:30
Iyed Nasra, Hervé Camus, Ghaith Manita, Amine Dhraief, Ouajdi Korbaa

GP 2

Wednesday, July 16, 15:30–16:50

Chair: Nelishia Pillay, *University of Pretoria, South Africa*

Alborán

Evolutionary Synthesis of Probabilistic Programs 15:30
Romina Doz, Francesca Randone, Eric Medvet, Luca Bortolussi

Reaching Meaningful Diversity with Speciation-Novelty in Genetic Improvement for Software 15:50
Zsolt Nemeth, Penn Faulkner Rainford, Barry Porter

Coordinate System Extraction as the Search Driver in Test-Based Genetic Programming 16:10
Dmytro Vitel, Kok Cheng Tan, Alessio Gaspar, Paul Wiegand

Coordinate System Extraction as the Search Driver in Test-Based Genetic Programming 16:10
Dmytro Vitel, Kok Cheng Tan, Alessio Gaspar, Paul Wiegand

Analysis of Memory-Runtime Trade-offs in Caching Strategies for Genetic Programming Symbolic Regression 16:30
Jiaming Shi, Kei Sen Fong, Mehul Motani

GECH 1 + Theory 2

Wednesday, July 16, 15:30–16:50

Chair: James McDermott, *University of Galway, Ireland*

Mena

★ **Augmented Decision Spaces for Stackelberg Security Games: Sparse evolution begets scalability** 15:30
Adam Żychowski, Abhishek Gupta, Yew-Soon Ong, Jacek Mańdziuk

★ **Improved Runtime Analysis of a Multi-Valued Compact Genetic Algorithm on Two Generalized OneMax Problems** 15:50
Sumit Adak, Carsten Witt

★ **Why Dominance Is Not Enough: Lessons from Practical Evolutionary Multi-Objective Algorithms** 16:10
Duc-Cuong Dang, Andre Opris, Dirk Sudholt

Diversity-driven Cooperating Portfolio of Metaheuristic Algorithms 16:30
Adam Żychowski, Xin Yao, Jacek Mańdziuk

ECOM 1

Wednesday, July 16, 15:30–16:50

Chair: Emma Hart, *Edinburgh Napier University, UK*

Alcazaba

Application of PBIG to the Minimum Global Domination Problem 15:30
Salim Bouamama, Christian Blum

A Path-Relinking-based Heuristic for the Multiobjective Subgraph Problem 15:50
Daniela Scherer dos Santos, Kathrin Klamroth, Pedro Martins, Luís Paquete

Pareto Front Grid Guided Multiobjective Optimization In Dynamic Pickup And Delivery Problem Considering Two-Sided Fairness 16:10
Hung Phan Duc, Bui Trong Duc, Tam Nguyen Thi, Huynh Thi Thanh Binh

PGU-SGP: A Pheno-Geno Unified Surrogate Genetic Programming For Real-life Container Terminal Truck Scheduling 16:30
Leshan Tan, Chenwei Jin, Xinan Chen, Rong Qu, Ruibin Bai

SI 2

Wednesday, July 16, 15:30–16:30

Chair: David J. Walker, *University of Exeter, UK*

Gibralfaro

Learning Grouping Heuristics in Ant Colony Optimization for Combinatorial Problems 15:30
Aseel Ismael Ali, Edward Keedwell, Ayah Helal

Adaptive Multi-Population Dynamic Optimization for Multimodal Dynamic Function Optimization 15:50
Shoei Fujita, Ryuki Ishizawa, Hiroyuki Sato, Keiki Takadama

An Ensemble Ant Colony Optimization Algorithm with a Hybrid Pheromone Model for Learning Rule Lists. 16:10
James Brookhouse, Ayah Helal, Fernando E.B. Otero

L4EC 2

Wednesday, July 16, 15:30–16:50

Chair: Anna Kononova, *Leiden University, Netherlands*

Jábega

Accurate Peak Detection in Multimodal Optimization via Approximated Landscape Learning 15:30
Zeyuan Ma, Hongqiao Lian, Wenjie Qiu, Yue-Jiao Gong

Instance Space Analysis for the Capacitated Vehicle Routing Problem with Mixture Discriminant Analysis 15:50
Danielle Notice, Hamed Soleimani, Nicos G. Pavlidis, Ahmed Kheiri, Mario Andrés Muñoz

Learning Adaptive Neighborhood Search with Dual Operator Selection for Capacitated Vehicle Routing Problem 16:10
Xiang-Ling Chen, Yi Mei, Mengjie Zhang

Interpretable Decision Trees to Predict Solution Fitness 16:30
GianCarlo Antonino Pasquale Ignazio Catalano, Alexander Brownlee, David Cairns, Russell Ainslie, John McCall

Wednesday, July 16, 17:30–19:00

ECOM 2

Wednesday, July 16, 17:30–18:50

Chair: Kehinde Babaagba, *Edinburgh Napier University, UK*

Azul

In the Search of Optimal Tree Networks: Hardness and Heuristics 17:30
Pavel Martynov, Maxim Buzdalov, Sergey Pankratov, Vitaliy Aksenov, Stefan Schmid

Elitist Evolutionary Algorithm for Optimization on Sets of Points 17:50
Takumi Matsuo, Kento Uchida, Shinichi Shirakawa

A Learning-assisted Discrete Differential Evolution for Resource Constrained Project Scheduling 18:10
Yun Dong, Lixin Tang, Weiyan Jia

A Multiform Many-Objective Genetic Programming Method for Dynamic Flexible Job Shop Scheduling 18:30
Junwei Pang, Yi Mei, Mengjie Zhang

GA 1 + SI 3

Wednesday, July 16, 17:30–18:50

Chair: Dirk Thierens, *Utrecht University, Netherlands*

Minotauro

★ **Empirical Linkage Learning Provably Builds Truthful Models on Concatenated Traps and H-IFF** 17:30
Marcus Schmidbauer, Dirk Sudholt

★ **Congestion-Aware Multi-Agent Path Planning for Pick-Up and Delivery Tasks** 17:50
Mehrdad Asadi, Ann Nowé, Javad Ghofrani

On the Use of Matching Algorithms to Transfer Solutions for the Travelling Salesperson Problem 18:10
Liam Wigney, Aneta Neumann, Yew-Soon Ong, Frank Neumann

Evolutionary Multitasking for the Scenario-based Travelling Thief Problem 18:30
Thilina Pathirage Don, Aneta Neumann, Frank Neumann

RWA 3

Wednesday, July 16, 17:30–18:50

Chair: Roman Kalkreuth, *RWTH Aachen University, Germany*

Malagueta

CLEAR: Cue Learning using Evolution for Accurate Recognition Applied to Sustainability Data Extraction 17:30
Peter Bentley, Soo Ling Lim, Fuyuki Ishikawa

Feature Selection Using Genetic Algorithm for Intrusion Detection on Resource-Constrained Edge Devices 17:50
Tijana Markovic, Pontus Lidholm, Per Erik Strandberg, Miguel Leon

Contribution of Probabilistic Structured Grammatical Evolution to efficient exploration of the search space. A case study in glucose prediction 18:10
Jessica Mégane, Nuno Lourenço, J. Ignacio Hidalgo, Penousal Machado

Seeking and leveraging alternative variable dependency concepts in gray-box-elusive bimodal land-use allocation problems 18:30
Jakub Maciążek, Michal Witold Przewozniczek, Jonas Schwaab

EMO 2

Wednesday, July 16, 17:30–18:50

Chair: Dimo Brockhoff, *Inria and Ecole Polytechnique, France*

Alborán

Multi-Objective Covariance Matrix Adaptation MAP-Annealing 17:30
Shihan Zhao, Stefanos Nikolaidis

Reference Point Specification in Greedy Inclusion Hypervolume-based Subset Selection: A Study on Two Objectives 17:50
Adrián Isaí Morales-Paredes, Jesús Guillermo Falcón-Cardona, Julio Juárez, Hugo Terashima-Marín, Carlos A. Coello Coello

Multiagent Credit Assignment for Multi-Objective Coordination 18:10
Raghav Thakar, Gaurav Dixit, Siddarth Iyer, Kagan Tumer

Customized Exploration of Landscape Features Driving Multi-Objective Combinatorial Optimization Performance 18:30
Ana Nikolikj, Gabriela Ochoa, Tome Eftimov

EML 3

Wednesday, July 16, 17:30–18:30

Chair: Ryan Urbanowicz, *Cedars-Sinai Medical Center, USA*

Mena

★ **Evolution of Inherently Interpretable Visual Control Policies** 17:30
Camilo De La Torre, Giorgia Nadizar, Yuri Lavinas, Hervé Luga, Dennis Wilson, Sylvain Cussat-Blanc

★ **Dynamic Influence For Coevolutionary Agents** 17:50
Everardo Gonzalez, Gaurav Dixit, Kagan Tumer

★ **Evolutionary Quadtree Pooling for Convolutional Neural Networks** 18:10
Po-Wei Harn, Bo Hui, Libo Sun, Wei-Shinn Ku

GECH 2

Wednesday, July 16, 17:30–18:50

Chair: Alberto Moraglio, *University of Exeter, UK*

Alcazaba

Unlearning Works Better Than You Think: Local Reinforcement-Based Selection of Auxiliary Objectives 17:30
Matthieu Lerasle, Abderrahim Bendahi, Adrien Fradin

Code Evolution Graphs: Understanding Large Language Model Driven Design of Algorithms 17:50
Niki van Stein, Anna Kononova, Lars Kotthoff, Thomas Bäck

Hybrid Selection Allows Steady-State Evolutionary Algorithms to Control the Selective Pressure in Multimodal Optimisation 18:10
Dogan Corus, Pietro S. Oliveto, Feiyang Zheng

Key Insights into Estimating Nash Equilibria in Simultaneous Continuous Multiplayer Games Using Coevolutionary Algorithms 18:30
Rui Leite, Hernan Aguirre, Kiyoshi Tanaka

BBSR 2

Wednesday, July 16, 17:30–18:50

Chair: Vanessa Volz, *Centrum Wiskunde & Informatica, Netherlands*

Gibralfaro

Evaluation Time Bias in Asynchronous Evolutionary Algorithms: A Replication Study and a Novel Mitigation Strategy 17:30
Joshua Karns, Travis Desell

Multi-objective L-shaped Test Functions 17:50
Angus Kenny, Tapabrata Ray, Hemant Singh

SynthACticBench: A Capability-Based Synthetic Benchmark for Algorithm Configuration 18:10
Valentin Margraf, Anna Lappe, Marcel Wever, Carolin Benjamins, Eyke Hüllermeier, Marius Lindauer

MILPBench: A Large-scale Benchmark Test Suite for Mixed Integer Linear Programming Problems 18:30
Huigen Ye, Yaoyang Cheng, Hua Xu, Zhiguang Cao, Hanzhang Qin

L4EC 3 Wednesday, July 16, 17:30–18:10
Chair: Jakub Kudela, *Brno University of Technology, Czechia* Jábega

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Reinforcement Learning-Based Self-Adaptive Differential Evolution through Automated Landscape Feature Learning 17:30
Hongshu Guo, Sijie Ma, Zechuan Huang, Yuzhi Hu, Zeyuan Ma, Xinglin Zhang, Yue-Jiao Gong

Surrogate Learning in Meta-Black-Box Optimization: A Preliminary Study 17:50
Zeyuan Ma, Zhiyang Huang, Jiacheng Chen, Zhiguang Cao, Yue-Jiao Gong

Thursday, July 17, 12:00–13:30

ECOM 3 Thursday, July 17, 12:00–13:20
Chair: Yi Mei, *Victoria University of Wellington, New Zealand* Azul

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Smooth Transition Instance Chains in Combinatorial Optimization Problems 12:00
Valentino Santucci, Marco Baioletti, Marco Tomassini

Ant Colony Optimization with Policy Gradients and Replay 12:20
William Jardee, John Sheppard

Ant Colony Optimization for Tourist Route Planning 12:40
Li-Ting Xu, Qiang Yang, Dan-Ting Duan, Xin Lin, Cheng-Zhi Qu, Zhen-Yu Lu, Jun Zhang

Ant Colony Optimization Algorithm for Safest Path Computation in Presence of Correlated Failures in Backbone Networks 13:00
Zoltán Tasnádi, Balázs Vass, Noemi Gasko

GP 3 + Impact Thursday, July 17, 12:00–13:40
Chair: Nelishia Pillay, *University of Pretoria, South Africa* Minotauro

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★ **An Online Genetic Programming Approach to Dynamic Production Scheduling** 12:00
Binh Tran, Su Nguyen

★ **Quality Diversity Genetic Programming for Learning Scheduling Heuristics** 12:20
Meng Xu, Frank Neumann, Aneta Neumann, Yew-Soon Ong

★ **Transformer Semantic Genetic Programming for Symbolic Regression** 12:40
Philipp Anthes, Dominik Sobania, Franz Rothlauf

☆ Benchmarking program synthesis in genetic programming and beyond: reflections and future directions 13:00
Thomas Helmuth, Lee Spector

MAPLE: Multi-Action Programs through Linear Evolution for Continuous Multi-Action Reinforcement Learning 13:20
Quentin Vacher, Stephen Kelly, Ali Naqvi, Nicolas Beuve, Tanya Djavaherpour, Mickaël Dardaillon, Karol Desnos

RWA 4

Thursday, July 17, 12:00–13:20

Chair: Roman Kalkreuth, *RWTH Aachen University, Germany*

Malagueta

Symbolic Pricing Policies for Attended Home Delivery – the Case of an Online Retailer 12:00
Miguel Lunet, Daniela Fernandes, Fábio Neves-Moreira, Pedro Amorim

Multi-Agent Swarm Optimization for Decentralized Energy Management Considering Game Behaviors of Electric Vehicles 12:20
Tai-You Chen, Feng-Feng Wei, Wei-Neng Chen

Ensemble Phased Genetic Programming for Roundabout Turn Restriction Prediction 12:40
Darren Chitty, Ayah Helal, Sareh Rowlands, Craig Willis, Christopher Underwood, Edward Keedwell

A Dijkstra Seeded Evolutionary Multiobjective Optimization System for a Sustainable User Multimodal Transport Routing 13:00
Guilherme Barbosa, Pedro José Pereira, Vasco Abelha, Rui Mendes, Paulo Cortez

EMO 3

Thursday, July 17, 12:00–13:20

Chair: Hisao Ishibuchi, *Southern University of Science and Technology and Osaka Prefecture University, China*

Alborán

Variable Metric Evolution Strategies for High-dimensional Multi-Objective Optimization 12:00
Tobias Glasmachers

An Evolutionary Algorithm for Solving Decision Space Constrained Multi-Objective Binary Optimization Problems 12:20
Felipe Honjo Ide, Hernan Aguirre, Kiyoshi Tanaka

On the Pareto Set and Front of Multiobjective Spherical Functions with Convex Constraints 12:40
Anne Auger, Dimo Brockhoff, Jordan Cork, Tea Tušar

Scalarization-based Exploratory Landscape Analysis for Multi-Objective Continuous Optimization Problems 13:00
Shuhei Tanaka, Shoichiro Tanaka, Toshiharu Hatanaka

CS 1 + NE 1

Thursday, July 17, 12:00–13:20

Chair: Dennis Wilson, *Université de Toulouse, France*

Mena

★ Competition and Attraction Improve Model Fusion 12:00
João Abrantes, Robert Tjarko Lange, Yujin Tang

★ Evolving Comprehensive Proxies for Zero-Shot Neural Architecture Search 12:20
Junhao Huang, Bing Xue, Yanan Sun, Mengjie Zhang

★ Extract-QD Framework: A Generic Approach for Quality-Diversity in Noisy, Stochastic or Uncertain Domains 12:40
Manon Flageat, Johann Huber, François Helenon, Stéphane Doncieux, Antoine Cully

★ Visualizing the Dynamics of Neuroevolution with Genetic Distance Projections 13:00
Evan Hayden Patterson, Joshua Karns, Zimeng Lyu, Travis Desell

GECH 3

Thursday, July 17, 12:00–13:40
Chair: Thomas Gabor, *LMU Munich, Germany*
Alcazaba

Analysing the Effectiveness of Mutation Operators for One-Sided Bipartite Crossing Minimisation 12:00
Jakob Baumann, Ignaz Rutter, Dirk Sudholt

Solving the Cubic Knapsack Problem using Quantum-Inspired Digital Annealer Technology 12:20
Thiago Alves de Queiroz, Manuel Iori, Alberto Locatelli, Matthieu Parizy

Quantum Circuit Construction and Optimization through Hybrid Evolutionary Algorithms 12:40
Leo Sünkel, Philipp Altmann, Michael Kölle, Gerhard Stenzel, Thomas Gabor, Claudia Linnhoff-Popien

Enhancing Quality-Diversity Optimization Through Domain-Specific Dissimilarity as Crowding Distance 13:00
Maciej Komosinski, Agnieszka Mensfelt

Evaluating Mutation Techniques in Genetic-Algorithm-Based Quantum Circuit Synthesis 13:20
Michael Kölle, Tom Bintener, Maximilian Zorn, Gerhard Stenzel, Leo Sünkel, Thomas Gabor, Claudia Linnhoff-Popien

BBSR 3

Thursday, July 17, 12:00–13:40
Chair: Diederick Vermetten, *Sorbonne Université, France*
Gibralfaro

Automated Algorithm Configuration and Systematic Benchmarking for Heterogeneous MNK-Landscapes 12:00
Oliver Ludger Preuß, Carolin Mensendiek, Jeroen Rook, Jakob Bossek, Heike Trautmann

rEGGression: an Interactive and Agnostic Tool for the Exploration of Symbolic Regression Models 12:20
Fabrício Olivetti de França, Gabriel Kronberger

Subfunction Structure Matters: A New Perspective on Local Optima Networks 12:40
Sarah L. Thomson, Michal Witold Przewozniczek

Evolving Diverse Differentiating Stochastic Constraints Using Multi-objective Indicators 13:00
Saba Sadeghi Ahouei, Aneta Neumann, Frank Neumann

RandOptGen: A Unified Random Problem Generator for Single- and Multi-Objective Optimization Problems with Mixed-Variable Input Spaces 13:20
Moritz Vinzent Seiler, Oliver Ludger Preuß, Heike Trautmann

GA 2

Thursday, July 17, 12:00–13:40
Chair: Francisco Chicano, *University of Málaga, Spain*
Jábega

Energy and Performance Analysis of Parallel Heterogeneous Genetic Algorithms under Various CPU and GPU DVFS Governors: A Preliminary Study on Predictive Profiling 12:00
Amr Abdelhafez, Alexey Lastovetsky

Evo-SINDy: Universal Discovery of Partial Differential Equations Using Cooperative Evolutionary Computation 12:20
Yuxin Jiang, Jianyong Sun

Gradient-Free Sparse Adversarial Attack on Object Detection Models 12:40
Chi Cuong Le, Tri Phan, Ngoc Hoang Luong

Dramatically Faster Partition Crossover for the Traveling Salesman Problem 13:00
Ozeas Quevedo de Carvalho, Darrell Whitley

How Partition Crossover Exposes Parallel Lattices and the Fractal Structure of k-Bounded Functions 13:20
Darrell Whitley, Gabriela Ochoa, Francisco Chicano

Thursday, July 17, 15:30–17:00

EML 4

Thursday, July 17, 15:30–16:50

Chair: Pierluca Lanzi, *Politecnico di Milano, Italy*

Azul

Feature selection based on cluster assumption in PU learning 15:30
Motonobu Uchikoshi, Youhei Akimoto

Rule-based Machine Learning: Separating Rule and Rule-Set Pareto-Optimization for Interpretable Noise-Agnostic Modeling 15:50
Gabriel Lipschutz-Villa, Harsh Bandhey, Ruonan Yin, Malek Kamoun, Ryan Urbanowicz

Dataset Reduction for Offline Reinforcement Learning using Genetic Algorithms with Image-Based Heuristics 16:10
Enrique Mateos-Melero, Miguel Iglesias Alcázar, Raquel Fuentetaja, Fernando Fernández

Genetic Algorithms for Tractable Bayesian Network Fusion via Pre-Fusion Edge Pruning 16:30
Pablo Torrijos, José A. Gámez, José M. Puerta, Juan A. Aledo

ECOM 4

Thursday, July 17, 15:30–16:50

Chair: Sarah L. Thomson, *Edinburgh Napier University, UK*

Minotauro

★ **To Repair or Not to Repair? Investigating the Importance of AB-Cycles for the State-of-the-Art TSP Heuristic EAX** 15:30
Jonathan Heins, Darrell Whitley, Pascal Kerschke

★ **On Revealing the Hidden Problem Structure in Real-World and Theoretical Problems Using Walsh Coefficient Influence** 15:50
Michal Witold Przewozniczek, Francisco Chicano, Renato Tinós, Jakub Nalepa, Bogdan Ruszczak, Agata Maria Wijata

★ **Large Neighborhood Search for Capacitated Facility Location with Customer Incompatibilities** 16:10
Ida Gjergji, Lucas Kletzander, Nysret Musliu, Andrea Schaerf

Dynamic Temperature Control of Simulated Annealing using Hyper-Heuristics 16:30
Francesca Da Ros, Luca Di Gaspero, Lucas Kletzander, Marie-Louise Lackner, Nysret Musliu, Andrea Schaerf

RWA 5

Thursday, July 17, 15:30–16:50

Chair: Fabrício Olivetti de França, *Universidade Federal do ABC, Brazil*

Malagueta

Evolutionary Algorithms for Metabolic Transformation through Multi-gene Knockout Optimization 15:30
Bruno Sá, Alexandre Oliveira, Miguel Rocha

Search-based Generation of Waypoints for Triggering Self-Adaptations in Maritime Autonomous Vessels 15:50
Karoline Nylænder, Aitor Arrieta, Shaukat Ali, Paolo Arcaini

A Quality Diversity Approach to Evolving Model Rockets 16:10
Jacob Schrum, Cody Crosby

Unveiling the dynamics of NOx pollution in internal combustion engines by Structured Grammatical Evolution 16:30
Marcos Llamazares López, Daniel Parra, Jose Manuel Velasco Cabo, Óscar Garnica, Rafael Jacinto Villanueva Micó, J. Ignacio Hidalgo

EMO 4

Thursday, July 17, 15:30–16:50

Chair: Tea Tušar, *Jožef Stefan Institute, Slovenia*

Alborán

Addressing Heterogeneous Evaluation Times in Constrained Multi-Objective Optimization using a Mixed-Fidelity Evaluation Technique: Proof-of-Concept Results 15:30
Balija Santoshkumar, Kalyanmoy Deb

Search Behavior Analysis of NSGA-III: Dominance-based and Decomposition-based Multi-objective Evolutionary Algorithm 15:50
Hisao Ishibuchi, Lie Meng Pang, Cheng Gong

Analyzing the Landscape of the Indicator-based Subset Selection Problem 16:10
Keisuke Korogi, Ryoji Tanabe

Influence of Subpopulation on the Performance of Coevolutionary Algorithms for Constrained Multiobjective Optimization Problems 16:30
Yanyu Chen, Hisao Ishibuchi, Yang Nan

L4EC 4

Thursday, July 17, 15:30–16:30

Chair: Clarisse Dhaenens, *Université de Lille, France*

Mena

★ **Deep reinforcement learning for instance-specific algorithm configuration** 15:30
Elias Schede, Moritz Vinzent Seiler, Kevin Tierney, Heike Trautmann

★ **The Pitfalls of Benchmarking in Algorithm Selection: What We Are Getting Wrong** 15:50
Gašper Petelin, Gjorgjina Cenikj

★ **On the Importance of Reward Design in Reinforcement Learning-based Dynamic Algorithm Configuration: A Case Study on OneMax with (1+(λ,λ))-GA** 16:10
Tai Nguyen, Phong Le, André Biedenkapp, Carola Doerr, Nguyen Dang

ENUM 2

Thursday, July 17, 15:30–16:50

Chair: Anne Auger, *Inria and Ecole Polytechnique, France*

Alcazaba

Toward Efficient Mixed-Integer Black-Box Optimization via Evolution Strategies with Plateau Handling Techniques 15:30
Tuan Anh Nguyen, Ngoc Hoang Luong

Abnormal Mutations: Evolution Strategies Don't Require Gaussianity 15:50
Jacob de Nobel, Diederick Vermetten, Hao Wang, Anna Kononova, Günter Rudolph, Thomas Bäck

More Efficient Real-Valued Gray-Box Optimization through Incremental Distribution Estimation in RV-GOMEA 16:10
Renzo Scholman, Tanja Alderliesten, Peter A.N. Bosman

A Perturbation and Speciation-Based Algorithm for Dynamic Optimization Uninformed of Change 16:30
Federico Signorelli, Anil Yaman

NE 2

Thursday, July 17, 15:30–16:50

Chair: Bing Xue, *Victoria University of Wellington, New Zealand*

Gibralfaro

Neuroevolution of Self-Attention Over Proto-Objects 15:30
Rafael Coimbra Pinto, Anderson Rocha Tavares

SiamNAS: Siamese Surrogate Model for Dominance Relation Prediction in Multi-objective Neural Architecture Search 15:50
Yuyang Zhou, Ferrante Neri, Yew-Soon Ong, Ruibin Bai

CPPN2WFC: Extending Wave Function Collapse to Generate Globally Coherent Content 16:10
Oleg Jarma Montoya, František Srb, Djordje Grbic, Sebastian Risi

Integrating Neural Architecture Search and Rematerialization for Efficient On-Device Learning 16:30
Chih-Ling Chen, Kai-Chiang Wu, Ning-Chi Huang

CS 2

Thursday, July 17, 15:30–16:50

Chair: Hannah Janmohamed, *Imperial College, UK*

Jábega

Overcoming Deceptiveness in Fitness Optimization with Unsupervised Quality-Diversity 15:30
Lisa Coiffard, Paul Templier, Antoine Cully

Controller Distillation Reduces Fragile Brain-Body Co-Adaptation and Enables Migrations in MAP-Elites 15:50
Alican Mertan, Nick Cheney

Dominated Novelty Search: Rethinking Local Competition in Quality-Diversity 16:10
Ryan Bahlous-Boldi, Maxence Faldor, Luca Grillotti, Hannah Janmohamed, Lisa Coiffard, Lee Spector, Antoine Cully

Multi-Objective Quality-Diversity in Unstructured and Unbounded Spaces 16:30
Hannah Janmohamed, Antoine Cully

Friday, July 18, 10:00–11:30

EML 5

Friday, July 18, 10:00–11:00

Chair: Franz Rothlauf, *University of Mainz, Germany*

Azul

Guiding Evolutionary AutoEncoder Training with Activation-Based Pruning Operators 10:00
Steven Jorgensen, Erik Hemberg, Jamal Toutouh, Una-May O'Reilly

Black-Box Adversarial Attack on Dialogue Generation via Multi-Objective Optimization 10:20
Khang Gia Le, Ngoc Hoang Luong

ImageBreeder: Guiding Diffusion Models with Evolutionary Computation 10:40
Dominik Sobania, Martin Briesch, Franz Rothlauf

GP 4

Friday, July 18, 10:00–11:20

Chair: Wolfgang Bhanzaf, *Michigan State University, USA*

Minotauro

Improving Genetic Programming for Symbolic Regression with Equality Graphs 10:00
Fabrício Olivetti de França, Gabriel Kronberger

Uniform Projection of Program Space Geometry for Genetic Improvement of Software 10:20
Benjamin Craine, Barry Porter

Slim_gsgp: A Python Library for Non-Bloating GSGP 10:40
Liah Rosenfeld, Davide Farinati, Diogo Rasteiro, Gloria Pietropolli, Karina Brotto Rebuli, Sara Silva, Leonardo Vanneschi

Program Synthesis with LLM-Predicted Minimal Specialized Grammars 11:00
David Vella Zarb, Geoff Parks, Timoleon Kipouros

RWA 6

Friday, July 18, 10:00–11:00

Chair: Alexander Brownlee, *University of Stirling, UK*

Malagueta

Bayesian Optimization for CVaR-based portfolio optimization 10:00
Robert Millar, Jinglai Li

Optimization of Conformal Cooling Channels for Injection Molding Using Multi-Objective Artificial Intelligence Techniques 10:20
Antonio Gaspar-Cunha, João Melo, Tomás Marques, António Pontes

GA-PRE: A Genetic Algorithm-Based Automatic Data Preprocessing Algorithm 10:40
Jian Jiao, Liu Yuan

EMO 5

Friday, July 18, 10:00–11:20

Chair: Carlos A. Coello Coello, *CINVESTAV-IPN, Mexico*

Alborán

Improved Convergence-relaxed Mechanism for Handling Imbalance Between Convergence and Diversity in the Decision Space in Multimodal Multi-objective optimization 10:00
Zhipan Li, Wenkai Mao, Huigui Rong, Jianguo Chen, Shengxu Huo, Zilu Zhao

Constrained Multi-objective Optimization with Search Direction Learning 10:20
Mingcheng Zuo, Dunwei Gong, Tianyang Xue, Chunliang Zhao, Yongde Guo

High-Dimensional Expensive Multiobjective Optimization Using a Surrogate-Assisted Multifactorial Evolutionary Algorithm 10:40
Yuma Horaguchi, Masaya Nakata

Genotype vs. Phenotype: A Crossover Operator Comparison for the Multi-Objective Coverage Path Planning Problem 11:00
Lukas Bostelmann-Arp, Christoph Steup, Sanaz Mostaghim

ECOM 5

Friday, July 18, 10:00–11:20

Chair: Yi Mei, *Victoria University of Wellington, New Zealand*

Mena

Moving between high-quality optima using multi-satisfiability characteristics in hard-to-solve Max3Sat instances 10:00
Jędrzej Piątek, Michal Witold Przewozniczek, Francisco Chicano, Renato Tinós

Performance Comparison between Evolutionary Algorithms and Linear Programming-based Relaxation Methods for Multi-Objective Knapsack Problems 10:20
Cheng Gong, Ping Guo, Lie Meng Pang, Qingfu Zhang, Hisao Ishibuchi

Cluster Prevention in Evolutionary Diversity Optimization for Parallel Machine Scheduling 10:40
Dominic Wittner, Jakob Bossek

Local Optima Networks for Constrained Search Spaces 11:00
Jonathan Fieldsend, Arnaud Liefooghe, Katherine Mary Malan, Sébastien Verel

ENUM 3

Friday, July 18, 10:00–11:20

Chair: Youhei Akimoto, *University of Tsukuba and RIKEN AIP, Japan*

Alcazaba

Classification-Based Linear Surrogate Modeling of Constraints for AL-CMA-ES 10:00
Oskar Girardin, Nikolaus Hansen, Dimo Brockhoff, Anne Auger

An Adaptive Re-evaluation Method for Evolution Strategy under Additive Noise 10:20
Catalin-Viorel Dinu, Yash J. Patel, Xavier Bonet-Monroig, Hao Wang

Surrogate-Assisted CMA-ES for Problems with Low Effective Dimensionality 10:40
Yuta Sekino, Yohei Watanabe, Kento Uchida, Shinichi Shirakawa

Adaptive Estimation of the Number of Algorithm Runs in Stochastic Optimization 11:00
Tome Eftimov, Peter Korošec

NE 3

Friday, July 18, 10:00–11:20

Chair: Risto Miikkulainen, *University of Texas at Austin, USA*

Gibralfaro

A Multi-Objective Approach to Optimizing Kolmogorov-Arnold Networks 10:00
Quan Long, Bin Wang, Bing Xue, Mengjie Zhang

Neuro-Evolutionary Approach to Physics-Aware Symbolic Regression 10:20
Jiří Kubalík, Robert Babuska

Diversity in Reinforcement Learning Through the Occupancy Measure 10:40
Arno Feiden, Jochen Garcke

Scaling Policy Gradient Quality-Diversity with Massive Parallelization via Behavioral Variations 11:00
Konstantinos Mitsides, Maxence Faldor, Antoine Cully

CS 3

Friday, July 18, 10:00–11:00

Chair: Malcolm Heywood, *Dalhousie University, Canada*

Jábega

Fertility During Learning in Evolutionary Robot Systems 10:00
Jacopo Michele Di Matteo, Oliver Weissl, A.E. Eiben

Classifier Systems as Linear Probability Models 10:20
Gijs Schröder, Johannes Textor

Emergent Braitenberg-style Behaviours for Navigating the ViZDoom 'My Way Home' Labyrinth 10:40
Caleidgh Bayer, Robert Smith, Malcolm Heywood

Posters

Posters by Track

Benchmarking, Benchmarks, Software, and Reproducibility (BBSR)

A Comparison of Dimensionality Reduction Techniques for Visualising Search Behaviour
Helena Stegherr, Michael Heider, Jonathan Wurth, Jörg Hähner

An Investigation of Inherent Structural Bias in Established Benchmark Sets
David Ibehej, Alexandros Tzanetos, Martin Juricek, Jakub Kudela

Analyzing per-component energy consumption of evolutionary algorithms implemented in low-level languages
Jj Merelo, Gustavo Romero López, Mario García-Valdez

CRust_GP: A Framework for the Modular Construction and Evaluation of Cartesian Genetic Programming in Rust
Henning Cui, Jörg Hähner

CoSPLib – A Benchmark Library for Conference Scheduling Problems
Ahmed Kheiri, Yaroslav Pylyavskyy, Peter Jacko

Empirical Complexity Analysis of Optimization Algorithms
Raúl Martín-Santamaría, Manuel López-Ibáñez, Jose Manuel Colmenar

Energy Efficiency of C++ Standard Random Number Generators
Gustavo Romero López, Jj Merelo

Evolutionary Generation of Random Surreal Numbers for Benchmarking
Matthew Roughan

Evolve On Click (EvOC) – An Intuitive Web Platform to Collaboratively Implement, Execute, and Visualize Evolutionary Algorithms
Ritwik Murali, Ashwin Narayanan Sivamani, Abhinav Ramakrishnan, Hariharan Arul, Ananya R.

Large Language Model Driven Evolutionary Optimization Benchmark Generation Algorithm
Yuhiro Ono, Tomohiro Harada, Yukiya Miura

Othimi: A Block-Based Educational Programming Tool for Metaheuristic Design and Optimization
Gara Miranda, Casiano Rodriguez-Leon, Eduardo Segredo

TinyverseGP: Towards a Modular Cross-domain Benchmarking Framework for Genetic Programming
Roman Kalkreuth, Fabrício Olivetti de França, Anja Janković, Marie Anastacio, Julian Dierkes, Zdenek Vasicek, Holger Hoos

Evorobotpy3: a flexible and easy-to-use simulation tool for Evolutionary Robotics
Paolo Pagliuca, Stefano Nolfi, Alessandra Vitanza

IGJSP: A Reproducible Instance Generator for Job Shop Scheduling
Christian Perez, Carlos March, Miguel A. Salido

softpy: A User-Friendly Python Library for Soft Computing
Andrea Campagner, Davide Ciucci

Complex Systems (CS)

Accelerating Soft Robot Evolution Using N-gram-based Controller Inheritance and Genetic Co-Design
Yue Xie, Xueming Yan, Fumiya Iida

Autoverse: Evolving Symbolic Neural Cellular Automata Environments to Train Player Agents
Sam Earle, Julian Togelius

Size Matters: Variable-Length Bones in Evolvable Modular Robots
Maarten Alexander Stork, Roy de Regt, Duy Tan Robin Nguyen, A.E. Eiben

Hybrid Approach for Multi-Robot Task Allocation in Search and Rescue Operations Using NSGA-II and Variable Neighborhood Descent
Tatiana Machado Brito dos Santos, Milena Faria Pinto, Matheus Jenevain, Lais Rios Berno, Igor Machado Coelho

Evolutionary Combinatorial Optimization and Metaheuristics (ECOM)

A Tabu Search Algorithm Based on Symmetry Local Search for Multi-objective Combinatorial Optimization Problems
Tianyang Li, Ying Meng, Lixin Tang, Qingxin Guo

An analysis of training models to evolve relocation rules for the container relocation problem
Marko Đurasević, Mateja Đumić, Francisco Javier Gil Gala, Domagoj Jakobović

Automated Design of Heuristics with Genetic Programming for the Electric Vehicle Routing Problem with Partial Recharging
Magda Smolić-Ročak, Marko Đurasević, Josip Hrvatić, Francisco Javier Gil Gala

Clustering Assisted Ant Colony Optimization for Large-Scale Travelling Salesman Problem
Zhong-Heng Jiang, Qiang Yang, Dan-Ting Duan, Pei-Lan Xu, Cheng-Zhi Qu, Zhen-Yu Lu, Jun Zhang

Destination-Oriented Route Construction for Ant Colony Optimization to Solve MinMax Multiple Travelling Salesmen Problems
Hai-Long Bai, Qiang Yang, Pei-Yan Yuan, Dan-Ting Duan, Tao Li, Dong Liu, Jun Zhang

Empirical Studies of Multimodality in Feature Selection: Generalized Crowding for Genetic Algorithms
Corentin Masson, Ole Jakob Mengshoel, Xavier F. C. Sánchez-Díaz

Evolving Cryptographic Boolean Functions with Reaction Systems
Rocco Ascone, Luca Mariot, Luca Manzoni, Gloria Pietropolli

Generalising the Team Orienteering problem through Multi-constraining and Multi-objectives
Raimundo Gross, Elizabeth Montero, Nicolás Gálvez Ramírez, Adriana Menchaca-Méndez

Greedy Randomised Adaptive Solution Builder using Priority Rules
Francisco Javier Gil Gala, Marko Đurasević, Maria R. Sierra, Jorge Puente

L-DEGR: A Novel Hybrid Algorithm for Multi-Skill Resource-Constrained Project Scheduling in Large-Scale
Konrad Gmyrek, Paweł B. Myszkowski, Jan Gregor, Lukasz P. Olech

Lazy Hypervolume Subset Selection Algorithm with Contributions Update
Andrzej Jaszkiewicz, Piotr Zielniewicz

New QUBO Transformations to Improve Quantum and Simulated Annealing Performance for Quadratic Knapsack
Nicolás Borrajo, Juan Marcos Ramirez, Farzam Nosrati, Jose Aguilar, Vincenzo Mancuso, Antonio Fernández Anta

Solution Approaches for the Balanced Task Planning Problem
Fabian Nagler, Nysret Musliu, Felix Winter

Spectral Walsh analysis and surrogate-assisted optimization: example of the bus stops spacing problem
Valentin Vendi, Sébastien Verel, Cyril Fonlupt

Improving Deep Optimisation for the Multi-dimensional Knapsack Problem using Elastic Weight Consolidation
Antoine Calame, Ruth Misener, Joshua Knowles

Evolutionary Machine Learning (EML)

A Comparison and Analysis of LLM Agents within the Context of An LLM-Guided Evolution for Object Detection
YiMing Yu, Jason Paul Zutty

CGP-CANTS-N: A Versatile Graph-Based Framework for Scalable and Adaptive Problem Solving Across Domains
AbdElRahman ElSaid, Travis Desell

Diversifying Adversarial Attacks on Text-to-image Generation
Thai Huy Nguyen, Ngoc Hoang Luong

GLCM and Genetic Algorithms for Automated Diabetic Retinopathy Prediction Based on Retinal Images
Michał Gandor, Wojciech Książek

Hybrid Deterministic and Metaheuristic Optimization for Physical Adversarial Attack on End-to-End Autoencoder Wireless Communication Systems
Ho Viet Duc Luong, Trinh Van Chien, Lang Hong Nguyet Anh, Huynh Thi Thanh Binh

Investigating Combined Algorithm Selection and Hyperparameter Optimization for Fairness
Zhiang Chen, Mark Connor, Sudarshan Pant, Michael O'Neill

LIMES: Learning from Imbalanced Data via Multiform Multi-Objective Feature Selection
Ruwang Jiao, Tao Peng, Naoki Masuyama, Yusuke Nojima

On the Investigation of Evolutionary Multi-Objective Optimization for Discrete Prompt Search
Hien H. Mai, Ngoc Hoang Luong

Partition2Vec – Towards Representation Learning for Evolutionary Clustering using Siamese Autoencoders
Julia Handl

Q-Learning-Assisted DE and PSO for Enhanced Dose Planning in Radiotherapy
Devika Gautam, Yogesh Kumar

Reinforcement Learning-based Cloud Autoscaler Initialization via Evolutionary Algorithms
Luciano Ivan Robino, Elina Pacini, Yisel Garí, Cristian Mateos, Virginia Yannibelli, David Monge

Reinforcement Learning-based Genetic Algorithm for Computation Offloading Optimization in UAV-assisted MEC Systems
Nguyen Thi My Binh, Le Vu Minh Tam, Ho Viet Duc Luong, Trinh Van Chien, Huynh Thi Thanh Binh

Unifying Zeroth-Order Optimization and Genetic Algorithms for Reinforcement Learning
So Nakashima, Tetsuya J. Kobayashi

A Two-Stage Explanation-Based Method Using Particle Swarm Optimization for Black-Box Adversarial Attack
Chaoxin Zhang, Gonglin Yuan, Hongwei Ge, Yaqing Hou

An Evolutionary Approach to Interpretable Machine Learning for ICU Length of Stay Prediction
Reshma Kar, Eslin Kiran Ilangovan, Gulhan Bizel, Braja Gopal Patra

Evaluating the Generalizability of Machine Learning Pipelines When Using Lexicase or Tournament Selection
Jose Guadalupe Hernandez, Anil Kumar Saini, Ankit Gupta, Jason Moore

Explainable AI Based Diagnosis of Poisoning Attacks in Evolutionary Swarms
Mehrdad Asadi, Roxana Radulescu, Ann Nowé

Particle Swarm Optimization for Automating Prompt Optimization in Large Language Models on Text Classification and Generation Tasks
Linsen Li, Bin Wang, Bing Xue, Mengjie Zhang

Particle Swarm-Optimized U-Net Framework for Precise Multimodal Brain Tumor Segmentation
Shoffan Saifullah, Rafał Dreżewski

SLIME: Supralocal Interpretable Model-Agnostic Explanations via Evolved Equation-Based Surrogates
Kei Sen Fong, Mehul Motani

Sparse Transformer for Long-term Forecasting via Genetic Algorithm
Jingeun Kim, Yourim Yoon

Evolutionary Multiobjective Optimization (EMO)

A Continuation Method Based on CMA-ES
Hoang Nguyen Vu, Dimo Brockhoff

A Large Language Model-assisted Evolutionary Algorithm for Expensive Constrained Multi-objective Optimization
Siyu Chen, Haoran Tang, Jinyuan Zhang, Ke Tang

A New Framework for Visualising Diversity Properties of Pareto Front Approximations in Many-objective Optimisation
Kai Eivind Wu, George Panoutsos

A Simple Combination of Local Search and MOEAD for Combinatorial Multi-objective Optimization
Bilel Derbel

A bi-objective Medical Sampling Service System
Hue Thi Tran, Ky Tuan Hoang, Phuong Khanh Nguyen, Huynh Thi Thanh Binh

A customized MOEA/D with active element pattern surrogate model for direction finding array design
Hanhua Zou, Ruwang Jiao, Fei Zhao, Changhe Li, Sanyou Zeng

An Arithmetic Optimization Algorithm with Dynamic State Estimation for Deadline-Constrained Workflow Scheduling
Najoua Kouka, Sabrina De Capitani di Vimercati, Vincenzo Piuri, Pierangela Samarati

Benchmarking MOEAs for solving continuous multi-objective RL problems
Roberto Santana, Carlos Ignacio Hernández Castellanos

COTLEA: COpula-based Transfer Learning Evolutionary Algorithm for Multi-Objective Optimization Problems
Fodil Benali, Cyril De Runz, Nicolas Labroche, Hicham Elmokhtari

CRSGA: Cluster-Based Region Selection Genetic Algorithm Solving Multi-Objective Travelling Thief Problem
Lukasz P. Olech, Paweł B. Myszkowski, Konrad Gmyrek

Efficient Contextual Preferential Bayesian Optimization with Historical Examples
Farha A. Khan, Tanmay Chakraborty, Joerg P. Dietrich, Christian Wirth

GraCo: Towards GRammar Assisted COunterfactuals
Dhiraj Kumar Singh, Allan de Lima, Darian Reyes Fernández de Bulnes, Conor Ryan

Impact of Reformulation for the Real-World Constrained Multi-Objective Problems on the Performance of Evolutionary Algorithms
Jinglin Wang, Hongyu Zhu, Yang Nan, Hisao Ishibuchi

Improving the Convergence and Diversity of Evolutionary Algorithms in Biobjective Optimization Problems
Antonio Borrego, Mariano Luque, Rubén Saborido

Investigating the Climbing Mechanism of the Weight-Guided Random Bit Climber for Many-Objective Optimization
Yudai Tagawa, Hernan Aguirre, Kiyoshi Tanaka

Investigating the Spreadability of Problems in Evolutionary Multi-objective Optimization Algorithms
Weifeng Guan, Fangqing Gu, Yingxuan Liang, Hai-lin Liu, Yuping Wang

MGDA/D: A Multiple Gradient Descent Algorithm Based on Decomposition
Yawen Zhou, Ke Xue, Chao Qian

Modeling and Solution to Hot Rolling Production Rescheduling Problem
Gejian Xu, Guodong Zhao, Yang Yang, Hua Zou

Multi-Objective Evolutionary Sunshade Design
Geoff Nitschke, Farzana Toma

Multi-criteria Optimization Algorithms specially tailored for Programmable Networks with Quality Management.
Stanislaw Kozdrowski, Wojciech Makos, Zbigniew Kopertowski, Slawomir Sujecki

Multi-objective Traveling Salesman Problem with Profits and Passengers: Exact, Heuristic and Evolutionary Approaches
Juvenal Bruno Andrade da Silva, Tarcisio Assis Pereira Brito, Ricardo Araújo Rios, Tatiane Nogueira Rios, Islame Felipe da Costa Fernandes

Optimization of Time-Variant Charging Station Placement Using Evolutionary Algorithms
Sai Lokesh Kancharla, Sebastian Brulin, Sanaz Mostaghim, Markus Olhofer

Reinforcement Learning-Guided Multi-Environmental Selection Strategy for Constrained Multi-Objective Evolutionary Optimization
Mingcheng Zuo, Yuan Xue, Dunwei Gong, Shujing Gao, Yongde Guo

Targeting Evaluation, Computation and Interaction Costs in Expensive Black-Box Multi-Objective Optimization
Arash Heidari, Sebastian Rojas Gonzalez, Ivo Couckuyt

Uncertainty Quantification of the Hypervolume for Evolutionary Multi-Objetive Reinforcement Learning
Alberto Maximiliano Millán Prado, Carlos Ignacio Hernández Castellanos

When to Truncate the Archive? On the Effect of the Truncation Frequency in Multi-Objective Optimisation
Zhiji Cui, Zimin Liang, Lie Meng Pang, Hisao Ishibuchi, Miqing Li

A Constrained Multi-objective Co-Evolutionary Algorithm Based on Operator Score and Reward
Kangshun Li, Juhong Wu, Shumin Xie

A Dynamic Constrained Multiobjective Evolutionary Algorithm based on Convergence Path Interpolation
Guangyuan Sui, Cuicui Yang, Junzhong Ji, Xiaoyu Zhang

A Hyper-feasible Solutions Based Update Weight Vectors Evolutionary Algorithm for Constrained Multiobjective Optimization Problem
Kangshun Li, Tianjin Zhu, Shumin Xie

Local Self-Adaptive Mutation: Enhancing Multi-Objective Optimization through Localized Operator Selection and Parameter Adaptation
Michał Antkiewicz

Model-Adaptive Reference Points Generation based on Gaussian Process for Many-Objective Optimization
Atiya Masood

Multi-Objective Fairness Approach Using Causal Bayesian Networks & Grammatical Evolution
Zahid Irfan, Róisín Loughran, Muhammad Adil Raja, Fergal McCaffery

Multi-Objective Optimisation of the Generalized Bin Packing Problem
Rosephine Georgina Rakotonirainy, Andrea Plumbley

Simulated Annealing-based Evolutionary Algorithm for Constrained Multimodal Multiobjective Optimization
Juan Zou, Yu Li, Qi Deng, Tian-Bin Xie, Sheng-Xiang Yang, Jin-Hua Zheng

Evolutionary Numerical Optimization (ENUM)

A Novel Two-Phase Cooperative Co-evolution Framework for Large-Scale Global Optimization with Complex Overlapping
Wenjie Qiu, Hongshu Guo, Zeyuan Ma, Yue-Jiao Gong

CMA-ES with Individual Adaptive Reevaluation for Black Box Value-At-Risk Optimization
Ze Kai Ng, Daiki Morinaga, Youhei Akimoto

Comparing Optimization Algorithms Through the Lens of Search Behavior Analysis
Gjorgjina Cenikj, Gašper Petelin, Tome Eftimov

Covariance Matrix Adaptation Evolution Strategy without a matrix
Jarosław Arabas, Adam Stelmaszczyk, Eryk Warchulski, Dariusz Jagodziński, Rafał Biedrzycki

Efficient Quality Diversity Optimization with Monte Carlo Bayesian Sampling
Matteo Palmas, Varun Bhatt, Shihan Zhao, Stefanos Nikolaidis, Ralph Lange, Michaela Klauck

Geometric Learning in Black-Box Optimization: A GNN Framework for Algorithm Performance Prediction
Ana Kostovska, Carola Doerr, Sašo Džeroski, Panče Panov, Tome Eftimov

Learning Rate Adaptation CMA-ES for Multimodal and Noisy Problems with Low Effective Dimensionality
Haruhito Nakagawa, Yutaro Yamada, Kento Uchida, Shinichi Shirakawa

Search Space Selection Using Constrained Mixed-Integer Optimization Method
Kento Uchida, Yohei Watanabe, Ryoki Hamano, Shinichi Shirakawa

Using Variable Interaction Graphs to Improve Particle Swarm Optimization
Casimir Czworkowski, John Sheppard

Enhancing CMA-ES-PDM for Mixed-Integer Black-Box Optimization
Duc Manh Nguyen

Exploring Heterogeneity in Constrained Optimization: An Adaptive Two-Stage Surrogate-Assisted Evolutionary Algorithm
Chenyan Gu, Handing Wang

General Evolutionary Computation and Hybrids (GECH)

A Framework for Automatically Setting Multiple Penalty Weights in Quadratic Unconstrained Binary Optimization
Jiajie Liu, Alberto Moraglio

GOM-Based Compatible Substitutions Optimization for Variable-Length Representation Gray-Box Problems
Maciej Komosinski, Konrad Miazga

Generalizing the Structure of a University Timetabling Solver for Flexible Automatic Algorithm Configuration
Thomas Feutrier, Nadarajen Veerapen, Marie-Eléonore Kessaci

Hierarchical Convergence to Multiple Alternate Solutions: Population versus Point-based Algorithms
Ahmer Khan, Kalyanmoy Deb

On the Generation of Diverse Solution Sets in a Tourist Trip Design Problem – An Experimental Study
Boris Pérez-Cañedo, Pavel Novoa-Hernández, David A. Pelta

Riesz Energy-Based Hybrid Algorithms for Constrained Multi-Objective Optimization
Lourdes Uribe, Yael Andrade-Ibarra, Adriana Lara

Towards Deep Optimization in Operations Scheduling
Linus Danardya, Joshua Knowles, Richard Allmendinger

Written by Artificial Intelligence, Evolved by Genetic Algorithms: An Evolutionary Challenge to Solving the Traveling Salesperson Problem with ChatGPT
Tae-Hun Kim, Yong-Hyuk Kim

Adaptive Reference Vectors Cooperate with Generalized Pareto Dominance for Irregular Many-objective Problems
Liusheng Zeng, Yuchen Li, Jingxue Hu, Shuwei Zhu, Meiji Cui

Evolutionary and Coevolutionary Multi-Agent Design Choices and Dynamics
Erik Hemberg, Stephen Moskal, Eric Liu, Lucille Fuller, Una-May O'Reilly

Genetic Algorithms (GA)

A Genetic Algorithm for Solving the Three-Dimensional Bin Set Selection Problem
Leon Binder, Michael Scholz

A Parameter Adaptive Genetic Algorithm With Restarts for Flexible Job Shop Scheduling Problems with Worker Flexibility
David Hutter, Thomas Steinberger, Michael Hellwig

An LLM-Based Genetic Algorithm for Prompt Engineering
Leandro Augusto Loss, Pratikkumar Dhuvad

Evolutionary Black-box Patch Attacks on Face Verification
Khoa Tran, Linh Ly, Ngoc Hoang Luong

Local Search Integrated Genetic Algorithms for Solving the Colored Traveling Salesman Problem
Karuna Panwar, Kusum Deep

Smart Starts: Accelerating Convergence Through Uncommon Region Exploration
Xinyu Zhang, Mário Antunes, Tyler Estro, Erez Zadok, Klaus Mueller

Avoiding Premature Convergence to Local Optima with Adaptive Exploration for Genetic Algorithms
Sumaiya Saima Sultana, Tomohiko Tanabe, Tobias Fausten, Mitsuru Irie

Genetic Algorithm-Based Optimization of High-Density EEG Channels for Eye State Classification with a Refined Subset Approach
Indrajit Dutta, Sandip Chakraborty, Sourav Samanta, Bibhash Sen

Leveraging Genetic Algorithm to Refine Genetic Programming-Evolved Dispatching Rules for Flexible Job Shop Scheduling
Shady Salama, Mate Kovacs

Genetic Programming (GP)

A Symbolic Hessian-Based Approach for Assessing Model Complexity in Symbolic Regression
Nathan Haut, Stuart Card, Mark Kotanchek

An empirical study on the feature selection abilities of SLIM-GSGP
Davide Farinati, Leonardo Vanneschi

Comparing Data Transformation Techniques for System Identification With Standard Symbolic Regression
Alberto Tonda, Hengzhe Zhang, Qi Chen, Bing Xue, Mengjie Zhang, Evelyne Lutton

Data-Informed Model Complexity Metric for Optimizing Symbolic Regression Models
Nathan Haut, Zenas Huang, Adam Alessio

Embedding-Based Selection Operators for Genetic Programming
Oumaima Bel Moudden, Rym Guibadj, Denis Robilliard, Cyril Fonlupt, Abdeslam Kadrani

Geometric Semantic Genetic Programming for Evolving Real-Valued Functions with Order Awareness
Kritpol Bunjerdtaweeporn, Alberto Moraglio

Heterosis-Based Crossover: Leveraging Structural Differences to Control Diversity and Bloat in Genetic Programming
Lute Lillo, Nick Cheney

Kozax: Flexible and Scalable Genetic Programming in JAX
Sigur de Vries, Sander Wessel Keemink, Marcel Antonius Johannes van Gerven

Learning Semantics-aware Search Operators for Genetic Programming
Piotr Wyrwiński, Krzysztof Krawiec

Novel Application of Mutual Information in Transfer Learning for Genetic Programming
Yilin Liu, Gareth Taylor, Zhengwen Huang

Program Trace Optimization for Language Model Search: the Abstraction and Reasoning Corpus case
Alberto Moraglio, Alberto Tonda

Synergistic Hybridization of GP and DE: Innovations in Evolutionary Computation
Radomil Matousek, Miroslav Korenek, Tomas Hulka, Ladislav Dobrovsky

Adaptive Multi-Tree Genetic Programming for Multiple Feature Construction
Jiaxin Niu, Xiaoying Gao, Minghui Bai, Jianbin Ma

Comparing PushGP and GPT-4o on Program Synthesis with only Input-Output Examples
Jose Guadalupe Hernandez, Anil Kumar Saini, Gabriel Ketron, Jason Moore

Generative Evolutionary Computation: An Automatic Gene Targeting Differential Evolution Via Genetic Programming
Yi-Chao Huang, Xin-Xin Xu, Jian-Yu Li, Sam Kwong, Jun Zhang, Zhi-Hui Zhan

Genetic Programming Algorithm with a Fast Logical Search for Analyzing Graph Contagion
Krzysztof Michalak

Learning to Predict Code Review Rounds in Modern Code Review Using Multi-Objective Genetic Programming
Moataz Chouchen, Issam Oukhay, Ali Ouni

Mutual Information-Based Evolutionary Feature Construction via Minimizing Redundancy and Maximizing Relevance
Yunze Leng, Kei Sen Fong, Mehul Motani

Transformer-Guided Genetic Programming for Symbolic Regression
Chao Xu, Junlan Dong, Yanqiao Lv, Jinghui Zhong

Learning for Evolutionary Computation (L4EC)

A General Genetic Algorithm Using Natural Language Evolutionary Operators
Gerhard Stenzel, Sarah Gerner, Michael Kölle, Maximilian Zorn, Thomas Gabor

A Search Trajectory Networks Model to Understand irace
Pablo Estobar, Nicolas Rojas-Morales, Diana Gil-Silvestre, Gabriela Ochoa

An LLM-Based Multi-Agent Framework for Evolutionary Blackbox Optimization
Jill Baumann, Oliver Kramer

Bi-Level Hybrid Genetic Algorithm Enhanced with Multiple Reinforcement Learning Methods for EV Charging Scheduling
Abdennour Azerine, Mahmoud Golabi, Lhassane Idoumghar

Boltzmann Machine Is Useful for Enhancing Search Performance of Ising Machines
Satoru Jimbo, Kazushi Kawamura

Class Incremental Learning for Algorithm Selection
Mate Botond Nemeth, Emma Hart, Kevin Sim, Quentin Renau

Combining Feature Space Refinement and Outcome Accumulation Type Evolutionary Rule Discovery
Tomonori Obana, Kaoru Shimada

Rank-based Linear-Quadratic Surrogate Assisted CMA-ES
Mohamed Gharafi, Nikolaus Hansen, Rodolphe Le Riche, Dimo Brockhoff

Genetic Programming Based Feature Construction for Automated Algorithm Selection
Qingbin Guo, Handing Wang

Ranking prediction based evolutionary algorithm for expensive many-objective optimization problems
Yimo Zhang, Shuwei Zhu, Wei Fang, Kalyanmoy Deb, Meiji Cui

Neuroevolution (NE)

Curriculum learning with a hierarchical cellular encoding
Giacomo Vassallo, Eleni Nisioti, Joachim Winther Pedersen, Erwan Plantec, Milton Llera Montero, Sebastian Risi

Designing morphologies of soft medical devices using cooperative neuro coevolution
Hugo Alcaraz Herrera, Michail-Antisthenis Tsompanas, Igor Balaz, Andrew Adamatzky

EM-NAS: A Cell-Based Evolutionary Multi-scale Neural Architecture Search for Medical Image Segmentation
Hanyu Zhang, Lixin Tang, Xiangman Song

Evolutionary Neural Architecture Search using Random Weight Distributions
Sebastian Gregory Dal Toe, Bernard Tiddeman, Christine Zarges

Evolutionary Policy Optimization
Zelal Su Mustafaoglu, Keshav Pingali, Risto Miikkulainen

Evolving Swarm-Robotic Behavioral Allocations
Geoff Nitschke, Bilal Aslan, Ameel Valjee

Exploring Multi-Modal Representations Based on an Improved Multi-Objective Optimization Algorithm for Molecular Property Prediction
Yaguo Dong, Meiling Xu, Lixin Tang

Improving Neural Architecture Search with Class Visualization and Bilevel Optimization for Imbalanced Data
Alejandro Rosales-Pérez, Saúl Zapotecas-Martínez, Carlos A. Coello Coello

Surrogate-Assisted Evolution for Efficient Multi-branch Connection Design in Deep Neural Networks
Fergal Stapleton, Daniel García Núñez, Yanan Sun, Edgar Galván

Surrogate-Assisted Genetic Programming in Efficient Neural Architecture Search for Image Segmentation
José-Antonio Fuentes-Tomás, Efrén Mezura-Montes, Héctor-Gabriel Acosta-Mesa, David Herrera-Sánchez

Closing the Optimization and Generalization Gap in Deep Learning with A Multi-Objective Evolutionary Algorithm
Toki Tahmid Inan, Shahana Shultana, Amarda Shehu

Low Rank Factorizations are Indirect Encodings for Evolved Neural Networks
Jack Garbus, Jordan Pollack

POMONAG: Pareto-Optimal Many-Objective Neural Architecture Generator
Eugenio Lomurno, Samuele Mariani, Matteo Monti, Matteo Matteucci

Real World Applications (RWA)

A Genetic Algorithm Framework for Jailbreaking Large Language Models
Lorenzo Bonin, Lorenzo Cusin, Andrea De Lorenzo, Mauro Castelli, Luca Manzoni

A Genetic Ensemble Method for Correcting Maritime Wind Forecasts
Chaerim Park, Tae-Hoon Kim, Yong-Hyuk Kim, Seung-Hyun Moon

A Two-step Approach to Find Short Compilation Transformation Sequences for Optimal Software Runtime Performance
Juan Carlos de la Torre, José Miguel Aragón-Jurado, Javier Jareño, Bernabé Dorronsoro, Patricia Ruiz

Advanced Techniques for Maximizing Demand Satisfaction in EV Charging Scheduling
Abdennour Azerine, Mahmoud Golabi, Ammar Oulamara, Lhassane Idoumghar

An LGBM-aided low-cost evoluationary algorithm for optimizing analog circuit sizing
Zongchen Han, Chunliang Zhao, Dunwei Gong, Jing Sun

Application of the Multi-Parent Biased Random-Key Genetic Algorithm (MP-BRKGA) with Geo-Information Data for Automated Heating Network Planning
Felix Lewandowski, Petrit Patrick Vuthi, Jan Sudeikat, Irene Peters

Balancing Metabolic Homeostasis and Enzyme Cost with Multi-Objective Evolutionary Algorithms
Arthur Lequertier, Alberto Tonda, Wolfram Liebermeister

Bi-objective Optimisation of Cybersecurity Investment: Reducing Component Vulnerability and Security Breach Risk
Seyedamirhossein Salehiamiri, Xiuqin Li, Richard Allmendinger, Elvira Uyarra, James Mercer

Biomarker Modelling in Omics Technologies Using Symbolic Regression
David Eduardo Rojas-Velazquez, Alberto Tonda, Alejandro Lopez-Rincon

Comparing Modern Differential Evolution Variants in Multiobjective Cloud Scheduling
Pavel Krömer, Vojtech Uher

Degree is Important: On Evolving Homogeneous Boolean Functions
Claude Carlet, Marko Đurasević, Domagoj Jakobović, Luca Mariot, Stjepan Picek

Designing New Data Augmentation Functions for Fish Spectral Data by Genetic Programming
Huang Zhixing, Bing Xue, Mengjie Zhang, Jeremy S. Rooney, Keith C. Gordon, Daniel P. Killeen

Efficient Path Planning for Maritime Search and Rescue: A Surrogate-Assisted Memetic Algorithm
So-Jung Lee, Pablo Moscato, Yong-Hyuk Kim

Empowering Quantum Chemistry through Evolutionary Neural Architecture Search
Junfeng Zhao, Lixin Tang, Xiangman Song

Evolutionary Algorithms for Spatial Control of Gas-Solid Fluidized Beds
Pravin Pandey, Sanaz Mostaghim, Berend van Wachem

Evolutionary Ensemble for Prediction of Drifter Trajectories Using Weighted Majority
Tae-Hoon Kim, Seung-Hyun Moon, Yong-Hyuk Kim

Evolutionary Optimization of the Gas/Charging Stations Topology for the Electric Vehicle Market
Enrique Mateos-Melero, Javier Moralejo-Piñas, Francisco Martinez-Gil, María Soriano, Fernando Fernández

Evolving Financial Trading Strategies with Vectorial Genetic Programming
Rui Menoita, Sara Silva

Finding Molecules with Specific Properties: Simulated Annealing vs. Evolution
Steven A. Alexander, Dominc Mashak

Genetic Feature Selection for Multimodal Wound Detection
Agata Maria Wijata, Maria Bieńkowska, Michal Witold Przewozniczek, Jakub Nalepa

Hiding Structure of Reconstructed Network from Subgraphs Using Evolutionary Multi-Objective Optimization
Hirotaka Kaji, Toshihiro Tanizawa

Improving Academic Plan Efficiency with Genetic Algorithm and Stochastic Simulation
Oliver Cuate, Roxana Torrijos, Lourdes Uribe

Improving Continuous Coverage Path Planning through Subpath Selection and Multi-Objective Bilevel Optimization
Lukas Bostelmann-Arp, Christoph Steup, Sanaz Mostaghim

Interval-Tree based Multi-Objective 3D Bin Packing using Evolutionary Extreme Point Heuristic
Hermann Foot

Itemsets with Approximate Logistic Curve as Statistical Background
Akari Oda, Kaoru Shimada

Machine Learning and Genetic Algorithms: An Intricate Relationship for Locating Methane in Satellite Images
Agata Maria Wijata, Nicolas Longépé, Michal Witold Przewozniczek, Jakub Nalepa

Modified Non-dominated Sorting for Multi-Objective Data Analysis
Rachel Ellen Brown, Qihao Shan, Sanaz Mostaghim

Multi-Objective Signal Optimization to Balance Multiple Conflicting Metrics in RIS-Assisted MIMO Systems
Bui Trong Duc, Trinh Van Chien, Hien Quoc Ngo, Huynh Thi Thanh Binh

Multi-objective Evolutionary Algorithm for Production Planning in Cold-Rolling
Weiyan Jia, Lixin Tang, Yang Yang, Yun Dong, Yanyan Zhang

Multiobjective Ingredient Optimization for Recipe Planning
Nga Man Chan, Julia Handl

Refining Neural Network with Symbolic Regression
Wei Wei, Qiang Lu, Can Huang, Jake Luo

Search-based Inference of Class Invariants
Juan Manuel Copia, Facundo Molina, Alessandra Gorla, Nazareno Aguirre, Pablo Ponzio

Single- and Multi-Objective Genetic Optimization of Hyperspectral Image Pre-Processing
Bogdan Ruszczak, Sabina Kubiciel-Lodzińska, Katarzyna Rudnik, Zineb Bougriche, Agata Maria Wijata, Jakub Nalepa

Symbolic Regression for Modelling Decarbonisation Pathways in the Global Energy-Economy-Climate System
James McDermott, James Glynn, Iain Morrow, Evangelos Panos

The Segregated and Hybrid TBPSA algorithm with applications in SRF test pattern scheduling
Marius-Octavian Bulhac, Nicolae-Eugen Croitoru

Utility-aware Social Network Anonymization using Genetic Algorithms
Samuel Bonello, Rachel G. de Jong, Thomas Bäck, Frank W. Takes

A Local Search Deep Q-Network to Optimize On-Demand Tranportation Problems
Mariem Ayari, Sonia Nasri, Hend Bouziri, Wassila Aggoune-Mtalaa

A Novel Decomposition-Based Algorithm for Optimizing Demand-Side Response in Dynamic Economic Emission Dispatch Considering Gridable Vehicles Management
Hongda Guo, Chixin Xiao, Dechen Jiang, Maoxin He

Adaptive Denoising of Sequential Data with Multi-Objective Genetic Algorithms
Kok Cheng Tan, Dmytro Vitel, Daniel Zantedeschi, Alessio Gaspar

Connected and Autonomous Shuttles for Optimal Passenger Transportation and Last-Mile Parcel Delivery
Daniel H. Stolfi, Elhadja Chaalal, Sébastien Faye

Discovering Blue Team Solutions for an Autonomous Cyber Operations Challenge using an Evolutionary Heuristic Search
Yuxuan Wang, Nur Zincir-Heywood, Malcolm Heywood

Evolutionary Boss Improvement in Doom
Pedro Regattieri Rocha, Leonardo Tórtoro Pereira, Cláudio Fabiano Motta Toledo

Evolutionary Level Repair
Debosmita Bhaumik, Julian Togelius, Georgios N. Yannakakis, Ahmed Khalifa

Evolving Macro-Actions for MCTS Video Game Agents
Andrew Gourley, Michael Dann, Xiaodong Li, Fabio Zambetta

Optimizing Wind Farm Project Assessments Using Genetic Algorithms
Italo Firmino da Silva, Telles B. Lazzarin, Lenon Schmitz, Alison R. Panisson

Searching for Model Structures on Murine Neonatal Sepsis Data Using Genetic Programming
Tabitha Grace Lewis, Noemi Picco, Alma Rahat, Thomas Woolley, Peter Ghazal

Swarm Intelligence (SI)

Ant Colony Optimization for Route Planning of Multiple Tourists
Jun Zheng, Qiang Yang, Dan-Ting Duan, Pei-Lan Xu, Cheng-Zhi Qu, Zhen-Yu Lu, Jun Zhang

Multimodal Ant Colony Optimization for Finding Multiple Different Routes for Autonomous Underwater Vehicle
Ying Chen, Qiang Yang, Dan-Ting Duan, Pei-Lan Xu, Xin Lin, Zhen-Yu Lu, Jun Zhang

Particle Swarm Optimization for Large-Scale Mixed-Variable Optimization Problems
So Fukuhara, Masao Arakawa

Using Ant Colony Optimization for Fractional Orienteering Problem with Mandatory Nodes
Vladimír Holý, Ondřej Sokol

A new Hybrid Dynamic Tournament Topology Particle Swarm Optimizaton with Parameter Independence
Piotr Dziwiński

Enhancing Explainability and Reliable Decision-Making in Particle Swarm Optimization through Communication Topologies
Nitin Gupta, Indu Bala, Bapi Dutta, Luis Martínez, Anupam Yadav

Hybrid-Surrogate-Assisted Particle Swarm Optimization with Adaptive Surrogate Selection for Solving High-Dimensional Expensive Optimization Problems
Maoxin He, Chixin Xiao, Dechen Jiang

Resampling Framework Based on Swarm Intelligence Optimization for Imbalanced Data Classification
Yutianyi Liu, Hanyi Wu, Haotong Wang, Yongxue Shan, Xin Yang, Ziqi Wei

Theory

Evo-devo Computational Comparison of Evolvable Soma Theory of Ageing and Standard Evolutionary Ageing Theories
Alessandro Fontana, Marios Kyriazis

Evolving the Level of Selective Pressure – A Game-Theoretical Perspective
Bruno Gašperov, Branko Šter

Application of Limit Theorems to Runtime Analysis of the $(1 + (\lambda, \lambda))$ Genetic Algorithm
Anton Eremeev, Valentin Topchii

Late-Breaking Abstracts

Applying Multi-Objective Differential Evolution for IoT Application Design in the Edge-Cloud Continuum
Gianluigi Folino, Antonio Francesco Gentile, Rosa Varchera, Andrea Vinci

Augmentation of Laser Welding Dataset through a combination of Evolutionary Optimization and Deep Learning
Gleb Solovev, Mikhail Sokolov, Aveen Hussein, Nikolay Nikitin

Indirect Credit Without A Heuristic For Coevolving Agents
Everardo Gonzalez, Raghav Thakar, Kagan Tumer

Initial Population of NSGA-II for Solving Similar Multi-Objective Optimization Problems
Yuji Sato, Mikiko Sato

Introducing H-Leading-Ones as a Mixed-Category Benchmark Problem for Evolutionary Algorithms
Côme Frappé - - Vialatoux, Pierre Parrend

Resilience of Evolutionary Algorithms to Aggressive Compilation Optimization
Carlos Cotta, Jesús Martínez-Cruz

Towards Swarms of Long Heavy Articulated Vehicles
Adrian Schönnagel, Michael Dubé, Sanaz Mostaghim

Walking School Bus Planning
Leena Ahmed, Matthias Ehrgott, Judith Y.T. Wang, Ahmed Kheiri

A Novel Metaheuristic Approach to Monolith Decomposition into Microservices
Ana Martínez Saucedo, Guillermo Rodriguez, Virginia Yannibelli

Evolutionary Manifold Learning for Automated Extraction of Data Topology
Julia Borisova, Alexander Hvatov

From Trees to Cuts: Statistical Insights into Spanning-Tree-Based Max-Cut Algorithms
Ho-Jun Jang, Yong-Hyuk Kim

Numerical Global Optimization Competition on GNBG-II generated Test Suite
Rohit Salgotra, Amir H. Gandomi, Kalyanmoy Deb

Towards Automated Innovization for Route Planning: Innovized Heuristics and Problem Class Bounds
Eva Röper, Christoph Steup, Sanaz Mostaghim

Competition Posters

Neighborhood Adaptive Differential Evolution
Niki van Stein

EASE-ing into Global Optimization with LLMs
Adam Viktorin, Tomas Kadavy, Jozef Kovac, Michal Pluháček, Roman Senkerik

LLM-Driven Evolution of Metaheuristic Components for GNBG Benchmark
Paweł Kolendo, Wojciech Chmiel, Michal Pluháček

Constructing Differential Evolution via LLM Prompt Chaining
Dominik Papaj, Tomasz Karpiński, Rohit Salgotra

ALSHADE-jSO Algorithm Solving the GNBG-II Test Suite
Pooja Verma, Reshu Chaudhary, Amanjot Kaur Lamba, Rohit Salgotra

Hot off the Press

HOP 1

Wednesday, July 16, 12:00–13:20

Chair: Bing Xue, *Victoria University of Wellington, New Zealand*

Arlequín & Tauromaquia

Fitness Landscapes of Buffer Allocation Problem in Production Lines and Genetic Algorithms Performance 12:00
Alexandre Dolgui, Anton Eremeev, Vyatcheslav Sigaev

An Archive Can Bring Provable Speed-ups in Multi-Objective Evolutionary Algorithms 12:10
Chao Bian, Shengjie Ren, Miqing Li, Chao Qian

Hot off the Press: Runtime Analysis of the Compact Genetic Algorithm on the LeadingOnes Benchmark 12:20
Marcel Chwiałkowski, Benjamin Doerr, Martin S. Krejca

Explainable Benchmarking for Iterative Optimization Heuristics 12:30
Niki van Stein, Diederick Vermetten, Anna Kononova, Thomas Bäck

Hot off the Press: Speeding Up the NSGA-II With a Simple Tie-Breaking Rule 12:40
Benjamin Doerr, Tudor Ivan, Martin S. Krejca

New evolutionary methods for solving single- and multi-objective political redistricting problems: The context of Poland 12:50
Michał Tomczyk, Miłosz Kadziński

EVOTER: Evolution of Transparent Explainable Rule sets 13:00
Hormoz Shahrzad, Babak Hodjat, Risto Miikkulainen

Multi-Objective Bayesian Optimization with Reinforcement Learning for Edge Deployment of DNNs on Microcontrollers 13:10
Mark Deutel, Georgios Kontes, Christopher Mutschler, Jürgen Teich

HOP 2

Wednesday, July 16, 15:30–16:50

Chair: Sarah L. Thomson, *Napier Edinburgh University, UK*

Arlequín & Tauromaquia

Knowledge-based Optimization in Epidemics Prevention 15:30
Krzysztof Michalak

Evolutionary Multiobjective Optimization Assisted by Scalarization Function Approximation for High-Dimensional Expensive Problems (HOP GECCO'25) 15:40
Yuma Horaguchi, Kei Nishihara, Masaya Nakata

Hot off the Press: Proven Runtime Guarantees for How the MOEA/D Computes the Pareto Front From the Subproblem Solutions 15:50
Benjamin Doerr, Martin S. Krejca, Noé Weeks

On Defining and Discovering Non-Symmetrical Dependencies 16:00
Michal Witold Przewozniczek, Bartosz Frej, Marcin Michal Komarnicki

Selection Methods in Genetic Programming: A Performance Analysis 16:10
Alina Geiger, Dominik Sobania, Franz Rothlauf

Doubly Stochastic Matrix Models and the Quadratic Assignment Problem 16:20
Valentino Santucci, Josu Ceberio

Hot off the Press: Finding ϵ-locally Optimal Solutions for Multi-objective Multimodal Optimization 16:30
Angel E. Rodriguez-Fernandez, Lennart Schäpermeier, Carlos Ignacio Hernández Castellanos, Pascal Kerschke, Heike Trautmann, Oliver Schütze

Hot off the Press: Can Evolutionary Clustering Have Theoretical Guarantees? 16:40
Chao Qian

HOP 3

Wednesday, July 16, 17:30–18:50
Chair: Fabrício Olivetti de França, *Universidade Federal do ABC, Brazil* Arlequín & Tauromaquia

Discovering Shared Function Structures with Adaptable Parameters for Multi-Level Modeling via Symbolic Regression 17:30
Kei Sen Fong, Mehul Motani

Alternating between Surrogate Model Construction and Search for Configurations of an Autonomous Delivery System (Hot off the Press at GECCO 2025) 17:40
Chin-Hsuan Sun, Thomas Laurent, Paolo Arcaini, Fuyuki Ishikawa

Hot off the Press: Near-Tight Runtime Guarantees for Many-Objective Evolutionary Algorithms 17:50
Simon Wietheger, Benjamin Doerr

Hot Off the Press: A Newton Method for Hausdorff Approximations of the Pareto Front within Multi-objective Evolutionary Algorithms 18:00
Hao Wang, Angel E. Rodriguez-Fernandez, Lourdes Uribe, André Deutz, Oziel Cortés-Piña, Oliver Schütze

Hot off the Press: Runtime Analysis for Multi-Objective Evolutionary Algorithms in Unbounded Integer Spaces 18:10
Benjamin Doerr, Martin S. Krejca, Günter Rudolph

Hot off the Press: Runtime Analysis for State-of-the-Art Multi-objective Evolutionary Algorithms on the Subset Selection Problem 18:20
Renzhong Deng, Weijie Zheng, Mingfeng Li, Jie Liu, Benjamin Doerr

Analyzing Single-objective Black-box Optimization Algorithms Using the Empirical Attainment Function 18:30
Manuel López-Ibáñez, Diederick Vermetten, Johann Dreo, Carola Doerr

Hot off the Press: No Free Lunch Theorem and Black-Box Complexity Analysis for Adversarial Optimisation 18:40
Per Kristian Lehre, Shishen Lin

HOP 4

Thursday, July 17, 12:00–13:20
Chair: Nuno Lourenço, *University of Coimbra, Portugal* Arlequín & Tauromaquia

Maintaining Diversity Provably Helps in Evolutionary Multimodal Optimization 12:00
Shengjie Ren, Zhijia Qiu, Chao Bian, Miqing Li, Chao Qian

Hot Off the Press: Multi-Objectivising Acquisition Functions in Bayesian Optimisation 12:10
Chao Jiang, Miqing Li

LLaMEA: A Large Language Model Evolutionary Algorithm for Automatically Generating Metaheuristics 12:20
Niki van Stein, Thomas Bäck

Gradient-Guided Local Search for Large-Scale Hypervolume Subset Selection 12:30
Yang Nan, Tianye Shu, Hisao Ishibuchi, Ke Shang

Landscape Analysis for Surrogate Models in the Evolutionary Black-Box Context (Extended Abstract) 12:40
Zbyněk Pitra, Jan Koza, Jiří Tumpach, Martin Holeňa

Evidential Fuzzy Rule-Based Machine Learning to Quantify Classification Uncertainty 12:50
Hiroki Shiraishi, Hisao Ishibuchi, Masaya Nakata

Evolutionary Co-Optimization of Rule Shape and Fuzziness in Rule-Based Machine Learning 13:00
Hiroki Shiraishi, Yohei Hayamizu, Tomonori Hashiyama, Keiki Takadama, Hisao Ishibuchi, Masaya Nakata

Interpreting Tangled Program Graphs Under Partially Observable Dota 2 Invoker Tasks 13:10
Robert Smith, Malcolm Heywood

HOP 5

Friday, July 18, 10:00–11:20
Chair: Anna Kononova, *Leiden University, Netherlands*
Arlequín & Tauromaquia

Hot off the Press: Bayesian Inverse Transfer in Evolutionary Multiobjective Optimization 10:00
Jiao Liu, Abhishek Gupta, Yew-Soon Ong

Towards Running Time Analysis of Interactive Multi-objective Evolutionary Algorithms 10:10
Tianhao Lu, Chao Bian, Chao Qian

Hot off the Press: First Steps Towards a Runtime Analysis When Starting With a Good Solution 10:20
Denis Antipov, Maxim Buzdalov, Benjamin Doerr

A Many-Objective Problem Where Crossover is Provably Indispensable 10:30
Andre Opris

Finding the Set of Nearly Optimal Solutions of a Multi-objective Optimization Problem 10:40
Oliver Schütze, Angel E. Rodriguez-Fernandez, Carlos Segura, Carlos Ignacio Hernández Castellanos

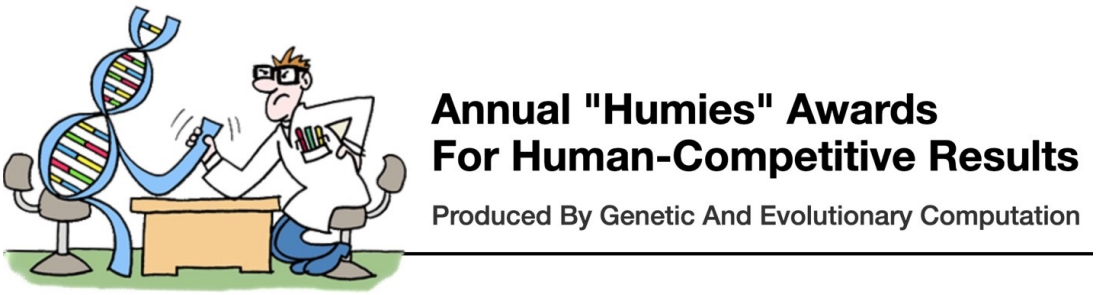
GSGP-Hardware: FPGA implementation of GSGP 10:50
Yazmin Maldonado, Ruben Salas, Joel A. Quevedo, Rogelio Valdez, Leonardo Trujillo

On the Generalisation Performance of Geometric Semantic Genetic Programming for Boolean Functions: Learning Block Mutations 11:00
Dogan Corus, Pietro S. Oliveto

Hot off the Press: Quality-Diversity Algorithms Can Provably Be Helpful for Optimization 11:10
Chao Qian, Ke Xue, Ren-Jian Wang

Other Events

Humies



22nd Human-Competitive Results Awards Competition ("Humies")
Final Presentations at GECCO 2025 in Málaga,
Thursday, July 17, 17:30–19:00, in Arlequín & Tauromaquia

Techniques of genetic and evolutionary computation are being increasingly applied to difficult real-world problems – often yielding results that are not merely academically interesting, but competitive with the work done by creative and inventive humans. Starting at the Genetic and Evolutionary Computation Conference (GECCO) in 2004, cash prizes have been awarded for human-competitive results that had been produced by some form of genetic and evolutionary computation in the previous year.

This prize competition is based on published results. The publication must be a refereed publication in the open literature (e.g., the GECCO conference, any another reviewed conference or workshop, journal, or chapter in edited book). Submission of more than one entry by a single person or team is allowed.

The rules under which the Humies operate are given on the Humies website, www.human-competitive.org, and all of this year's entries are listed there, as well. Entries for this year are closed and 8 finalists have been chosen from among 15 entries. Please attend the final presentation session either virtually or in person.

Website: https://www.human-competitive.org/

Judging Panel:

- Erik Goodman, *Michigan State University, USA*
- Wolfgang Banzhaf, *Michigan State University, USA*
- Darrell Whitley, *Colorado State University, USA*
- Lee Spector, *Amherst College, University of Massachusetts Amherst and Hampshire College, USA*
- Stephanie Forrest, *Arizona State University, USA*

Publicity Chair: William B. Langdon

Schedule

A Computational Model for Multiobjective Optimization of Multipolar Stimulation in Cochlear Implants: An Enhanced Focusing Approach 17:30
Marcos Hernández-Gil, Ángel Ramos-de-Miguel, David Greiner, Domingo Benítez, Ángel Ramos-Macías, José María Escobar

LLaMEA: A Large Language Model Evolutionary Algorithm for Automatically Generating Metaheuristics 17:40
Optimizing Photonic Structures with Large Language Model Driven Algorithm Discovery
Niki van Stein, Thomas Bäck, Haoran Yin, Anna Kononova

Designing Hardware-Friendly Hash Functions for Network Security Using Cartesian Genetic Programming 17:50
Mujtaba Hassan, Jo Vliegen, Stjepan Picek, Nele Mentens

Unlocking the Potential of Global Human Expertise 18:00
Elliot Meyerson, Olivier Francon, Darren Sargent, Babak Hodjat, Risto Miikkulainen

AUTOSTUB: Genetic Programming-Based Stub Creation for Symbolic Execution 18:10
Felix Mächtle, Nils Loose, Jan-Niclas Serr, Jonas Sander, Thomas Eisenbarth

Software Product Line Engineering via Software Transplantation 18:20
Leandro Oliveira de Souza, Eduardo Santana de Almeida, Paulo Anselmo da Mota Silveira Neto, Earl T. Barr, Justyna Petke

Hybrid Generative AI for De Novo Design of Co-Crystals with Enhanced Tabletability 18:30
Nina Gubina, Andrei Dmitrenko, Gleb Solovev, Lyubov Yamshchikova, Oleg Petrov, Ivan Lebedev, Nikita Serov, Grigorii Kirgizov, Nikolay Nikitin, Vladimir Vinogradov

Video Game Procedural Content Generation Through Software Transplantation 18:40
Game Software Engineering: A Controlled Experiment Comparing Automated Content Generation Techniques
Mar Zamorano, Daniel Blasco, África Domingo, Carlos Cetina, Federica Sarro

Evolutionary Computation in Practice (ECiP)

Organizers:	Thomas Bartz-Beielstein, *IDE+A and TH Köln, Germany* Richard Schulz, *IDE+A and TH Köln, Germany*
Time & location:	Wednesday, July 16, 12:00–13:30, Arlequín & Tauromaquia

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In the Evolutionary Computation in Practice (ECiP) track, well-known speakers with outstanding reputation in academia and industry present background and insider information on how to establish reliable cooperation with industrial partners. They actually run companies or are involved in cooperation between academia and industry.

If you attend, you will learn multiple ways to extend EC practice beyond the approaches found in textbooks. Experts in real-world optimization with decades of experience share their approaches to creating successful projects for real-world clients. Some of what they do is based on sound project management principles, and some is specific to our type of optimization projects. If you are working in academia and are interested in managing industrial projects, you will receive valuable hints for your own research projects.

In 2025, ECiP will be an onsite event. We will do our best to enable opportunities for establishing contacts among participants.

For more detailed information, please visit: https://idea.gm.th-koeln.de/?page_id=508

Schedule

Quantum (computing) needs you! Quantum (computing) wants you! 12:00
Xavier Bonet-Monroig

Robust Contextual Preferential Bayesian Optimization for Real-World Applications with Biased Data and Minimal Expert Involvement 12:20
Farha A. Khan

Application of Quantum Annealing to Optimize Parts Storage Arrangement in a Logistics Center 12:40
Hirotaka Kaji

On the antagonism between foundations and applications in graph-based genetic programming 13:00
Roman Kalkreuth

Women+@GECCO

Organizers:	Elena Raponi, *Leiden University, Netherlands* Gloria Pietropolli, *University of Trieste, Italy*
Time & location:	Monday, July 14, 19:10–21:10, Arlequín & Tauromaquia

The Women+@GECCO workshop began in 2013 as a space to welcome and support women in evolutionary computation. Over the years, it has evolved into a broader forum for open conversations around equity, inclusion, research culture, and the challenges we face as a community. This year's edition will take a **fully interactive format**. Participants will select the topics that matter most to them and work together in small groups to explore these issues, mapping out the current state, identifying key challenges, and brainstorming directions for the future.

A central part of the session will be an interactive poster session. Each poster will represent a topic or theme chosen by participants, serving as a shared space to collect ideas, reflect on experiences, and encourage discussion. **Together, we aim to build a collective picture of where we are and where we want to go as a community.**

Whether you are new to GECCO or have attended for many years, your perspective is valuable. We warmly invite you to join us, share your thoughts, and contribute to shaping the future directions of our community. We are looking forward to a creative and slightly unconventional session, and we would be very happy to have you with us.

Feel free to reach out to the organizers:

- Elena Raponi, e.raponi@liacs.leidenuniv.nl
- Gloria Pietropolli, gloria.pietropolli@gmail.com

Job Market

Organizers:	Boris Naujoks, *TH Köln, Germany* Elena Raponi, *Leiden University, Netherlands*
Time & location:	Thursday, July 17, 15:30–17:00, Arlequín & Tauromaquia

The GECCO Job Market is an event where people offering jobs can advertise open positions and meet with potential candidates. Any kind of positions are eligible (PhD, Postdoc, Professor, Engineer, etc.) – from the academia as well as the industry.

The Job Market will be organized as a hybrid event during GECCO on Thursday, July 17, from 15:30 to 17:00. After brief presentations of the available positions, participants will have the possibility to join face-to-face meetings in person and on Gather for further discussions.

To participate with a job offer, create a new ad at the SIGEVO web site. Make sure to check the "GECCO availability" option that confirms your attendance at the Job Market. In addition, prepare one slide describing the job and send it to the Job Market Chairs Boris Naujoks (email address: boris.naujoks@th-koeln.de or Elena Raponi (email address: e.raponi@liacs.leidenuniv.nl, by **Monday, July 7, 2025**.

And keep in mind: You are very welcome to join even if you don't have a formal vacancy yet but expect to hire soon and would like to meet potential candidates. Likewise, students and researchers who are already on the job market or planning to start their job search soon are warmly encouraged to attend and begin building connections!

Links:

- Job Ads at the SIGEVO web site
- Job Market Gather room

SIGEVO Summer School

Organizers:	Miguel Nicolau, *University College Dublin, Ireland* Vanessa Volz, *Centrum Wiskunde & Informatica, Netherlands*
Time & location:	• Friday, July 11 – Sunday, July 13, Rectorate building of the University of Málaga • Monday, July 14 – Tuesday, July 15, NH Málaga

Held in conjunction with the GECCO 2025 Conference, the SIGEVO Summer School (S3) goes into round 8. It is carefully tailored for Evolutionary Computation graduate students, particularly those attending GECCO for the first time. It is held on the three days leading up to GECCO (11-13 July), and works in conjunction with the GECCO workshops & tutorials.

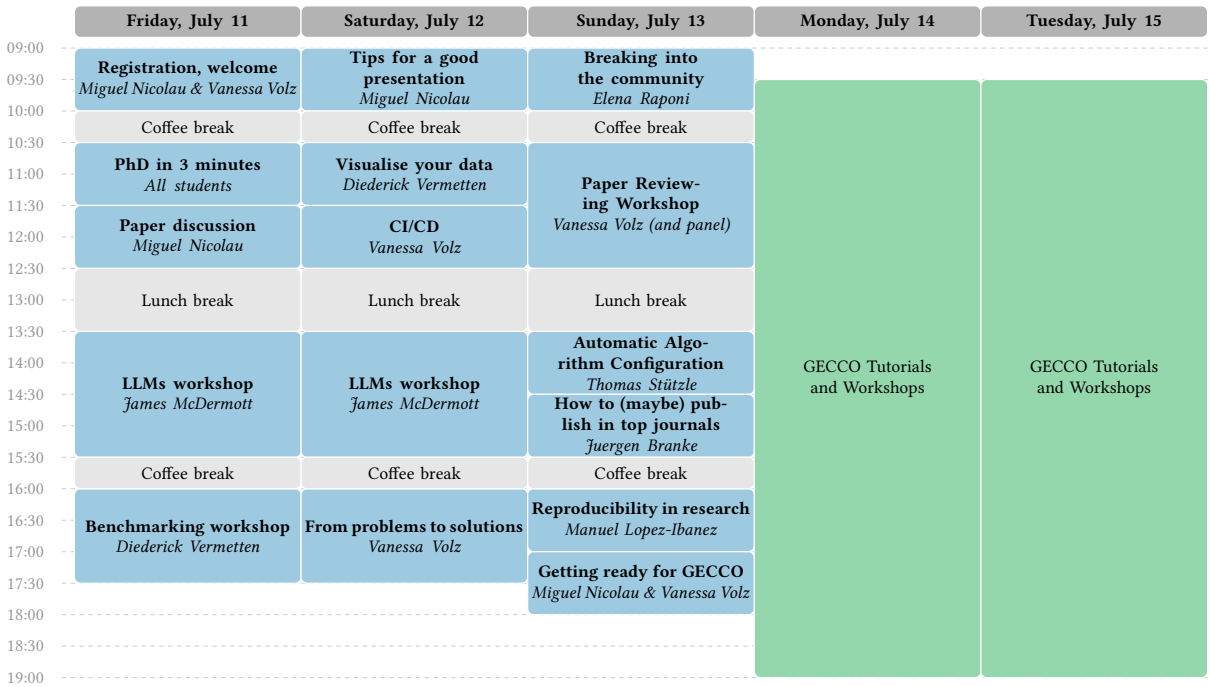
The school covers the following areas of knowledge:

- **General research skills needed by GECCO participants:** reviewing, paper writing and presenting, best practices for the empirical evaluation of evolutionary algorithms, etc.
- **In-depth knowledge about specific topics within GECCO:** based on individual interests, through attending tutorials and workshops at GECCO.
- **Networking:** perhaps the most important part of the Summer School, it focuses on ensuring that leading research figures of tomorrow get a chance of meeting at an early career stage, and also get to interact with current prominent figures in the field, in a relaxed and focused environment.

The School relies on a carefully selected set of mentors:

- Juergen Branke, *University of Warwick, UK*
- Thomas Stützle, *Université Libre de Bruxelles, Belgium*
- James McDermott, *University of Galway, Ireland*
- Manuel López-Ibáñez, *University of Manchester, UK*
- Diederick Vermetten, *Sorbonne Université, France*
- Elena Raponi, *Leiden University, Netherlands*

Schedule



Paper Abstracts

Benchmarking, Benchmarks, Software, and Reproducibility (BBSR)

BBSR 1 + ENUM 1

Wednesday, July 16, 12:00–13:30 Mena

★ Why We Should be Benchmarking Evolutionary Algorithms on Neural Network Training Tasks
Katherine Mary Malan, Mario Andrés Muñoz

Progress in evolutionary algorithms is strongly influenced by competitions with their associated benchmark suites. These suites usually consist of artificial functions, designed to cover a range of problem complexities, such as separable and non-separable functions. For these benchmarks to be effective as proxies for fine-tuning algorithms for use in practice, they should ideally match the features found in real-world optimisation problems. The training of neural networks is an optimisation task on which evolutionary algorithms are known to perform poorly compared to gradient-based search strategies. In this paper we analyse the search spaces of a suite of neural network training tasks using exploratory landscape analysis (ELA). We show that the features of the neural network training tasks occupy a different region of ELA feature space than the widely used Black-Box Optimisation Benchmarking (BBOB) suite. We argue that continuous optimisation benchmark suites should be extended to include problems such as neural network learning tasks that exhibit weak global structure, multiple global optima and large areas of neutrality. By benchmarking on such tasks, we hope that evolutionary algorithms can be developed to provide competitive performance on the training of neural networks in scenarios where exploiting the gradient may not be the best approach.

★ When Does Neuroevolution Outcompete Reinforcement Learning in Transfer Learning Tasks?
Eleni Nisioti, Erwan Plantec, Milton Llera Montero, Joachim Winther Pedersen, Sebastian Risi

The ability to continuously and efficiently transfer skills across tasks is a hallmark of biological intelligence and a long-standing goal in artificial systems. Reinforcement learning (RL), a dominant paradigm for learning in high-dimensional control tasks, is known to suffer from brittleness to task variations and catastrophic forgetting. Neuroevolution (NE) has recently gained attention for its robustness, scalability, and capacity to escape local optima. In this paper, we investigate an understudied dimension of NE: its transfer learning capabilities. To this end, we introduce two benchmarks: a) in *stepping gates*, neural networks are tasked with emulating logic circuits, with designs that emphasize modular repetition and variation b) *ecorobot* extends the Brax physics engine with physical objects such as walls and obstacles and the ability to easily switch between different robotic morphologies. Crucial in both benchmarks is the presence of a *curriculum* that enables evaluating skill transfer across tasks of increasing complexity.y. Our empirical analysis shows that NE methods vary in their transfer abilities and frequently outperform RL baselines. Our findings support the potential of NE as a foundation for building more adaptable agents and highlight future challenges for scaling NE to complex, real-world problems.

BBSR 2

Wednesday, July 16, 17:30–19:00 Gibralfaro

Evaluation Time Bias in Asynchronous Evolutionary Algorithms: A Replication Study and a Novel Mitigation Strategy
Joshua Karns, Travis Desell

Evolutionary Algorithms (EAs) are a flexible and powerful search technique that are frequently applied to a wide variety of problems. Much of their power comes from their ease of parallelization, lending themselves well to a master-worker parallelization scheme. When a synchronous (μ, λ)-style EA is parallelized and genome evaluation time is not constant, worker processors may spend a significant amount of time idle waiting for other genome evaluations to complete. (μ, λ)-style EAs with a steady-state population are frequently employed to avoid this idle time. There is an existing body of work that suggests that, while this does reduce idle processor time, it may not lead to better solutions because of evaluation time bias. In this work, results from a paper that demonstrate this experimentally are fully reproduced from scratch. During this replication, the roles crossover and population initialization play in this bias were uncovered. This is evaluated experimentally and motivates a mitigation strategy, which is compared to other mitigation strategies and is found to perform about as well as other strategies, without modifying anything other than the way the population is initialized. Moreover, a new open source library was developed in order to facilitate these experiments and further investigations.

Multi-objective L-shaped Test Functions
Angus Kenny, Tapabrata Ray, Hemant Singh

Many real-world multi-objective optimization problems exhibit L-shaped Pareto fronts, characterized by steep trade-offs between objectives near their extreme values. This class of problems poses significant challenges for evolutionary algorithms in obtaining uniformly spread solutions across the Pareto front (PF). This paper introduces eight new test functions with L-shaped and reflected L-shaped PFs, intended to provide a valuable framework for benchmarking multi-objective optimization algorithms. The functions are based on modifications of the well-known DTLZ2 problem and a reciprocal function formulation, each formulated in standard and 'hard' variants. The 'hard' variants introduce modifications to the auxiliary functions, increasing problem difficulty by biasing the distribution of non-Pareto solutions away from the PF as the problem dimensionality increases. Numerical experiments are conducted using NSGA-II and MOEA/D algorithms, with performance evaluated using hypervolume and inverted generational distance metrics. The results demonstrate that the proposed test functions effectively challenge the algorithms, especially in their 'hard' variants, and outline the differences in algorithm performance

based on the shape of the PF. These findings highlight the need for development of more robust multi-objective optimization techniques capable of handling such PF geometries.

SynthACticBench: A Capability-Based Synthetic Benchmark for Algorithm Configuration
Valentin Margraf, Anna Lappe, Marcel Wever, Carolin Benjamins, Eyke Hüllermeier, Marius Lindauer

Algorithm configuration deals with the automatic optimization of an algorithm's parameters to maximize its performance on a distribution of problem instances, such as Boolean satisfiability or the traveling salesperson problem. While significant progress has been made in developing optimizers for algorithm configuration – so-called algorithm configurators – their evaluation remains computationally expensive and often relies on real-world scenarios with hard-to-control characteristics. This makes it challenging to analyze their strengths and weaknesses systematically. To address this, we introduce SynthACticBench, a synthetic benchmark specifically designed to isolate and investigate key properties of algorithm configuration problems. Our benchmark distinguishes between properties related to the configuration space and those associated with the objective function. We define a configurator's ability to handle a particular property as its capability – for example, the capability to manage hierarchical configuration spaces. Using SynthACticBench, we evaluate two state-of-the-art algorithm configurators, SMAC and irace, examining their complementary capabilities and analyzing their performances across diverse benchmark functions. By providing a controlled, scalable, and capability-based evaluation environment, SynthACticBench facilitates a more targeted analysis of algorithm configurators, helping to advance research in the field. The benchmark is available at: https://github.com/annaelisalappe/SynthACticBench/.

MILPBench: A Large-scale Benchmark Test Suite for Mixed Integer Linear Programming Problems
Huigen Ye, Yaoyang Cheng, Hua Xu, Zhiguang Cao, Hanzhang Qin

Mixed-integer linear programming (MILP) is a cornerstone of optimization with applications across numerous domains. However, the development and evaluation of MILP-solving algorithms are hindered by existing benchmark datasets, which are often limited in scale, lack diversity, and are poorly structured, making them inadequate for systematic testing across different solving approaches, especially for machine learning (ML)-based methods. To address these issues, we introduce MILPBench, a large-scale benchmark suite comprising 100,000 MILP instances organized into 60 well-categorized classes. Using structural properties and embedding similarity metrics, we developed a novel classification framework to ensure both intra-class homogeneity and inter-class diversity. In addition to the dataset, MILPBench includes a comprehensive baseline library featuring 15 mainstream solving methods, spanning traditional solvers, heuristic algorithms, and ML-based approaches. This design enables rigorous and standardized evaluation of MILP-solving algorithms under diverse conditions. Extensive benchmarking demonstrates the utility of MILPBench as a scalable and versatile testbed for advancing MILP research, fostering innovation in solver development, and bridging the gap between optimization and machine learning.

BBSR 3

Thursday, July 17, 12:00–13:30 Gibralfaro

Automated Algorithm Configuration and Systematic Benchmarking for Heterogeneous MNK-Landscapes
Oliver Ludger Preuß, Carolin Mensendiek, Jeroen Rook, Jakob Bossek, Heike Trautmann

MNK-landscapes are a class of multi-objective combinatorial optimisation problems that simulate interactions between system components with adjustable parameters. Recently, heterogeneous MNK-landscapes were introduced, which feature objectives with varying interdependencies, offering a new direction in multi-objective (multi-modal) landscape research. This study benchmarks various evolutionary multi-objective optimisation algorithms and local search algorithms on such landscapes by means of automated algorithm configuration. Our systematic analysis yields various insights into the behaviour and competitiveness of these algorithms and reveals that, particularly, the omni-optimizer algorithm and iterated Pareto local search yield strong, complementary, performance. These findings facilitate the case for automated algorithm selection, which we also investigate in this paper.

rEGGression: an Interactive and Agnostic Tool for the Exploration of Symbolic Regression Models
Fabrício Olivetti de França, Gabriel Kronberger

Regression analysis is used for prediction and to understand the effect of independent variables on dependent variables. Symbolic regression (SR) automates the search for non-linear regression models, delivering a set of hypotheses that balances accuracy with the possibility to understand the phenomena. Many SR implementations return a Pareto front allowing the choice of the best trade-off. However, this hides alternatives that are close to non-domination, limiting these choices. Equality graphs (e-graphs) allow to represent large sets of expressions compactly by efficiently handling duplicated parts occurring in multiple expressions. The e-graphs allow to efficiently store and query all solution candidates visited in one or multiple runs of different algorithms and open the possibility to analyze much larger sets of SR solution candidates. We introduce rEGGression, a tool using e-graphs to enable the exploration of a large set of symbolic expressions which provides querying, filtering, and pattern matching features creating an interactive experience to gain insights about SR models. The main highlight is its focus in the exploration of the building blocks found during the search that can help the experts to find insights about the studied phenomena. This is possible by exploiting the pattern matching capability of the e-graph data structure.

Subfunction Structure Matters: A New Perspective on Local Optima Networks
Sarah L. Thomson, Michal Witold Przewozniczek

Local optima networks (LONs) capture fitness landscape information. They are typically constructed in a black-box manner; information about the problem structure is not

utilised. This also applies to the analysis of LONs: knowledge about the problem, such as interaction between variables, is not considered. We challenge this status-quo with an alternative approach: we consider how LON analysis can be improved by incorporating subfunction-based information — this can either be known a-priori or learned during search. To this end, LONs are constructed for several benchmark pseudo-boolean problems using three approaches: firstly, the standard algorithm; a second algorithm which uses deterministic grey-box crossover; and a third algorithm which selects perturbations based on learned information about variable interactions. Metrics related to subfunction changes in a LON are proposed and compared with metrics from previous literature which capture other aspects of a LON. Incorporating problem structure in LON construction and analysing it can bring enriched insight into optimisation dynamics. Such information may be crucial to understanding the difficulty of solving a given problem with state-of-the-art linkage learning optimisers. In light of the results, we suggest incorporation of problem structure as an alternative paradigm in landscape analysis for problems with known or suspected subfunction structure.

Evolving Diverse Differentiating Stochastic Constraints Using Multi-objective Indicators
Saba Sadeghi Ahouei, Aneta Neumann, Frank Neumann

Evolutionary diversity optimization using multi-objective indicators, aims to evolve diverse solutions considering multiple features simultaneously. In this paper, we evolve diverse discriminating instances for chance-constraint submodular problems using multi-objective quality indicators. For any pair of algorithms, discriminating instances are easy to solve by one algorithm and hard to solve by the other. These instances help with investigating the strengths and weaknesses of different algorithms in solving a given problem. Hence, the availability of diverse sets of discriminating instances for important problems is essential. We introduce a (μ+1) evolutionary algorithm to evolve diverse differentiating instance sets for the chance-constrained maximum coverage problem. This problem contains stochastic costs on the vertices, each represented by its expected value and variance. In the selection process of our algorithm, we use inverted generational distance and hypervolume to optimize the diversity of the set. The experimental results demonstrate these indicators significantly improve the diversity of the set of instances in a multi-dimensional feature space while ensuring all of them are clearly differentiating.

RandOptGen: A Unified Random Problem Generator for Single- and Multi-Objective Optimization Problems with Mixed-Variable Input Spaces
Moritz Vinzent Seiler, Oliver Ludger Preuß, Heike Trautmann

We propose a versatile problem generator, called RandOptGen, for creating diverse and complex mixed-variable optimization problems, including single- and multi-objective problems. The generator implements a tree-based structure where decision variables from continuous, integer, and categorical domains are transformed into complex objectives using arbitrary mathematical operators. It ensures the feasibility of the generated problems through a validation process by, e.g., verifying that the objective spaces lie within pre-defined bounds and that multi-objective problems exhibit meaningful trade-offs, characterized by a well-formed Pareto front of the generated multi-objective problems. In our experiments, we demonstrate that our generator meaningfully extends existing benchmark sets. It allows for generating a desired number of instances that are largely diverse in existing feature spaces, including so far uncovered regions. Further, we can demonstrate that our generated instances reveal broader diversity within the performance space. We thus provide an efficient and scalable framework for generating complex and diverse optimization problems, thereby extending benchmark sets and advancing research in optimization and algorithm design.

Complex Systems (CS)

CS 1 + NE 1

Thursday, July 17, 12:00–13:30 Mena

★ Extract-QD Framework: A Generic Approach for Quality-Diversity in Noisy, Stochastic or Uncertain Domains
Manon Flageat, Johann Huber, François Helenon, Stéphane Doncieux, Antoine Cully

Quality-Diversity (QD) has demonstrated potential in discovering collections of diverse solutions to optimisation problems. Originally designed for deterministic environments, QD has been extended to noisy, stochastic, or uncertain domains through various Uncertain-QD (UQD) methods. However, the large number of UQD methods, each with unique constraints, makes selecting the most suitable one challenging. To remedy this situation, we present two contributions: first, the Extract-QD Framework (EQD Framework), and second, Extract-MAP-Elites (EME), a new method derived from it. The EQD Framework unifies existing approaches within a modular view, and facilitates developing novel methods by interchanging modules. We use it to derive EME, a novel method that consistently outperforms or matches the best existing methods on standard benchmarks, while previous methods show varying performance. In a second experiment, we show how our EQD Framework can be used to augment existing QD algorithms and, in particular, the well-established Policy-Gradient-Assisted-ME method, and demonstrate improved performance in uncertain domains at no additional evaluation cost. For any new uncertain task, our contributions now provide EME as a reliable "first guess" method, and the EQD Framework as a tool for developing task-specific approaches. Together, these contributions aim to lower the cost of adopting UQD insights in QD applications.

CS 2

Thursday, July 17, 15:30–17:00 Jábega

Overcoming Deceptiveness in Fitness Optimization with Unsupervised Quality-Diversity

Lisa Coiffard, Paul Templier, Antoine Cully

Policy optimization seeks the best solution to a control problem according to an objective or fitness function, serving as a fundamental field of engineering and research with applications in robotics. Traditional optimization methods like reinforcement learning and evolutionary algorithms struggle with deceptive fitness landscapes, where following immediate improvements leads to suboptimal solutions. Quality-diversity (QD) algorithms offer a promising approach by maintaining diverse intermediate solutions as stepping stones for escaping local optima. However, QD algorithms require domain expertise to define hand-crafted features, limiting their applicability where characterizing solution diversity remains unclear. In this paper, we show that unsupervised QD algorithms – specifically the AURORA framework, which learns features from sensory data – efficiently solve deceptive optimization problems without domain expertise. By enhancing AURORA with contrastive learning and periodic extinction events, we propose AURORA-XCon, which outperforms all traditional optimization baselines and matches, in some cases even improving by up to 34%, the best QD baseline with domain-specific hand-crafted features. This work establishes a novel application of unsupervised QD algorithms, shifting their focus from discovering novel solutions toward traditional optimization and expanding their potential to domains where defining feature spaces poses challenges.

Controller Distillation Reduces Fragile Brain-Body Co-Adaptation and Enables Migrations in MAP-Elites

Alican Mertan, Nick Cheney

Brain-body co-optimization suffers from fragile co-adaptation where brains become over-specialized for particular bodies, hindering their ability to transfer well to others. Evolutionary algorithms tend to discard such low-performing solutions, eliminating promising morphologies. Previous work considered applying MAP-Elites, where niche descriptors are based on morphological features, to promote better search over morphology space. In this work, we show that this approach still suffers from fragile co-adaptation: where a core mechanism of MAP-Elites, creating stepping stones through solutions that migrate from one niche to another, is disrupted. We suggest that this disruption occurs because the body mutations that move an offspring to a new morphological niche break the robots' fragile brain-body co-adaptation and thus significantly decrease the performance of those potential solutions – reducing their likelihood of outcompeting an existing elite in that new niche. We utilize a technique, we call Pollination, that periodically replaces the controllers of certain solutions with a distilled controller with better generalization across morphologies to reduce fragile brain-body co-adaptation and thus promote MAP-Elites migrations. Pollination increases the success of body mutations and the number of migrations, resulting in better quality-diversity metrics. We believe we develop important insights that could apply to other domains where MAP-Elites is used.

Dominated Novelty Search: Rethinking Local Competition in Quality-Diversity

Ryan Bahlous-Boldi, Maxence Faldor, Luca Grillotti, Hannah Janmohamed, Lisa Coiffard, Lee Spector, Antoine Cully

Quality-Diversity is a family of evolutionary algorithms that generate diverse, high-performing solutions through local competition principles inspired by natural evolution. While research has focused on improving specific aspects of Quality-Diversity algorithms, surprisingly little attention has been paid to investigating alternative formulations of local competition itself — a core mechanism distinguishing Quality-Diversity from traditional evolutionary algorithms. Most current approaches implement local competition using explicit collection mechanisms like fixed grids or unstructured archives. These often rely on predefined bounds or hard-to-tune parameters, presenting opportunities for alternative strategies. We outline how Quality-Diversity methods can be framed as Genetic Algorithms where local competition occurs through fitness transformations rather than explicit collection mechanisms. Inspired by this insight, we introduce Dominated Novelty Search, a Quality-Diversity algorithm that implements local competition through dynamic fitness transformations, without relying on predefined bounds or parameters. Our experiments show that Dominated Novelty Search significantly outperforms existing approaches across standard Quality-Diversity benchmarks, while maintaining its advantage in challenging scenarios like high-dimensional or unsupervised behavior spaces.

Multi-Objective Quality-Diversity in Unstructured and Unbounded Spaces

Hannah Janmohamed, Antoine Cully

Quality-Diversity algorithms are powerful tools for discovering diverse, high-performing solutions. Recently, Multi-Objective Quality-Diversity (MOQD) extends QD to problems with several objectives while preserving solution diversity. MOQD has shown promise in fields such as robotics and materials science, where finding trade-offs between competing objectives like energy efficiency and speed, or material properties is essential. However, existing methods in MOQD rely on tessellating the feature space into a grid structure, which prevents their application in domains where feature spaces are unknown or must be learned, such as complex biological systems or latent exploration tasks. In this work, we introduce Multi-Objective Unstructured Repertoire for Quality-Diversity (MOUR-QD), a MOQD algorithm designed for unstructured and unbounded feature spaces. We evaluate MOUR-QD on five robotic tasks. Importantly, we show that our method excels in tasks where features must be learned, paving the way for applying MOQD to unsupervised domains. We also demonstrate that MOUR-QD is advantageous in domains with unbounded feature spaces, outperforming existing grid-based methods. Finally, we demonstrate that MOUR-QD is competitive with established MOQD methods on existing MOQD tasks and achieves double the MOQD-score in some environments. MOUR-QD opens up new opportunities for MOQD in domains like protein design and image generation.

CS 3

Friday, July 18, 10:00–11:30 Jábega

Fertility During Learning in Evolutionary Robot Systems

Jacopo Michele Di Matteo, Oliver Weissl, A.E. Eiben

Robot evolution systems in which bodies and brains evolve in tandem can be significantly improved by extending them with the ability to learn. Technically, this means that 'newborn' robots are given the opportunity to optimize their inherited brain to control the inherited body adequately. Robots are in an underdeveloped 'infant' stage during this learning stage since their brains and fitness are still being improved. An open issue with regard to this infancy period is that of 'fertility': Should the robot be eligible for mating during the learning stage? This paper explores two distinct approaches from the literature, based on the Triangle of Life (TOL) model, where infant robots cannot produce offspring, and the Morphological Innovation Protection (MIP) mechanism, where they can. The main contribution is a new algorithm, TOL with infant fertility (TOL+IF), inspired by MIP. Experimental comparisons with TOL and MIP show that the new method is superior. TOL+IF is successful not only in producing robots with much higher fitness but also in maintaining the population diversity at higher levels and in evolving different interesting morphologies.

Classifier Systems as Linear Probability Models

Gijs Schröder, Johannes Textor

Classifier systems solve regression and classification problems in high-dimensional spaces by generating and evolving large populations of simple rules; examples include learning classifier systems and artificial immune systems. The properties of these flexible adaptable systems are less well understood than those of more classical machine learning algorithms. Here, we reveal a deep connection between classifier systems and probabilistic models such as Naïve Bayes and Markov chains by showing that all of these can be expressed as generalized linear probability models. This connection shows that any probability distribution can in principle be expressed by a classifier system. We then harness this new perspective to investigate the tradeoff between model complexity and calibration – i.e., the ability to accurately fit the sequence probabilities observed in the training set – for classifier systems applied to sequence probability modeling. Contrasting our results to Markov chains of varying order, we find that a simple model classifier system has a broadly similar complexity-calibration tradeoff. We hope that our approach paves the way for further systematic investigation of the fundamental properties of classifier systems, which could make them more accessible for the machine learning community.

Emergent Braitenberg-style Behaviours for Navigating the ViZDoom 'My Way Home' Labyrinth

Caleidgh Bayer, Robert Smith, Malcolm Heywood

The navigation of complex labyrinths under partially observable *visual* state is typically addressed using complex recurrent, convolutional learning architectures (i.e. deep reinforcement learning). Conversely, in this work, we show that navigation can be achieved through the emergent evolution of a simple Braitentberg-style vehicle. We demonstrate that the interaction between agent and labyrinth is sufficient to learn a complex navigation behaviour from simple heuristics. To do so, the approach of tangled program graphs is assumed in which programs cooperatively coevolve to develop a modular indexing scheme that employs <2.5% of state space. We attribute this simplicity to several biases implicit in the representation, such as: (1) the use of pixel indexing as opposed to deploying a convolutional kernel or image processing operators, and; (2) extensive support for modularity in which behaviours are always decomposed into contexts and corresponding actions.

Evolutionary Combinatorial Optimization and Metaheuristics (ECOM)

ECOM 1

Wednesday, July 16, 15:30–17:00 Alcazaba

Application of PBIG to the Minimum Global Domination Problem

Salim Bouamama, Christian Blum

The Minimum Global Domination (MGD) problem is a challenging NP-hard variant of the classical Minimum Dominating Set (MDS) problem, which has numerous practical applications. Given an undirected graph, a global dominating set is a set of vertices that dominates all vertices both in the given graph and in its complement graph. In this work, we propose a Population-Based Iterated Greedy (PBIG) algorithm to effectively address the MGD problem. The algorithm employs a semi-greedy solution reconstruction strategy and a redundancy removal mechanism to enhance efficiency and solution quality. We benchmark PBIG against current state-of-the-art approaches, including the CMSA metaheuristic and the CPLEX solver, across 1440 problem instances. Experimental results demonstrate that PBIG outperforms existing methods in solution quality while significantly reducing computational time, establishing it as a powerful and efficient algorithm for the MGD problem.

A Path-Relinking-based Heuristic for the Multiobjective Subgraph Problem

Daniela Scherer dos Santos, Kathrin Klamroth, Pedro Martins, Luís Paquete

Given a simple undirected graph G, the *Multiobjective Subgraph* (MOS) problem aims to find a subgraph in G that maximizes the number of edges while minimizing the number of vertices. Addressing the MOS problem allows to solve the related *Multiobjective Quasi-clique* problem, which seeks a quasi-clique with maximum density and number of vertices and has many real-life applications. These problems

have only been addressed using exact methods, which can be computationally intensive due to their NP-hard nature. In this paper, we introduce a heuristic method for solving the MOS problem. We show that a subset of optimal MOS subgraphs exhibits a *nestedness* property, meaning they satisfy an inclusion-wise relation. We explore this property to develop a path-relinking-based heuristic, where subgraphs from this subset serve as starting and ending points of a path to find new high-quality subgraphs. Additionally, we derive an upper bound on the number of edges for MOS subgraphs, which is used to evaluate the quality of the subgraphs generated by our heuristic. Experimental results on synthetic and real-life sparse graphs indicate that our heuristic produces high-quality subgraphs, with an average error of 2.3 edges compared to the exact method, while spending only 6.2% of its runtime.

Pareto Front Grid Guided Multiobjective Optimization In Dynamic Pickup And Delivery Problem Considering Two-Sided Fairness

Hung Phan Duc, Bui Trong Duc, Tam Nguyen Thi, Huynh Thi Thanh Binh

The dynamic delivery problem poses a complex challenge with many practical applications in logistics and transportation. Unlike the static delivery problem, where all order details are known, the dynamic delivery problem deals with continuously evolving information, with only partial data about orders available at any given moment. This paper presents the Multi-objective Dynamic Pickup and Delivery Problem with Time Windows (MODPDPTW) framework, which integrates multiple objectives, including minimizing energy consumption, reducing waiting time, and ensuring fairness for both customers and vehicles. The goal is to lower overall system costs while balancing the customer experience and the workload of service providers. Previous research has primarily focused on optimizing a single objective or converting other objectives into constraints, which can limit the flexibility and effectiveness of the solutions. Our approach tackles this challenge by introducing PFG-2F, a Pareto Front Grid-guided Multi-Objective Evolutionary Algorithm that incorporates two-sided fairness—ensuring equitable treatment for customers and service providers. The experimental results reveal that our method substantially outperforms existing multi-objective and single-objective algorithms specifically designed for the dynamic pickup and delivery problem (DPDP) on HV-metric and IGD-metric.

PGU-SGP: A Pheno-Geno Unified Surrogate Genetic Programming For Real-life Container Terminal Truck Scheduling

Leshan Tan, Chenwei Jin, Xinan Chen, Rong Qu, Ruibin Bai

Data-driven genetic programming (GP) has proven highly effective in solving combinatorial optimization problems under dynamic and uncertain environments. A central challenge lies in fast fitness evaluations on large training datasets, especially for complex real-world problems involving time-consuming simulations. Surrogate models, like phenotypic characterization (PC)-based K-nearest neighbors (KNN), have been applied to reduce computational cost. However, the PC-based similarity measure is confined to behavioral characteristics, overlooking genotypic differences, which can limit surrogate quality and impair performance. To address these issues, this paper proposes a pheno-geno unified surrogate GP algorithm, PGU-SGP, integrating phenotypic and genotypic characterization (GC) to enhance surrogate sample selection and fitness prediction. A novel unified similarity metric combining PC and GC distances is proposed, along with an effective and efficient GC representation. Experimental results of a real-life vehicle scheduling problem demonstrate that PGU-SGP reduces training time by approximately 76% while achieving comparable performance to traditional GP. With the same training time, PGU-SGP significantly outperforms traditional GP and the state-of-the-art algorithm on most datasets. Additionally, PGU-SGP shows faster convergence and improved surrogate quality by maintaining accurate fitness rankings and appropriate selection pressure, further validating its effectiveness.

ECOM 2

Wednesday, July 16, 17:30–19:00 Azul

In the Search of Optimal Tree Networks: Hardness and Heuristics

Pavel Martynov, Maxim Buzdalov, Sergey Pankratov, Vitaliy Aksenov, Stefan Schmid

Traffic in datacenters may follow some pattern: some pairs of servers communicate more frequently than others. Demand-oblivious networks may perform poorly for such workloads, and demand-aware networks optimized for traffic should be used instead. Unfortunately, not all shapes of networks are feasible in real hardware. Practical limitations are usually provided in the form of a topology. For example, a network may be required to be a binary tree, a bounded-degree graph or a Fat tree. In this work, we consider a topology of a binary tree, one of the most fundamental network topologies. We show that already finding an optimal demand-aware binary tree network is NP-hard. Then, we explore how various optimization techniques, including simple local searches, as well as deterministic mutation and crossover operators, cope with generating efficient tree networks on real-life and synthetic workloads.

Elitist Evolutionary Algorithm for Optimization on Sets of Points

Takumi Matsuo, Kento Uchida, Shinichi Shirakawa

This study focuses on the search space composed of disjoint subspaces, each containing common or distinct finite points on Euclidean space. This problem setting is called an optimization problem on sets of points (SoP), and acceptable solutions are constructed by selecting possible points in the subspaces. In optimization on SoP, it is essential to capture the positional relation between the points. Recently, CMA-ES-SoP was proposed as an optimization method on SoP by introducing additional mechanisms based on the Delaunay diagram to CMA-ES. However, there are two problems: the worst-case complexity of the Delaunay diagram is exponential in the number of dimensions, and the convergence of CMA-ES-SoP is relatively slow because of the non-elitist strategy. In this study, we propose an elitist evolutionary algorithm for the optimization on SoP. The pro-

posed method, (1+1)-EA-SoP, adaptively switches two mutation methods; the neighboring-point mutation selects the mutated point from the neighbors on the graph, and the global mutation randomly selects one point. In addition, we develop a novel graph structure that can be constructed with polynomial complexity and possesses several desirable properties related to the Delaunay diagram. The experimental results show that (1+1)-EA-SoP with the proposed graph realizes an effective optimization on SoP.

A Learning-assisted Discrete Differential Evolution for Resource Constrained Project Scheduling
Yun Dong, Lixin Tang, Weiyan Jia

This paper studies a resource-constrained project scheduling problem, aiming to optimize the start times of project activities under resource and precedence constraints in order to minimize the makespan. To solve this complex problem more efficiently, we propose a problem-specific solution algorithm that combines hybrid metaheuristics with machine learning techniques. Specifically, a discrete differential evolution serves as the main framework, which is augmented with adaptive mutation, crossover, and parameter strategies. During the evolution phase, the differential evolution competes with a sequential pattern-based adaptive large-neighborhood search to generate offspring solutions. In the subsequent selection phase, a precedence decomposition scheme cooperates with a Hamming distance-based k-nearest neighbor model to evaluate the offspring solutions. Extensive experiments utilizing benchmark datasets demonstrate that each algorithmic component positively contributes to performance enhancement, and the proposed algorithm outperforms state-of-the-art algorithms. Furthermore, we analyze the search behavior of the algorithm from various views to assess the influence of different strategies on its overall performance.

A Multiform Many-Objective Genetic Programming Method for Dynamic Flexible Job Shop Scheduling
Junwei Pang, Yi Mei, Mengjie Zhang

Genetic programming-based hyper-heuristic approaches have successfully evolved effective scheduling heuristics for dynamic flexible job shop scheduling. However, in addition to effectiveness, users may prefer other important factors such as model size (i.e., bloat control), structural complexity, and interpretability. To evolve scheduling heuristics considering a wide range of factors, we aim to solve a new many-objective optimisation problem with one effectiveness indicator and four commonly considered model structural complexity measures. To solve this problem, we design a new multiform many-objective genetic programming-based hyper-heuristic algorithm, which optimises this proposed many-objective optimisation task and a constructed single-objective auxiliary task in a multitask manner. This auxiliary task is specifically designed to optimise effectiveness, aiming to find effective individuals and provide beneficial genetic materials for the original task to improve search performance via knowledge transfer. The experimental results show that this approach can produce scheduling heuristics that approximate the Pareto front better than the compared state-of-the-art algorithms across a series of scenarios. Further analysis demonstrates the interpretability of evolved scheduling heuristics and the advantages of considering comprehensive structural complexity measures simultaneously.

ECOM 3

Thursday, July 17, 12:00–13:30 Azul

Smooth Transition Instance Chains in Combinatorial Optimization Problems
Valentino Santucci, Marco Baioletti, Marco Tomassini

In this work, by using an adiabatic principle and the Maximum Cut Problem, we investigate the evolution of problem instances from a given initial instance to a given final instance. The path followed goes from one instance to the next by using a statistical concept of distance such that the transition is smooth in the sense that this distance is short. In other words, the process takes place in the instance space by following a trajectory of minimal change. During the process we study the evolution of the similarity between consecutive instances and the movement of the global optima. In particular, we investigated whether a smooth path in the instance space always exists between the initial and the final instance. This allow us to discuss a number of statistical results that are of general interest for the understanding of the instance space of difficult combinatorial optimization problems.

Ant Colony Optimization with Policy Gradients and Replay
William Jardee, John Sheppard

Ant Colony Optimization (ACO) has served as a widely-utilized metaheuristic algorithm for decades for solving combinatorial optimization problems. Since its initial construction, ACO has seen a wide variety of modifications and connections to Reinforcement Learning (RL). Substantial parallels can be seen as early as 1995 with Ant-Q's relationship with Q-learning, through 2022 with ADACO's connection with Policy Gradient. In this work, we describe ACO, more specifically the Stochastic Gradient Descent ACO algorithm (ACOSGD), explicitly as an off-policy Policy Gradient (PG) method. We also incorporate experience replay into several ACO algorithm variants, including AS, MaxMin-ACO, ACOSGD, ADACO, and our two policy gradient-based versions: PGACO and PPOACO, drawing the connection to elitist ACO strategies. We show that our implementation of PG in ACO with experience replay and a baselined reward update strategy applied to eight TSP problems of varying sizes performs competitively with both fundamental ACO and SGD-based ACO versions. We also show that the replay buffer seems to unilaterally improve the performance of ACO algorithms through an ablation study.

Ant Colony Optimization for Tourist Route Planning
Li-Ting Xu, Qiang Yang, Dan-Ting Duan, Xin Lin, Cheng-Zhi Qu, Zhen-Yu Lu, Jun Zhang

This paper develops a new Tourist Route Planning (TRP) model by incorporating the entrance fees and the experience values of scenic spots, the travelling costs between scenic spots, and the budget of the tourist. Resultantly, the new TRP aims at finding an optimal route by maximizing the experi-

ence value of the tourist with the constraint that the total cost of the route including the travelling costs and the entrance fees does not exceed the given budget. To effectively solve this new TRP, this paper adapts the five classical ant colony optimization algorithms (ACO), namely ant system (AS), elite AS (EAS), rank-based AS (RAS), max-min AS (MMAS), and ant colony system (ACS). Further, a new local search strategy encompassing 2-opt and one spot insertion operator is designed to improve the quality of the route under the budget constraint. Experiments have been conducted on various TRP instances of three scales, namely small-scale, medium-scale, and large-scale. The experimental results demonstrate that all the adapted five ACO algorithms are effective for addressing the new TRP. Among them, RAS performs the best on small-scale TRP, and ACS obtains the best results on medium-scale TRP, while MMAS is the most effective one in addressing large-scale TRP.

Ant Colony Optimization Algorithm for Safest Path Computation in Presence of Correlated Failures in Backbone Networks

Zoltán Tasnádi, Balázs Vass, Noemi Gasko

Safest path computation with multiple correlated failures is a challenging computational task, with several application possibilities. In communication backbone networks, for example, establishing a path as safe as possible between the two communication endpoints is a crucial component for achieving the ambitious availability requirements on which emerging technologies like autonomous driving, AR/VR applications, or telesurgery depend. In this paper, after proving the NP-hardness of the problem, we propose the Safest Path Ant Colony Optimization (SP-ACO) algorithm to solve the problem. The proposed algorithm is based on the Min-Max Ant System. Numerical experiments conducted on both real-world and synthetic inputs prove the effectiveness of the proposed approach. The proposed SP-ACO algorithm typically provides at least as safe paths as the state-of-the-art algorithms, even outperforming them in a significant share of the parameter settings. This grants a place for the SP-ACO among the best solutions for safest path finding in the presence of correlated failures.

ECOM 4

Thursday, July 17, 15:30–17:00 Minotauro

★ To Repair or Not to Repair? Investigating the Importance of AB-Cycles for the State-of-the-Art TSP Heuristic EAX

Jonathan Heins, Darrell Whitley, Pascal Kerschke

The Edge Assembly Crossover (EAX) algorithm is the state-of-the-art heuristic for solving the Traveling Salesperson Problem (TSP). It regularly outperforms other methods, such as the Lin-Kernighan-Helsgaun heuristic (LKH), across diverse sets of TSP instances. Essentially, EAX employs a two-stage mechanism that focuses on improving the current solutions, first, at the local and, subsequently, at the global level. Although the second phase of the algorithm has been thoroughly studied, configured, and refined in the past, in particular, its first stage has hardly been examined. In this paper, we thus focus on the first stage of EAX and introduce a novel method that quickly verifies whether the AB-cycles, generated during its internal optimization procedure, yield valid tours – or whether they need to be repaired. Knowledge of the latter is also particularly relevant before applying other powerful crossover operators such as the Generalized Partition Crossover (GPX). Based on our insights, we propose and evaluate several improved versions of EAX. According to our benchmark study across 10 000 different TSP instances, the most promising of our proposed EAX variants demonstrates improved computational efficiency and solution quality on previously rather difficult instances compared to the current state-of-the-art EAX algorithm.

★ On Revealing the Hidden Problem Structure in Real-World and Theoretical Problems Using Walsh Coefficient Influence

Michal Witold Przewozniczek, Francisco Chicano, Renato Tinós, Jakub Nalepa, Bogdan Ruszczak, Agata Maria Wijata

Gray-box optimization employs Walsh decomposition to obtain non-linear variable dependencies and utilize them to propose masks of variables that have a joint non-linear influence on fitness value. These masks significantly improve the effectiveness of variation operators. In some problems, all variables are non-linearly dependent, making the aforementioned masks useless. We analyze the features of the real-world instances of such problems and show that many of their dependencies may have noise-like origins. Such noise-caused dependencies are irrelevant to the optimization process and can be ignored. To identify them, we propose extending the use of Walsh decomposition by measuring variable dependency strength that allows the construction of the weighted dynamic Variable Interaction Graph (wdVIG). wdVIGs adjust the dependency strength to mixed individuals. They allow the filtering of irrelevant dependencies and reenable using dependency-based masks by variation operators. We verify the wdVIG potential on a large benchmark suite. For problems with noise, the wdVIG masks can improve the optimizer's effectiveness. If all dependencies are relevant for the optimization, i.e., the problem is not noised, the influence of wdVIG masks is similar to that of state-of-the-art structures of this kind.

★ Large Neighborhood Search for Capacitated Facility Location with Customer Incompatibilities

Ida Gjergji, Lucas Kletzander, Nysret Musliu, Andrea Schaerf

A new variant of the classic capacitated facility location problem, which considers incompatibilities between customers, has recently been introduced in the literature. This problem captures the situation where given pairs of customers cannot be served by the same facility. Such a feature is crucial for many practical cases of location problems, such as the presence of hazardous or polluting materials or contention between competing costumers. In this paper, we propose a large neighborhood search (LNS) method to solve this problem. Within the framework of LNS, we introduce three different destroy operators and we use an exact solver in the repair phase. We critically analyze the effectiveness and the efficiency of both destroy and repair operators. The experimental analysis shows that our new method outperforms ex-

isting state-of-the-art metaheuristics, providing new best solutions for all available benchmark instances.

Dynamic Temperature Control of Simulated Annealing using Hyper-Heuristics
Francesca Da Ros, Luca Di Gaspero, Lucas Kletzander, Marie-Louise Lackner, Nysret Musliu, Andrea Schaerf

This paper explores the potential for dynamically adapting the temperature of Simulated Annealing (SA) in a problem-independent manner, eliminating the need for extensive tuning or prior knowledge of instance-specific features. Our goals are to bypass expensive tuning procedures and to ensure a balanced interplay between exploration and exploitation at appropriate stages of the search process. To achieve this, we developed a framework called HHSA that employs Hyper-Heuristics (HHs) and makes use of fixed-temperature SA as their low-level heuristics. The proposed approach is evaluated across three state-of-the-art HHs and four problem domains (i.e., k-Graph Coloring, Permutation Flowshop, Traveling Salesperson, and Facility Location). Comparative results against a fine-tuned SA reveal that HHSA consistently achieves comparable or superior results in three out of the four studied problems. The findings reinforce the broader applicability of hyper-heuristics, demonstrating their potential to generalize across different problem domains without relying on instance-specific configurations.

ECOM 5

Friday, July 18, 10:00–11:30 Mena

Moving between high-quality optima using multi-satisfiability characteristics in hard-to-solve Max3Sat instances
Jędrzej Piątek, Michal Witold Przewozniczek, Francisco Chicano, Renato Tinós

Gray-box optimization proposes effective and efficient optimizers of general use. To this end, it leverages information about variable dependencies and the subfunction-based problem representation. These approaches were already shown effective by enabling *tunnelling* between local optima even if these moves require the modification of many dependent variables. Tunnelling is useful in solving the maximum satisfiability problem (MaxSat), which can be reformulated to Max3Sat. Since many real-world problems can be brought to solving the MaxSat/Max3Sat instances, it is important to solve them effectively and efficiently. Therefore, we focus on Max3Sat instances for which tunnelling fails to introduce improving moves between locally optimal high-quality solutions and the region of globally optimal solutions. We analyze the features of such instances on the ground of phase transitions. Based on these observations, we propose manipulating clause-satisfiability characteristics that allow connecting high-quality solutions distant in the solution space. We utilize multi-satisfiability characteristics in the optimizer built from typical gray-box mechanisms. The experimental study shows that the proposed optimizer can solve those Max3Sat instances that are out of the grasp of state-of-the-art gray-box optimizers. At the same time, it remains effective for instances that have already been successfully solved by gray-box.

Performance Comparison between Evolutionary Algorithms and Linear Programming-based Relaxation Methods for Multi-Objective Knapsack Problems
Cheng Gong, Ping Guo, Lie Meng Pang, Qingfu Zhang, Hisao Ishibuchi

Recently, performance comparison results of evolutionary multi-objective optimization (EMO) algorithms have been reported in many studies. However, EMO algorithms have not been compared with mathematical programming-based methods in those studies. To demonstrate the usefulness of EMO algorithms, it is needed to clearly show their advantages over mathematical programming-based methods in solving multi-objective optimization problems since those methods are usually highly efficient and effective. In this paper, a novel improved linear programming-based relaxation method, named ILP-R, is proposed for addressing multi-objective knapsack problems (MOKP), which are used as the test problems for performance comparison. Extensive experimental results show that ILP-R outperforms a basic linear programming-based relaxation method and EMO algorithms. Nevertheless, EMO algorithms exhibit the ability to further improve the solutions generated by the ILP-R method. Furthermore, a knowledge-based mutation method is explored to demonstrate its effectiveness in further improving the performance of EMO algorithms that use the heuristic ILP-R solutions as the initial population.

Cluster Prevention in Evolutionary Diversity Optimization for Parallel Machine Scheduling
Dominic Wittner, Jakob Bossek

This paper addresses the prevention of undesired clusters in solution sets generated by evolutionary diversity optimization (EDO), which seeks to compute diverse solutions of high quality. We demonstrate that employing ℓ^p-norms when designing a diversity measure based on pairwise comparisons discourages clusters in a population, in accordance with the intuitive notion of diversity. Furthermore, we propose a novel diversity measure specifically tailored for parallel machine scheduling, leveraging direct sequential relationships between job pairs. Through experimental validation, we demonstrate that integrating our diversity measure into an established evolutionary algorithm yields highly diverse solution sets and show that the use of ℓ^p-norms leads to solution sets exhibiting higher robustness than established methods, enabling better adaptability to subsequent modifications of the model.

Local Optima Networks for Constrained Search Spaces
Jonathan Fieldsend, Arnaud Liefooghe, Katherine Mary Malan, Sébastien Verel

Local Optima Networks (LON)s have been used extensively to understand the global structure of optimisation problems and to study algorithm behaviour. The central idea is to compress the search space into a graph object capturing the local optima along with information on their basins of attraction and the connections between them. This enables the visualisation of high dimensional search spaces, and the ex-

traction of metrics for characterising and contrasting different problem instances. In this paper we extend the canonical LON definition to encompass search spaces with constraints. We use a well-known pairwise comparison operator for constrained problems, and capture the features of the constraint violation landscape that present a challenge for such an operator, such as infeasible local traps. The concept of a constrained LON is illustrated through a range of problem instances. Most problems in the context of real-world applications have constraints. By including the notion of feasibility and constraint violation into the definition of LONs, it becomes possible to use this powerful analysis tool on a much wider range of real-world problems.

Evolutionary Machine Learning (EML)

EML 1

Wednesday, July 16, 12:00–13:30 Azul

LAOS: Large Language Model-Driven Adaptive Operator Selection for Evolutionary Algorithms

Yisong Zhang, Guoxing Yi

Adaptive Operator Selection (AOS) is a strategy in Evolutionary Algorithms (EAs) that dynamically adjusts the application frequency of operators to enhance search efficiency based on online performance feedback. This paper introduces LAOS, an AOS framework driven by Large Language Models (LLMs). We design a meta-prompt to provide optimization state information (such as optimization progress, best fitness, and population diversity) and operator credit assignment, assisting LLMs in making adaptive decisions. Furthermore, LAOS maintains a dual-layer replay buffer structure: the offline layer records historical experiences under fixed operator strategies, while the online layer accumulates dynamically generated experiences during execution. By employing a similar experience sampling strategy, the framework can provide decision-making support for LLMs, enhancing both the efficiency and accuracy of search strategies. Experimental results on continuous numerical optimization and three categories of combinatorial optimization problems validate the effectiveness and generalization capability of LAOS. This study demonstrates the feasibility of leveraging LLMs for AOS, showcasing their potential in enhancing optimization performance and supporting automated algorithm design.

PropNEAT – Efficient GPU-Compatible Backpropagation over NeuroEvolutionary Augmenting Topology Networks

Michael Merry, Patricia Riddle, James Warren

We introduce PropNEAT, a fast backpropagation implementation of NEAT that uses a bidirectional mapping of the genome graph to a layer-based architecture that preserves the NEAT genomes whilst enabling efficient GPU backpropagation. We test PropNEAT on 58 binary classification datasets from the Penn Machine Learning Benchmarks database, comparing the performance against logistic regression, dense neural networks and random forests, as well as a densely retrained variant of the final PropNEAT model. Random forests was the highest performer, with no significant difference between it, PropNEAT, PropNEAT-retrain or dense neural networks. Logistic regression was significantly worse than all other models. PropNEAT was faster than a naive NEAT backpropagation method, and both were faster and had better performance than the original NEAT implementation. The per-epoch training time for PropNEAT scales linearly with network depth, and is efficient on GPU implementations for backpropagation. This implementation could be extended to support reinforcement learning or convolutional networks, and is able to find well-performing, sparser and smaller networks with potential for applications in low-power contexts.

Interpretable Non-linear Survival Analysis with Evolutionary Symbolic Regression

Luigi Rovito, Marco Virgolin

Survival Regression (SuR) is a key technique for modeling time to event in important applications such as clinical trials and semiconductor manufacturing. Currently, SuR algorithms belong to one of three classes: non-linear black-box—allowing adaptability to many datasets but offering limited interpretability (e.g., tree ensembles); linear glass-box—being easier to interpret but limited to modeling only linear interactions (e.g., Cox proportional hazards); and non-linear glass-box—allowing adaptability and interpretability, but empirically found to have several limitations (e.g., explainable boosting machines, survival trees). In this work, we investigate whether Symbolic Regression (SR), i.e., the automated search of mathematical expressions from data, can lead to non-linear glass-box survival models that are interpretable and accurate. We propose an evolutionary, multi-objective, and multi-expression implementation of SR adapted to SuR. Our empirical results on five real-world datasets show that SR consistently outperforms traditional glass-box methods for SuR in terms of accuracy per number of dimensions in the model, while exhibiting comparable accuracy with black-box methods. Furthermore, we offer qualitative examples to assess the interpretability potential of SR models for SuR. Code at: https://github.com/lurovi/SurvivalMultiTree-pyNSGP.

Machine Learning-Assisted Constraint Handling Under Variable Uncertainty for Preference-based Multi-Objective Optimization

Deepanshu Yadav, Palaniappan Ramu, Kalyanmoy Deb

Evolutionary Multi-objective Optimization (EMO) algorithms are widely used to solve real-world multi-objective optimization problems, aiming to obtain a set of non-dominated solutions close to the Pareto front. However, most EMO methods assume deterministic decision variables, ignoring inherent uncertainties in engineering applications, which can lead to design failures, especially in reliability-based designs.

Reliability-based Multi-objective Optimization (ReMOO) addresses this issue by incorporating variable uncertainty and probabilistic constraints to generate a Reliable Front. ReMOO operates using a bi-level framework: the outer level optimizes objective functions, while the inner level estimates reliability through computationally intensive methods, like Monte Carlo Simulation (MCS) or the Performance Measure Approach (PMA). Additionally, decision-makers (DMs) often select only a subset of reliable solutions, limiting computational efficiency. To overcome these challenges, this paper proposes a Machine Learning-assisted reliability-based Multi-Criteria Decision-Making (ML-ReMCDM) technique. ML models are trained on reliability-based constraints within the decision space before an EMO execution. In the inner loop, ML models predict probabilistic constraints and reliability indices, significantly reducing computational costs. Moreover, the outer loop computes only the DM-preferred segment of the reliable front, further enhancing efficiency. The ML-ReMCDM approach, implemented on several benchmark and real-world examples, demonstrates substantial improvements in computational efficiency as well as practical applicability.

EML 2

Wednesday, July 16, 15:30–17:00 Azul

Transformers as Surrogate Models for Genetic Programming in AutoML Tasks

Matheus Cândido Teixeira, Gisele Lobo Pappa

In applications where the fitness function has a high computational cost, one of the main drawbacks of Evolutionary Algorithms when compared to other search methods is a prohibitive computational cost. The use of surrogates as proxies for fitness function calculation to alleviate this problem is not new, but addressing the problem as a binary relation learning, i.e., evaluating if one individual is better or worse than another without estimating the actual value of the fitness, is a recent trend. This paper proposes a transformer-encoder as a surrogate to evaluate pairs of solutions and determine their relationship, i.e., which one is better/worse than the other. We experimented the model in the context of AutoML, which seeks to find the best combination of algorithms for a classification problem. To optimize the pipeline, we can use a genetic programming, but the cost of evaluating each individual is generally expensive. We trained the encoder with several parameters and compared its performance against traditional GP – evaluating fitness at each generation. Results confirm using the encoder as a surrogate does not degrade the fitness values of the evolved population of ML pipelines and can even improve it in some cases (up to 285 times faster).

Enhancing XCS with Dual-Stream Identification for Perceptual Aliasing in Multi-Step Decision-Making

Fumito Uwano, Will N. Browne

Perceptual aliasing, where distinct states appear indistinguishable due to sensor limitations or environmental ambiguities, poses significant challenges in multi-step decision-making. The eXtended Classifier System (XCS) addresses this issue by identifying unique state transition patterns and combining them to construct accurate policies. Additionally, state-action-state chains enhance XCS's ability to handle sequentially aliased states. However, XCS processes aliased states sequentially as they are perceived, which can lead to performance degradation when incorrect versions of aliased states are included in the chain. This limitation underscores the need for a more robust mechanism to accurately differentiate unique states from aliased ones to ensure reliable policy creation. To address this, we propose a dual-stream identification framework that enhances XCS's performance in environments with perceptual aliasing. The framework introduces two parallel identification processes: one captures immediate state-action relationships, while the other identifies broader patterns across multi-step sequences. By integrating these dual streams, the proposed approach effectively disambiguates aliased states, enabling more accurate decision-making. Experimental evaluations demonstrate that our dual-stream model outperforms state-of-the-art XCS implementations across 14 benchmark environments.

Adversarial attacks to image classification systems using evolutionary algorithms

Sergio Nesmachnow, Jamal Toutouh

Image classification currently faces significant security challenges due to adversarial attacks, which consist of intentional alterations designed to deceive classification models based on artificial intelligence. This article explores an approach to generate adversarial attacks against image classifiers using a combination of evolutionary algorithms and generative adversarial networks. The proposed approach explores the latent space of a generative adversarial network with an evolutionary algorithm to find vectors representing adversarial attacks. The approach was evaluated in two case studies corresponding to the classification of handwritten digits and object images. The results showed success rates of up to 35% for handwritten digits, and up to 75% for object images, improving over other search methods and reported results in related works. The applied method proved to be effective in handling data diversity on the target datasets, even in problem instances that presented additional challenges due to the complexity and richness of information.

Evolving Hard Maximum Cut Instances for Quantum Approximate Optimization Algorithms

Shuaiqun Pan, Yash J. Patel, Aneta Neumann, Frank Neumann, Thomas Bäck, Hao Wang

Variational quantum algorithms, such as the Recursive Quantum Approximate Optimization Algorithm (RQAOA), have become increasingly popular, offering promising avenues for employing Noisy Intermediate-Scale Quantum devices to address challenging combinatorial optimization tasks like the maximum cut problem. In this study, we utilize an evolutionary algorithm equipped with a unique fitness function. This approach targets hard maximum cut instances within the latent space of a Graph Autoencoder, identifying those that pose significant challenges or are particularly tractable for RQAOA, in contrast to the classic Goemans and Williamson algorithm. Our findings not only delineate the distinct capabilities and limitations of each algorithm but also expand our understanding of RQAOA's operational limits. Furthermore, the diverse set of graphs we have generated serves as a crucial benchmarking asset, emphasizing the need for more advanced algorithms to tackle combinatorial opti-

mization challenges. Additionally, our results pave the way for new avenues in graph generation research, offering exciting opportunities for future explorations.

EML 3

Wednesday, July 16, 17:30–19:00 Mena

★ Evolution of Inherently Interpretable Visual Control Policies

Camilo De La Torre, Giorgia Nadizar, Yuri Lavinas, Hervé Luga, Dennis Wilson, Sylvain Cussat-Blanc

Vision-based decision-making tasks encompass a wide range of applications, including safety-critical domains where trustworthiness is as key as performance. These tasks are often addressed using Deep Reinforcement Learning (DRL) techniques, based on Artificial Neural Networks (ANNs), to automate sequential decision making. However, the "black-box" nature of ANNs limits their applicability in these settings, where transparency and accountability are essential. To address this, various explanation methods have been proposed; however, they often fall short in fully elucidating the decision-making pipeline of ANNs, a critical aspect for ensuring reliability in safety-critical applications. To bridge this gap, we propose an approach based on Graph-based Genetic Programming (GGP) to generate transparent policies for vision-based control tasks. Our evolved policies are constrained in size and composed of simple and well-understood operational modules, enabling inherent interpretability. We evaluate our method on three Atari games, comparing explanations derived from common explainability techniques to those derived from interpreting the agent's true computational graph. We demonstrate that interpretable policies offer a more complete view of the decision process than explainability methods, enabling a full comprehension of competitive game-playing policies.

★ Dynamic Influence For Coevolutionary Agents

Everardo Gonzalez, Gaurav Dixit, Kagan Tumer

Multiagent settings are naturally characterized by coevolutionary dynamics, where agents must adapt and learn in the context of their teammates. A key challenge in such domains is determining how to credit an individual agent for their contribution to team performance. Fitness shaping approaches partially address this by identifying and isolating an agent's direct contribution to the team's success. However, when an agent's contribution is indirect—such as influencing other teammates to succeed—existing methods fail to account for its influence on the team. This paper introduces Dynamic Influence, a fitness shaping method for heterogeneous teams that isolates both direct and indirect contributions by evaluating how agents influence others over time. By considering inter-agent influence at a high temporal resolution, Dynamic Influence-Based Fitness Shaping allows agents to distill and extract direct credit from indirect interactions. Results in an autonomous aerial and terrestrial vehicle coordination problem demonstrate the efficacy of Dynamic Influence-Based Fitness Shaping, achieving superior cooperative behaviors compared to several static fitness shaping baselines.

★ Evolutionary Quadtree Pooling for Convolutional Neural Networks

Po-Wei Harn, Bo Hui, Libo Sun, Wei-Shinn Ku

Despite the success of Convolutional Neural Networks (CNNs) in computer vision, it can be beneficial to reduce parameters, increase computational efficiency, and regulate overfitting. One such reduction technique is the use of so-called pooling, which gradually reduces the spatial dimensions of the data throughout the network. Recently, Quadtree-based Genetic Programming has achieved state-of-the-art results for optimizing spatial areas on customized requirements in different grid structures. Motivated by its success, we propose to extend this approach to pooling layers of CNNs. In this direction, this paper introduces a new way to look at each pooling layer. Specifically, we propose an Evolutionary Quadtree Pooling (EQP) method that can identify the best pooling scheme. By embedding multiple quadtrees set as a pooling scheme in the pooling layers of a CNN, we are able to operate crossover and mutation on the feature maps. The evolutionary process of EQP guides the search to provide more reliable evaluations, where each individual can be seen as a CNN with a new type of pooling scheme. Our experimental results show that the best candidate network of EQP outperforms state-of-the-art max, average, stochastic, median, soft, and mixed pooling in accuracy and overfitting reduction while maintaining low computational costs.

EML 4

Thursday, July 17, 15:30–17:00 Azul

Feature selection based on cluster assumption in PU learning

Motonobu Uchikoshi, Youhei Akimoto

Feature selection is essential for efficient data mining and sometimes encounters the positive-unlabeled (PU) learning scenario, where only a few positive labels are available, while most data remains unlabeled. In certain real-world PU learning tasks, data subjected to adequate feature selection often form clusters with concentrated positive labels. Conventional feature selection methods that treat unlabeled data as negative may fail to capture the statistical characteristics of positive data in such scenarios, leading to suboptimal performance. To address this, we propose a novel feature selection method based on the cluster assumption in PU learning, called FSCPU. FSCPU formulates the feature selection problem as a binary optimization task, with an objective function explicitly designed to incorporate the cluster assumption in the PU learning setting. Experiments on synthetic datasets demonstrate the effectiveness of FSCPU across various data conditions. Moreover, comparisons with 10 conventional algorithms on three open datasets show that FSCPU achieves competitive performance in downstream classification tasks, even when the cluster assumption does not strictly hold.

Rule-based Machine Learning: Separating Rule and Rule-Set Pareto-Optimization for Interpretable Noise-Agnostic Modeling

Gabriel Lipschutz-Villa, Harsh Bandhey, Ruonan Yin, Malek Kamoun, Ryan Urbanowicz

Rule-based machine learning (RBML) algorithms, e.g. learning classifier systems (LCSs), can capture complex relationships while yielding more interpretable models than most other machine learning algorithms. Traditional LCSs rely on a single fitness function for both rule and/or rule-set optimization. However, ideal rule vs. rule-set discovery often requires distinct and multiple objectives. Recently, hybrid-LCSs were proposed that explicitly separated the task of rule vs. rule-set discovery but relied on distinct single-objective or weighted multi-objective fitness functions. This study introduces a newly developed Heuristic Evolutionary Rule Optimization System (HEROS) that combines previous LCS innovations aimed at tackling noisy, larger-scale, classification tasks, while adopting separation of rule vs. rule-set evolution. Uniquely, HEROS employs a custom Pareto-front-based multi-objective fitness function (for rule discovery) and NSGA-II-style multi-objective optimization (for rule-set discovery) to solve both clean and noisy-signal classification problems agnostically. Rule discovery is driven by rule-accuracy and instance coverage objectives, while rule-set discovery is driven by prediction accuracy and rule-set size objectives. Using diverse simulated benchmark datasets, i.e. noisy (GAMETES) and clean (MUX), we demonstrate proof-of-principle that HEROS can directly discover accurate, highly-compact, interpretable, and ideal solutions when compared to the established 'ExSTraCS' RBML algorithm, without objective weightings or adjusting hyperparameters.

Dataset Reduction for Offline Reinforcement Learning using Genetic Algorithms with Image-Based Heuristics

Enrique Mateos-Melero, Miguel Iglesias Alcázar, Raquel Fuentetaja, Fernando Fernández

In offline Reinforcement Learning (RL), the size and quality of the training dataset play a crucial role in determining policy performance. Large datasets can lead to excessive training times, while low-quality data can result in sub-optimal policies, particularly for deep learning-based RL frameworks. To address these challenges, we propose a novel approach that leverages genetic algorithms for efficient dataset reduction, paired with image-based learning using Convolutional Neural Networks (CNNs) to reduce the evaluation time of the fitness function. Specifically, our method predicts the performance of policies (fitness) learned from offline RL datasets (phenotype) and identifies optimized subsets that preserve or enhance policy quality. We evaluate our approach across three well-established RL domains, demonstrating that it effectively reduces dataset size while maintaining or improving policy performance. Furthermore, we show the transferability of the learned models to similar tasks, enabling efficient dataset optimization via transfer learning.

Genetic Algorithms for Tractable Bayesian Network Fusion via Pre-Fusion Edge Pruning

Pablo Torrijos, José A. Gámez, José M. Puerta, Juan A. Aledo

Bayesian Network (BN) fusion combines multiple input networks into a single structure, balancing dependency preservation with computational tractability. While unrestricted fusion retains all dependencies, it often results in overly complex networks with high treewidth, which affects inference scalability. Limited fusion mitigates this by pruning edges to control treewidth but risks overfitting to input-specific noise and omitting dependencies from the original BNs. This paper introduces a consensus framework that prioritizes shared structures among input networks while enforcing treewidth constraints, ensuring a good consensus. We propose genetic algorithms with advanced initialization, specialized operators, and a tailored fitness function. Additionally, we adapt existing methods to this problem and implement greedy baselines for benchmarking and further optimization. Experiments on synthetic and real-world BNs show the superiority of the proposed genetic algorithms over the adapted methods and greedy baselines.

EML 5

Friday, July 18, 10:00–11:30 Azul

Guiding Evolutionary AutoEncoder Training with Activation-Based Pruning Operators

Steven Jorgensen, Erik Hemberg, Jamal Toutouh, Una-May O'Reilly

This study explores a novel approach to neural network pruning using evolutionary computation, focusing on simultaneously pruning the encoder and decoder of an autoencoder. We introduce two new mutation operators that use layer activations to guide weight pruning. Our findings reveal that one of these activation-informed operators outperforms random pruning, resulting in more efficient autoencoders with comparable performance to canonically trained models. Prior work has established that autoencoder training is effective and scalable with a spatial coevolutionary algorithm that cooperatively coevolves a population of encoders with a population of decoders, rather than one autoencoder. We evaluate how the same activity-guided mutation operators transfer to this context. We find that random pruning is better than guided pruning, in the coevolutionary setting. This suggests activation-based guidance proves more effective in low-dimensional pruning environments, where constrained sample spaces can lead to deviations from true uniformity in randomization. Conversely, population-driven strategies enhance robustness by expanding the total pruning dimensionality, achieving statistically uniform randomness that better preserves system dynamics. We experiment with pruning according to different schedules and present best combinations of operator and schedule for the canonical and coevolving populations cases.

Black-Box Adversarial Attack on Dialogue Generation via Multi-Objective Optimization

Khang Gia Le, Ngoc Hoang Luong

Transformer-based dialogue generation (DG) models are ubiquitous in modern conversational artificial intelligence platforms. These models, however, are susceptible to adversarial attacks, i.e., prompts that appear indiscernible from normal inputs but are maliciously crafted to make the models generate incoherent and irrelevant responses. Evaluating the adversarial robustness of DG models is crucial to their real-world deployment. Adversarial methods typically exploit gradient information to effectively modify key input to-

kens, thereby achieving excellent attack performance. Nevertheless, such white-box approaches are impractical in real-world scenarios since the models' internal parameters are inaccessible. While black-box methods, which exploit only input prompts and DG models' output responses, offer a wider applicability, they often suffer from poor performance. In a human-machine conversation, good responses are expected to be semantically coherent and textually succinct. We formulate adversarial attack on DG models as a bi-objective optimization problem, where input prompts are modified in order to minimize the response coherence and maximize the generation length. We propose a DG attack framework (DGAttack) that employs multi-objective optimization to consider both objectives simultaneously when perturbing user prompts to craft adversarial inputs. Experiments across four benchmark datasets and (large) language models demonstrate the excellent performance of DGAttack compared to existing state-of-the-art approaches.

ImageBreeder: Guiding Diffusion Models with Evolutionary Computation

Dominik Sobania, Martin Briesch, Franz Rothlauf

With the recent advancements of diffusion models, it is quite easy to generate high-quality images. However, many attempts and manual changes are often necessary to achieve this high quality. Leveraging evolutionary algorithms to automate this process therefore presents a promising approach. Consequently, we introduce ImageBreeder as a framework to improve image generation at inference time driven by evolutionary algorithms. Additionally, we study the effectiveness of 10 different variation operators ranging from pixel-based blending techniques to modifications directly on the latent representation of the images. The results show that using evolutionary algorithms can significantly increase an image's quality as well as the alignment with a given prompt. Furthermore, all tested guided search methods are human competitive, as a random trial and error approach is outperformed on over 75% of the benchmark problems. In addition to the empirical results, we also critically discuss the benefits and challenges of our framework uncovering future research directions. We recommend researchers to focus on optimising latent image representations for this purpose as this may improve the ability of evolutionary algorithms to transfer promising features from one image to another, unlocking even better image generation.

Evolutionary Multiobjective Optimization (EMO)

EMO 1

Wednesday, July 16, 15:30–17:00 Minotauro

★ R2 Indicator Analysis using the Optimal Distributions of Solutions for R2 and Other Indicators

Yang Nan, Hisao Ishibuchi, Tianye Shu, Ke Shang

In the evolutionary multi-objective optimization (EMO) community, performance indicators are increasingly important. This is because the indicators can be used for evaluating and designing EMO algorithms. Among them, the hypervolume indicator is particularly popular because it is Pareto compliant. Recently, researchers have shown that the exact R2 indicator is also Pareto compliant. Some researchers have already investigated the optimal distribution of solutions for the hypervolume indicator. However, only a few studies have examined the optimal distribution of the approximate R2 indicator in the two-dimensional case. In this paper, we show the optimal distributions of solutions for the exact R2 indicator and some variants of the approximate R2 indicator in the three-dimensional case. The visualized optimal distributions are compared with each other and also with the best solution set for MOEA/D. Our analysis and results show that the optimal distribution of the exact R2 indicator is similar to that of the hypervolume indicator. The optimal distributions of the approximate R2 indicator's variants are similar to the best solution set for MOEA/D.

★ Exploring Phase-Specific Configuration of Interactive Evolutionary Multiobjective Optimization Methods

Giomara Larraga, Kaisa Miettinen

Interactive evolutionary multiobjective methods enable a decision maker to solve optimization problems involving multiple conflicting objective functions by iteratively incorporating preference information. When applying interactive methods, two phases can often be identified: a learning phase, where a decision maker gains insights on trade-offs and identifies a region of interest based on their preferences, and a decision phase focused on fine-tuning and selecting the most preferred solution. The configuration of evolutionary operators, like selection, crossover, and mutation, heavily influences the performance of evolutionary methods. However, despite extensive research on parameter tuning, identifying optimal configurations for these operators within interactive methods while accounting for the specific goals of each phase has not been studied. This study introduces a framework for the automatic configuration of interactive methods, taking the first step toward addressing this research gap. The framework systematically identifies phase-specific optimal configurations by combining the PHI indicator with the irace automatic configuration tool. Experiments with interactive RVEA and interactive RNSGA-II on problems involving three, five, and seven objective functions reveal notable differences in optimal configurations between the learning and decision phases. These findings lay a foundation for enhancing the performance of interactive evolutionary multiobjective methods and highlight the importance of phase-specific configurations.

EMO 2

Wednesday, July 16, 17:30–19:00 Alborán

Multi-Objective Covariance Matrix Adaptation

MAP-Annealing
Shihan Zhao, Stefanos Nikolaidis

Quality-Diversity (QD) optimization is an emerging field that focuses on finding a set of behaviorally diverse and high-quality solutions. While the quality is typically defined w.r.t. a single objective function, recent work on Multi-Objective Quality-Diversity (MOQD) extends QD optimization to simultaneously optimize multiple objective functions. This opens up multi-objective applications for QD, such as generating a diverse set of game maps that maximize difficulty, realism, or other properties. Existing MOQD algorithms use non-adaptive methods such as mutation and crossover to search for non-dominated solutions and construct an archive of Pareto Sets (PS). However, recent work in QD has demonstrated enhanced performance through the use of covariance-based evolution strategies for adaptive solution search. We propose bringing this insight into the MOQD problem, and introduce MO-CMA-MAE, a new MOQD algorithm that leverages Covariance Matrix AdaptationEvolution Strategies (CMA-ES) to optimize the hypervolume associated with every PS within the archive. We test MO-CMA-MAE on three MOQD domains, and for generating maps of a cooperative video game, showing significant improvements in performance.

Reference Point Specification in Greedy Inclusion Hypervolume-based Subset Selection: A Study on Two Objectives
Adrián Isaí Morales-Paredes, Jesús Guillermo Falcón-Cardona, Julio Juárez, Hugo Terashima-Marín, Carlos A. Coello Coello

The hypervolume indicator (HV) is widely used in evolutionary multi-objective optimization for performance evaluation and algorithm design. However, its utility heavily depends on selecting a reference point (RP). Depending on this point, HV may prefer non-uniform Pareto front approximations (PFAs) over other more uniform distributions. While existing studies have explored the impact of RP specification regarding μ-distribution settings, its impact on greedy inclusion hypervolume-based subset selection (GI-HSS) algorithms remains underexamined. These algorithms rely on incremental individual contributions to HV. This paper investigates the effect of the RP specification on the uniformity of PFAs generated by a GI-HSS algorithm. The focus is on two-objective Pareto fronts characterized by linear, concave, convex, and disconnected geometries. Using the lazy GI-HSS algorithm as a framework, we evaluate a comprehensive range of RP settings to identify those that promote more uniform distributions with up to 210 points. Our findings provide new insights into RP selection and offer practical guidelines for enhancing the performance of GI-HSS algorithms in multi-objective applications.

Multiagent Credit Assignment for Multi-Objective Coordination
Raghav Thakar, Gaurav Dixit, Siddarth Iyer, Kagan Tumer

Many real-world coordination tasks—such as environmental monitoring, traffic management, and underwater exploration—are best modelled as multiagent problems with multiple, often conflicting objectives. Achieving effective coordination in these settings requires addressing two main challenges: 1) balancing multiple objectives and 2) resolving the credit assignment problem to isolate each agent's contribution from team-level feedback. Existing multiagent credit assignment methods collapse multi-objective reward vectors into a single scalar—potentially overlooking nuanced trade-offs. In this paper, we introduce the Multi-Objective Difference Evaluation (*DMO*) operator to assign agent-level credit without a priori scalarisation. *DMO* measures the change in hypervolume when an agent's policy is replaced by a counterfactual default, capturing how much that policy contributes to each objective and to the Pareto front. We embed *DMO* into the popular NSGA-II algorithm to evolve a population of joint policies with distinct trade-offs. Empirical results on the Multi-Objective Beach Problem and the Multi-Objective Rover Exploration domain show that our approach matches or surpasses existing baselines, delivering up to a 33% performance improvement.

Customized Exploration of Landscape Features Driving Multi-Objective Combinatorial Optimization Performance
Ana Nikolikj, Gabriela Ochoa, Tome Eftimov

We present an analysis of landscape features for predicting the performance of multi-objective combinatorial optimization algorithms. We consider features from the recently proposed compressed Pareto Local Optimal Solutions Networks (C-PLOS-net) model of combinatorial landscapes. The benchmark instances are a set of ρmnk-landscapes with 2 and 3 objectives and various levels of ruggedness and objective correlation. We consider the performance of three algorithms – Pareto Local Search (PLS), Global Simple EMO Optimizer (GSEMO), and Non-dominated Sorting Genetic Algorithm (NSGA-II) – using the resolution and hypervolume metrics. Our tailored analysis reveals feature combinations that influence algorithm performance specific to certain landscapes. This study provides deeper insights into feature importance, tailored to specific ρmnk-landscapes and algorithms.

EMO 3

Thursday, July 17, 12:00–13:30 Alborán

Variable Metric Evolution Strategies for High-dimensional Multi-Objective Optimization
Tobias Glasmachers

We design a class of variable metric evolution strategies well suited for high-dimensional problems. We target problems with many variables, not (necessarily) with many objectives. The construction combines two independent developments: efficient algorithms for scaling covariance matrix adaptation to high dimensions, and evolution strategies for multi-objective optimization. In order to design a specific instance of the class we first develop a (1+1) version of the limited memory matrix adaptation evolution strategy and then use an established standard construction to turn a population thereof into a state-of-the-art multi-objective optimizer with indicator-based selection. The method compares favorably to adaptation of the full covariance matrix.

An Evolutionary Algorithm for Solving Decision Space Constrained Multi-Objective Binary Optimization Problems

Felipe Honjo Ide, Hernan Aguirre, Kiyoshi Tanaka

In real-world multi-objective optimization problems, it is common to find constraints that limit the feasible space, challenging the solver to explore the infeasible region and find good feasible solutions. Several evolutionary algorithms with various constraint-handling techniques have been proposed over the years. However, most focus on problems with continuous variables and constraints defined over the objective space and might not be suitable for binary problems and constraints defined on the decision space. This work proposes a multi-objective evolutionary algorithm for solving decision space-constrained multi-objective binary optimization problems. The proposed method can switch between a simple evolutionary algorithm, which optimizes constraint violation of infeasible solutions, and a random bit climber, which optimizes the objective functions of feasible solutions. We compare the performance of the proposed algorithm to other state-of-the-art evolutionary algorithms and study its behavior using SAT Constrained MNK-Landscapes. We show that the proposed algorithm can effectively optimize constraint violation of infeasible solutions, quickly find feasible solutions, and performs better than the compared algorithms in highly constrained problems with varying numbers of objectives, epistatic interactions, equality and inequality constraints, and constraint difficulty.

On the Pareto Set and Front of Multiobjective Spherical Functions with Convex Constraints

Anne Auger, Dimo Brockhoff, Jordan Cork, Tea Tušar

We analyze a fundamental class of multiobjective constrained problems where the objectives are spherical functions and the constraints are convex. As an application from the projection theorem on closed convex sets, we prove that the constrained Pareto set corresponds to the orthogonal projection of the unconstrained Pareto set onto the feasible region. We establish this fundamental geometric property and illustrate its implications using visualizations of Pareto sets and fronts under various constraint configurations. Furthermore, we assess the performance of NSGA-II on these problems, examining its ability to approximate the constrained Pareto set across different dimensions. Our findings highlight the importance of theoretically grounded and understood benchmark problems for assessing algorithmic behavior and contribute to a deeper understanding of constrained multiobjective landscapes.

Scalarization-based Exploratory Landscape Analysis for Multi-Objective Continuous Optimization Problems

Shuhei Tanaka, Shoichiro Tanaka, Toshiharu Hatanaka

In landscape-aware techniques, interpretable features provide decision makers with insights into the relationship between algorithm behavior and problem properties. We focus on Exploratory Landscape Analysis (ELA), which is a well-established method for extracting human-designed features at low computational cost. Although the effectiveness of ELA has been proven in single-objective continuous optimization, extending it to multi-objective domains while maintaining both feature interpretability and effectiveness remains an open challenge. To address this challenge, we introduce Scalarization-based ELA (S-ELA), a novel variation of ELA for multi-objective continuous optimization using scalarizing methods. S-ELA enables the computation of conventional ELA features by scalarizing objective vectors. In this study, we investigated two scalarizing approaches: (1) decomposition and (2) non-dominated sorting. Through experiments on bi-objective continuous optimization problems from the bbob-biobj test suite, we compared S-ELA with Deep-ELA, a state-of-the-art deep learning-based ELA. Our results demonstrate that S-ELA achieved accuracies of approximately 76% to 80%, comparable to Deep-ELA, in algorithm selection.

EMO 4

Thursday, July 17, 15:30–17:00 Alborán

Addressing Heterogeneous Evaluation Times in Constrained Multi-Objective Optimization using a Mixed-Fidelity Evaluation Technique: Proof-of-Concept Results

Balija Santoshkumar, Kalyanmoy Deb

Most practical optimization problems involve expensive evaluation procedures for computing objective and constraint functions. To obtain reasonable and accurate solutions close to true Pareto-optimal solutions, evolutionary multi-objective optimization (EMO) algorithms create surrogate models from already-evaluated high-fidelity solutions and use them during optimization to save computational time. However, most surrogate-assisted EMO algorithms are designed to evaluate all objectives and constraints of a solution, if found worthy of a high-fidelity evaluation. Such algorithms are inefficient if objectives and constraints involve heterogeneity with orders of magnitude of difference in evaluation times. Clearly, functions with relatively small evaluation time can be high-fidelity evaluated more often to obtain an overall idea of the potential importance of the solution before deciding to spend more time on evaluating expensive functions. In this paper, we propose an EMO approach that carefully determines which constraints and objectives should be high-fidelity evaluated for every population member and suggests a mixed-fidelity survival selection procedure capable of working with low- and high-fidelity evaluated population members. Results on a number of test and engineering problems indicate the viability of such a constrained multi- and many-objective optimization algorithm and encourage further attention.

Search Behavior Analysis of NSGA-III: Dominance-based and Decomposition-based Multi-objective Evolutionary Algorithm

Hisao Ishibuchi, Lie Meng Pang, Cheng Gong

In the field of evolutionary multi-objective optimization (EMO), EMO algorithms are often categorized into three types: dominance-based, decomposition-based and indicator-based algorithms. In this categorization, NSGA-III is handled as a decomposition-based algorithm. This is because a single solution is assigned to each of uniformly

generated reference vectors as in MOEA/D. However, in a recent survey paper, NSGA-III was categorized in the same group as NSGA-II based on their generation update mechanisms. Another recent study demonstrated that NSGA-III shows a similar search behavior to NSGA-II for combinatorial multi-objective problems. However, for DTLZ test problems, NSGA-III shows almost the same search behavior as MOEA/D. In this paper, we demonstrate that the shape of the Pareto front is the main factor about the search behavior of NSGA-III. If a test problem has a regular (i.e., triangular) Pareto front, NSGA-III shows the same search behavior as MOEA/D. However, if a test problem has an irregular Pareto front (e.g., inverted triangular), NSGA-III shows a similar search behavior to NSGA-II. We also demonstrate that the objective space normalization in NSGA-III is not stable for multi-objective problems with inverted triangular Pareto fronts.

Analyzing the Landscape of the Indicator-based Subset Selection Problem
Keisuke Korogi, Ryoji Tanabe

The indicator-based subset selection problem (ISSP) involves finding a point subset that minimizes or maximizes a quality indicator. The ISSP is frequently found in evolutionary multi-objective optimization (EMO). An in-depth understanding of the landscape of the ISSP could be helpful in developing efficient subset selection methods and explaining their performance. However, the landscape of the ISSP is poorly understood. To address this issue, this paper analyzes the landscape of the ISSP by using various traditional landscape analysis measures and exact local optima networks (LONs). This paper mainly investigates how the landscape of the ISSP is influenced by the choice of a quality indicator and the shape of the Pareto front. Our findings provide insightful information about the ISSP. For example, high neutrality and many local optima are observed in the results for ISSP instances with the additive ϵ-indicator.

Influence of Subpopulation on the Performance of Coevolutionary Algorithms for Constrained Multiobjective Optimization Problems
Yanyu Chen, Hisao Ishibuchi, Yang Nan

Coevolution is a state-of-the-art constraint handling technique (CHT), which optimizes objectives and satisfies constraints by simultaneously evolving two populations. One is the main population which is evolved considering constraints, and the other is the subpopulation evolved by ignoring some or all constraints. Existing coevolutionary algorithms maintain the utilization strategies for the subpopulation throughout the entire search process, which can result in inefficient use of computational resources. To effectively utilize the subpopulation in a coevolutionary algorithm for constrained multiobjective optimization problems (CMOPs), this paper divides its search process into two stages with different search priorities, leveraging the stage-switching mechanism of PPS-MOEA/D. Based on the CCMO framework, we propose several variants with different subpopulation utilization strategies in the second stage, and evaluate their performance on both artificial and real-world CMOPs. Our experimental results reveal that CMOPs can be classified into three categories, each requiring a distinct subpopulation utilization strategy. The results also confirm the usefulness of the two following subpopulation utilization strategies in the second stage: (i) to decrease the number of offspring generated in the subpopulation, and (ii) to enhance the cooperation (connection) between the main population and the subpopulation.

EMO 5

Friday, July 18, 10:00–11:30 Alborán

Improved Convergence-relaxed Mechanism for Handling Imbalance Between Convergence and Diversity in the Decision Space in Multimodal Multi-objective optimization
Zhipan Li, Wenkai Mao, Huigui Rong, Jianguo Chen, Shengxu Huo, Zilu Zhao

Balancing convergence and diversity in the decision space is essential in solving multimodal multi-objective optimization problems (MMOPs), which have multiple equivalent Pareto optimal sets (PSs) with the same Pareto optimal front (PF). For MMOPs with an imbalance between convergence and diversity in the decision space (MMOP-ICD), numerous efficient multimodal multi-objective evolutionary algorithms (MMEAs) avoid premature convergence and search for the imbalanced PS by relaxing the traditional convergence-first selection mechanism. Unfortunately, existing MMEAs suffer from convergence degradation due to excessive relaxation of the convergence-first selection mechanism. Therefore, this paper proposes an improved convergence-relaxed mechanism that includes an enhanced local convergence indicator and a two-stage matching selection. The enhanced local convergence indicator introduces the global convergence indicator into the local convergence indicator. The local convergence indicator can locate more equivalent PSs and prevent premature convergence caused by the global convergence indicator. The global convergence indicator can improve the convergence quality of the solution selected by the local convergence indicator. Then, the two-stage matching selection is used to enhance the diversity in the decision space and balance the improved convergence. Experimental results and statistical analysis show that the proposed algorithm is significantly superior to other state-of-the-art MMEAs.

Constrained Multi-objective Optimization with Search Direction Learning
Mingcheng Zuo, Dunwei Gong, Tianyang Xue, Chunliang Zhao, Yongde Guo

The solving process of constrained multi-objective evolutionary optimization algorithms (CMOEAs) is closely related to the search direction of the population. How to learn promising search directions through population data remains challenging. Therefore, this paper proposes a CMOEA with search direction learning. In this method, principal component analysis (PCA) is first used to learn the mainstream direction of population evolution, then single-constraint domination is used to learn the tributary direction of population evolution, and finally, the search directions are summarized to guide the generation of high-quality offspring populations. The performance comparison with five state-of-the-art algorithms on three standard test problems demonstrates the superiority of the proposed method. Its applicability in the field

of simulated integrated circuits proves the scalability of the proposed method.

High-Dimensional Expensive Multiobjective Optimization Using a Surrogate-Assisted Multifactorial Evolutionary Algorithm
Yuma Horaguchi, Masaya Nakata

The performance of surrogate-assisted multiobjective evolutionary algorithms (SAMOEAs) often degrades in high-dimensional problems. Recent studies have shown that decomposition-based approaches are particularly effective in handling high-dimensional search spaces, owing to their problem-simplifying capability. However, existing decomposition-based SAMOEAs are designed to sequentially solve each decomposed subproblem, still unnecessarily consuming function evaluations (FEs) and thus degrading the search efficiency. To address this issue, this paper proposes a novel decomposition-based SAMOEA that employs a multifactorial evolutionary algorithm (MFEA). The proposed algorithm aggregates multiple subproblems randomly and it collectively solves them using a surrogate-assisted MFEA framework. This approach enables the efficient discovery of promising solutions across multiple subproblems in a single FE, enhancing the search efficiency under a limited budget of FEs. Experimental results show that our proposed algorithm outperforms state-of-the-art SAMOEAs on problems with up to 300 dimensions. This suggests that our surrogate-assisted MFEA framework can bring out the further potential of decomposition-based SAMOEAs.

Genotype vs. Phenotype: A Crossover Operator Comparison for the Multi-Objective Coverage Path Planning Problem
Lukas Bostelmann-Arp, Christoph Steup, Sanaz Mostaghim

The crossover operator is a fundamental component of genetic algorithms, combining genetic material from parent solutions to generate offspring. Traditionally, crossover is performed in the search space using the genotype. However, it can also be executed in the solution space on the phenotype, offering potential advantages such as improved feasibility preservation, faster convergence, and greater explainability. These benefits, however, come with trade-offs, including increased implementation complexity, higher computational costs, and a likely reduction in solution diversity. This study examines the properties of search space and solution space crossover operators in the context of a multi-objective, weighted, and continuous coverage path planning problem. Three crossover strategies are tested: two of which operate directly on the genotype and one that uses intersections of the phenotype.

Evolutionary Numerical Optimization (ENUM)

BBSR 1 + ENUM 1
Wednesday, July 16, 12:00–13:30 Mena

★ CatCMA with Margin: Stochastic Optimization for Continuous, Integer, and Categorical Variables
Ryoki Hamano, Masahiro Nomura, Shota Saito, Kento Uchida, Shinichi Shirakawa

This study focuses on mixed-variable black-box optimization (MV-BBO), addressing continuous, integer, and categorical variables. Many real-world MV-BBO problems involve dependencies among these different types of variables, requiring efficient methods to optimize them simultaneously. Recently, stochastic optimization methods leveraging the mechanism of the covariance matrix adaptation evolution strategy have shown promising results in mixed-integer or mixed-category optimization. However, such methods cannot handle the three types of variables simultaneously. In this study, we propose CatCMA with Margin (CatCMAwM), a stochastic optimization method for MV-BBO that jointly optimizes continuous, integer, and categorical variables. CatCMAwM is developed by incorporating a novel integer handling into CatCMA, a mixed-category black-box optimization method employing a joint distribution of multivariate Gaussian and categorical distributions. The proposed integer handling is carefully designed by reviewing existing integer handlings and following the design principles of CatCMA. Even when applied to mixed-integer problems, it stabilizes the marginal probability and improves the convergence performance of continuous variables. Numerical experiments show that CatCMAwM effectively handles the three types of variables, outperforming state-of-the-art Bayesian optimization methods and baselines that simply incorporate existing integer handlings into CatCMA.

★ Challenges of Interaction in Optimizing Mixed Categorical-Continuous Variables
Youhei Akimoto, Xilin Gao, Ze Kai Ng, Daiki Morinaga

Optimization of mixed categorical-continuous variables is prevalent in real-world applications of black-box optimization. Recently, CatCMA has been proposed as a method for optimizing such variables and has demonstrated success in hyper-parameter optimization problems. However, it encounters challenges when optimizing categorical variables in the presence of interaction between continuous and categorical variables in the objective function. In this paper, we focus on optimizing mixed binary-continuous variables as a special case and identify two types of variable interactions that make the problem particularly challenging for CatCMA. To address these difficulties, we propose two algorithmic components: a warm-starting strategy and a hyper-representation technique. We analyze their theoretical impact on test problems exhibiting these interaction properties. Empirical results demonstrate that the proposed components effectively address the identified challenges, and CatCMA enhanced with these components, named ICatCMA, outperforms the original CatCMA.

ENUM 2

Thursday, July 17, 15:30–17:00 Alcazaba

Toward Efficient Mixed-Integer Black-Box Optimization via Evolution Strategies with Plateau Handling Techniques

Tuan Anh Nguyen, Ngoc Hoang Luong

Mixed-Integer Black-Box Optimization (MI-BBO) problems involve optimizing objective functions that have both continuous and integer decision variables without access to any problem-specific knowledge such as gradient or Hessian. Although recent studies have made notable progress in solving many MI-BBO problems, inherent challenges persist, particularly regarding the problem dimensionality and the expected runtime (ERT) required to reach the target values. In this paper, we propose an efficient MI-BBO method that uses evolution strategies with plateau handling techniques. To address problems with higher dimensions, we explore several high-dimensional algorithms, such as VD-CMA (a linear variant of CMA-ES for High Dimension Optimization) and CR-FM-NES (Cost-Reduction Fast Moving Natural Evolution Strategy), and appropriately adapt certain plateau handling techniques to enhance the optimization performance. Numerical experiments with standard benchmark functions against prominent recently-proposed MI-BBO algorithms demonstrate that our methods can solve problems with higher dimensions while maintaining the optimization efficiency. Moreover, the results also reveal the potential for scaling to more challenging problem classes with low computational costs. The source code can be found at: https://github.com/ELO-Lab/eMI-BBO.

Abnormal Mutations: Evolution Strategies Don't Require Gaussianity

Jacob de Nobel, Diederick Vermetten, Hao Wang, Anna Kononova, Günter Rudolph, Thomas Bäck

The mutation process in evolution strategies has been interlinked with the normal distribution since its inception. Many lines of reasoning have been given for this strong dependency, ranging from maximum entropy arguments to the need for isotropy. However, some theoretical results suggest that other distributions might lead to similar local convergence properties. This paper empirically shows that a wide range of evolutionary strategies, from the (1+1)-ES to CMA-ES, show comparable optimization performance when using a mutation distribution other than the standard Gaussian. Replacing it with, e.g., uniformly distributed mutations, does not deteriorate the performance of ES, when using the default adaptation mechanism for the strategy parameters. We observe that these results hold not only for the sphere model but also for a wider range of benchmark problems.

More Efficient Real-Valued Gray-Box Optimization through Incremental Distribution Estimation in RV-GOMEA

Renzo Scholman, Tanja Alderliesten, Peter A.N. Bosman

The Gene-pool Optimal Mixing EA (GOMEA) family of EAs offers a specific means to exploit problem-specific knowledge through linkage learning, i.e., inter-variable dependency detection, expressed using subsets of variables, that should undergo joint variation. Such knowledge can be exploited if faster fitness evaluations are possible when only a few variables are changed in a solution, enabling large speed-ups. The recent-most version of Real-Valued GOMEA (RV-GOMEA) can learn a conditional linkage model during optimization using fitness-based linkage learning, enabling fine-grained dependency exploitation in learning and sampling a Gaussian distribution. However, while the most efficient Gaussian-based EAs, like NES and CMA-ES, employ incremental learning of the Gaussian distribution rather than performing full re-estimation every generation, the recent-most RV-GOMEA version does not employ such incremental learning. In this paper, we therefore study whether incremental distribution estimation can lead to efficiency enhancements of RV-GOMEA. We consider various benchmark problems with varying degrees of overlapping dependencies. We find that, compared to RV-GOMEA and VKD-CMA-ES, the required number of evaluations to reach high-quality solutions can be reduced by a factor of up to 1.5 if population sizes are tuned problem-specifically, while a reduction by a factor of 2-3 can be achieved with generic population-sizing guidelines.

A Perturbation and Speciation-Based Algorithm for Dynamic Optimization Uninformed of Change

Federico Signorelli, Anil Yaman

Dynamic optimization problems (DOPs) are challenging due to their changing conditions. This requires algorithms to be highly adaptable and efficient in terms of finding rapidly new optimal solutions under changing conditions. Traditional approaches often depend on explicit change detection, which can be impractical or inefficient when the change detection is unreliable or unfeasible. We propose Perturbation and Speciation-Based Particle Swarm Optimization (PSPSO), a robust algorithm for uninformed dynamic optimization without requiring the information of environmental changes. The PSPSO combines speciation-based niching, deactivation, and a newly proposed random perturbation mechanism to handle DOPs. PSPSO leverages a cyclical multi-population framework, strategic resource allocation, and targeted noisy updates, to adapt to dynamic environments. We compare PSPSO with several state-of-the-art algorithms on the Generalized Moving Peaks Benchmark (GMPB), which covers a variety of scenarios, including simple and multi-modal dynamic optimization, frequent and intense changes, and high-dimensional spaces. Our results show that PSPSO outperforms other state-of-the-art uninformed algorithms in all scenarios and leads to competitive results compared to informed algorithms. In particular, PSPSO shows strength in functions with high dimensionality or high frequency of change in the GMPB. The ablation study showed the importance of the random perturbation component.

ENUM 3

Friday, July 18, 10:00–11:30 Alcazaba

Classification-Based Linear Surrogate Modeling of Constraints for AL-CMA-ES

Oskar Girardin, Nikolaus Hansen, Dimo Brockhoff, Anne

Auger

We introduce linear surrogate functions for modeling inequality constraints to solve constrained blackbox optimization problems with the Augmented Lagrangian CMA-ES. Each surrogate is constructed from a binary classifier that predicts the sign of the constraint value. The classifier, and consequently the resulting algorithm, is invariant under sign preserving transformations of the constraint values and can handle binary, flat, and deceptive constraints. Somewhat surprisingly, we find that adopting a sign-based classification model of the constraints allows to solve classes of constrained problems which can not be solved with the original Augmented Lagrangian method using the true constraint value.

An Adaptive Re-evaluation Method for Evolution Strategy under Additive Noise
Catalin-Viorel Dinu, Yash J. Patel, Xavier Bonet-Monroig, Hao Wang

The Covariance Matrix Adaptation Evolutionary Strategy (CMA-ES) is one of the most advanced algorithms in numerical black-box optimization. For noisy objective functions, several approaches were proposed to mitigate the noise, e.g., re-evaluations of the same solution or adapting the population size. In this paper, we devise a novel method to adaptively choose the optimal re-evaluation number for function values corrupted by additive Gaussian white noise. We derive a theoretical lower bound of the expected improvement achieved in one iteration of CMA-ES, given an estimation of the noise level and the Lipschitz constant of the function's gradient. Solving for the maximum of the lower bound, we obtain a simple expression of the optimal re-evaluation number. We experimentally compare our method to the state-of-the-art noise-handling methods for CMA-ES on a set of artificial test functions across various noise levels, optimization budgets, and dimensionality. Our method demonstrates significant advantages in terms of the probability of hitting near-optimal function values.

Surrogate-Assisted CMA-ES for Problems with Low Effective Dimensionality
Yuta Sekino, Yohei Watanabe, Kento Uchida, Shinichi Shirakawa

High-dimensional optimization problems in real-world applications often possess the property called low effective dimensionality (LED), where only a small part of directions in search space affect the evaluation value, and others are redundant. On problems with LED, because the redundant directions deteriorate the prediction performance of the surrogate model, the performance of several surrogate-assisted evolutionary algorithms is worsened. This paper focuses on the doubly trained surrogate CMA-ES (DTS-CMA-ES) that employs Gaussian process regression as a surrogate model and proposes DTS-CMA-ES-LED by incorporating several countermeasures for LED to DTS-CMA-ES. The proposed method considers directions along the eigenvectors of the covariance matrix and evaluates the effectiveness of each direction using the estimated element-wise signal-to-noise ratio of the update directions. Then, the proposed method reconstructs the kernel function with the computed effectiveness to reduce the effect of redundant directions. We also introduce the hyperparameter adaptation mechanism and refinement of the step-size adaptation as countermeasures for LED. The experimental results show that DTS-CMA-ES-LED effectively optimized the benchmark functions with LED.

Adaptive Estimation of the Number of Algorithm Runs in Stochastic Optimization
Tome Eftimov, Peter Korošec

Determining the number of algorithm runs is a critical aspect of experimental design, as it directly influences the experiment's duration and the reliability of its outcomes. This paper introduces an empirical approach to estimating the required number of runs per problem instance for accurate estimation of the performance of the continuous single-objective stochastic optimization algorithm. The method leverages probability theory, incorporating a robustness check to identify significant imbalances in the data distribution relative to the mean, and dynamically adjusts the number of runs during execution as an online approach. The proposed methodology was extensively tested across two algorithm portfolios (104 Differential Evolution configurations and the Nevergrad portfolio) and the COCO benchmark suite, totaling 5,748,000 runs. The results demonstrate 82%–95% accuracy in estimations across different algorithms, allowing a reduction of approximately 50% in the number of runs without compromising optimization outcomes. This online calculation of required runs not only improves benchmarking efficiency but also contributes to energy reduction, fostering a more environmentally sustainable computing ecosystem.

Genetic Algorithms (GA)

GA 1 + SI 3	
Wednesday, July 16, 17:30–19:00	Minotauro

★ Empirical Linkage Learning Provably Builds Truthful Models on Concatenated Traps and H-IFF
Marcus Schmidbauer, Dirk Sudholt

Linkage Learning aims to discover variable dependencies during the optimisation process. To this end, Statistical Linkage Learning (SLL) uses statistical analysis of gene value combinations, whereas Empirical Linkage Learning (ELL) is based on comparing the fitness of neighbouring solutions. ELL, in contrast to SLL, provably does not report false linkage, but is computationally more expensive. We present the first runtime analysis of an ELL-based evolutionary algorithm. Specifically, we analyse the ELL-based Parameter-less Population Pyramid (P3) on concatenated traps and the H-IFF problem, complementing a previous analysis of the SLL-based P3 and thus enabling the theory-founded comparison of linkage-learning techniques. We show that ELL builds models that accurately represent the ground truth based on

the currently available information, capturing the maximum possible amount of linkage. This underscores its effectiveness.

On the Use of Matching Algorithms to Transfer Solutions for the Travelling Salesperson Problem
Liam Wigney, Aneta Neumann, Yew-Soon Ong, Frank Neumann

Multitasking evolutionary algorithms can be effectively used to solve a number of problems with a single population. A key issue in deciding their effectiveness, is how to transfer good solutions from one problem instance to another problem instance which shares some characteristics. We investigate in this paper how to transfer solutions between different problem instances of the Travelling Salesperson Problem (TSP) based matching algorithms and introduce different transfer mechanisms based on matching the nodes between problem instances. In our experimental study, we examine how the different transfer approaches perform for different classes of TSP instances dependent on the characteristics of the considered problem instances.

Evolutionary Multitasking for the Scenario-based Travelling Thief Problem
Thilina Pathirage Don, Aneta Neumann, Frank Neumann

Evolutionary multitasking is an emerging paradigm in optimisation that draws inspiration from cognitive multitasking in humans. It seeks to solve multiple optimisation tasks in parallel referring to a shared population of individuals. This approach uses underlying commonalities between tasks to accelerate the convergence, by leveraging the principles of knowledge transfer. The travelling thief problem (TTP) combines the characteristics of both the travelling salesman problem (TSP) and the 0-1 knapsack problem (KP), depicting the interdependency of multiple components that can be seen in real-world applications. In this study, we represent the TTP problem as a combination of multiple scenarios where each scenario combines a similar TSP component, yet a different KP component. We set up scenarios for the experiments using both fixed weights and weights generated uniformly at random. We follow an evolutionary multitasking optimisation approach to solve multiple scenarios in parallel. By experimenting with a variety of TTP instances, we compare the performance of basic and advanced multitasking approaches, against classical methods. The analysis shows that multitasking brings a competitive advantage over the classical methods when operating on small time budgets.

GA 2

Thursday, July 17, 12:00–13:30 Jábega

Energy and Performance Analysis of Parallel Heterogeneous Genetic Algorithms under Various CPU and GPU DVFS Governors: A Preliminary Study on Predictive Profiling
Amr Abdelhafez, Alexey Lastovetsky

Parallel heterogeneous computing has emerged as a promising approach for addressing computationally intensive problems. Energy efficiency is a critical concern in high-performance computing, particularly when leveraging hybrid architectures such as CPU-GPU systems. This study aims to provide valuable insight into optimizing the trade-off between energy efficiency, performance, and power governors over hybrid architectures. In this work, we evaluate a Parallel Heterogeneous Genetic Algorithm (HPIGA) by running it under five Dynamic Voltage and Frequency Scaling (DVFS) configurations, exploring different frequency configurations for both CPU and GPU. These configurations investigate various combinations of CPU and GPU operating modes, including "powersave" and "performance". Through these experiments, we analyze the energy consumption and performance characteristics of the parallel algorithm under fixed computational loads. The results reveal interesting insights into CPU-GPU specific DVFS configurations, where setting the CPU and GPUs to high/low frequencies can significantly reduce dynamic energy usage in certain configurations. These findings contribute to the development of sustainable computing frameworks by addressing the challenges inherent in frequency scaling and heterogeneous computing environments. This study provides a foundation for future research aimed at developing predictive models and advanced scheduling techniques to further optimize energy efficiency in hybrid CPU/GPU architectures.

Evo-SINDy: Universal Discovery of Partial Differential Equations Using Cooperative Evolutionary Computation
Yuxin Jiang, Jianyong Sun

The discovery of the mathematical form of partial differential equations (PDEs) from data has broad applications and significant implications in many fields. Existing data-driven methods such as the well-known SINDy method, however, struggle to identify arbitrary forms of PDEs with minimal prior knowledge. In this paper, we propose a data-driven method for PDE identification, named Evo-SINDy, which leverages a multi-population co-evolutionary algorithm to address the limitations of SINDy. This method is able to efficiently identify PDEs from a sufficiently large search space that best match data characteristics, ensuring minimal reliance on prior knowledge. Experimental results demonstrate that Evo-SINDy can identify more numbers of one-dimensional PDEs within a unified framework than the other known methods, and outperforms two recently-proposed methods that use open libraries in terms of computational efficiency.

Gradient-Free Sparse Adversarial Attack on Object Detection Models
Chi Cuong Le, Tri Phan, Ngoc Hoang Luong

The rapid increase of object detection's applications leads to a growing need for these models to be robust to adversarial examples. However, it has been shown that deep neural networks (DNNs) are vulnerable to adversarial examples. In this work, we explore the vulnerability of recent object detection models by generating sparse adversarial examples that differ from the original images by only a few pixels. Moreover, to be suitable for real-world scenarios, we consider the context in which we are ignorant of victim models and employ a gradient-free approach to generate imperceptible ad-

versarial examples. Notably, there are two challenges that we have to address simultaneously: reducing the number of perturbed pixels and limiting the number of queries needed to successfully find an adversarial example. Existing methods usually try to solve only one of those challenges, regardless of the poor quality of the other, and result in high computational resources or perceptible adversarial examples. Our study aims to use only a small number of queries to generate imperceptible perturbations that make object detectors yield wrong predictions. Our experiments are conducted with the convolutional neural network-based YOLO family and the vision transformer-based models (i.e., DINO and DETR) on the PASCAL-VOC dataset.

Dramatically Faster Partition Crossover for the Traveling Salesman Problem
Ozeas Quevedo de Carvalho, Darrell Whitley

The Partition Crossover is a deterministic crossover operator for the Traveling Salesman Problem (TSP). It decomposes the union graph of two TSP solutions, A and B, into connected components known as AB-cycles, from which the lower-cost edges are selected and recombined to produce offspring. The operator finds the best offspring within a search space of 2^k solutions in linear time, where k is the number of recombining components. We introduce Generalized Partition Crossover 3 (GPX3), a new implementation of Partition Crossover. GPX3 features a new algorithm to quickly find AB-cycles in the union graph. It also identifies additional recombining AB-cycles, expanding the reachable search space. We show that GPX3 runs in $O(n)$ time and is more efficient and effective than previous implementations of Partition Crossover for the TSP.

How Partition Crossover Exposes Parallel Lattices and the Fractal Structure of k-Bounded Functions
Darrell Whitley, Gabriela Ochoa, Francisco Chicano

A combination of recombination and local search can expose the existence of an exponential number of parallel lattices that span the search space for all classes of k-bounded pseudo-Boolean functions, including MAX-kSAT problems. These "parallel" lattices sometimes have identical evaluations shifted by a constant. We use Partition Crossover to aid in the discovery of lattices, which are sets of 2^q possible offspring from recombination events, organized into q-dimensional hypercubes, where q is the number of recombining components given two parents. Finally, we show that recursively embedded subspace lattices display a fractal structure, which can be captured using rewrite rules based on a Lindenmayer system that accurately model how local optima are distributed across different size lattices.

General Evolutionary Computation and Hybrids (GECH)

GECH 1 + Theory 2
Wednesday, July 16, 15:30–17:00 Mena

★ Augmented Decision Spaces for Stackelberg Security Games: Sparse evolution begets scalability
Adam Żychowski, Abhishek Gupta, Yew-Soon Ong, Jacek Mańdziuk

This paper introduces the Augmented Decision Space Optimization (ADSO) method for sparsity-driven optimization of mixed strategies in Stackelberg Security Games (SSGs). The proposed method enhances traditional strategy optimization by combining binary variables to represent the presence of pure strategies with real-valued variables to refine their selection probabilities. Specifically, instead of waiting for an evolutionary process to gradually discover sparse solutions, the binary variables in ADS allow the real-valued variables to be switched on or off, thereby directly enforcing sparsity. This dual codification scheme achieves targets such as sparsification and computational efficiency in large-scale games. We demonstrate that ADS outperforms existing heuristic methods, offering superior solution quality, scalability, and stability. Empirical results across three different benchmark games show that ADS generates compact strategies with minimal computational overhead, achieving performance close to the exact methods. Furthermore, state-of-the-art results are obtained for problems where exact methods fail to scale effectively. Our framework promises broad applicability beyond SSGs, encompassing a wide range of game-theoretic and combinatorial optimization problems.

Diversity-driven Cooperating Portfolio of Metaheuristic Algorithms
Adam Żychowski, Xin Yao, Jacek Mańdziuk

The paper introduces a novel hybrid island-based framework in which diverse metaheuristics cooperate to effectively explore the search space. A core component of the framework is a diversity-driven migration mechanism, enabling adaptive management of the information flow between islands. Three fundamental aspects of migration – what to migrate, when to migrate, and where to migrate – are thoroughly analyzed, leading to the development of strategies that foster synergy between heterogeneous algorithms. These strategies balance exploration and exploitation, ensuring effective global and local search. The framework was evaluated on a set of diverse optimization benchmarks, both discrete (Traveling Salesman Problem instances) and continuous (BBOB functions). Experimental results demonstrate that the proposed approach surpasses traditional algorithms and their island-based variants in convergence speed, solution quality, and resilience to stagnation. Adaptive mechanisms dynamically adjust migration strategies during the optimization process, further enhancing the framework's effectiveness. The proposed method represents an advancement in hybrid metaheuristic systems, offering scalability and flexibility that are essential for solving complex optimization tasks.

GECH 2
Wednesday, July 16, 17:30–19:00 Alcazaba

Unlearning Works Better Than You Think: Local Reinforcement-Based Selection of Auxiliary Objectives
Matthieu Lerasle, Abderrahim Bendahi, Adrien Fradin

We introduce Local Reinforcement-Based Selection of Auxiliary Objectives (LRSAO), a novel approach that selects auxiliary objectives using reinforcement learning (RL) to support the optimization process of an evolutionary algorithm (EA) as in EA+RL framework and furthermore incorporates the ability to unlearn previously used objectives. By modifying the reward mechanism to penalize moves that do no increase the fitness value and relying on the local auxiliary objectives, LRSAO dynamically adapts its selection strategy to optimize performance according to the landscape and unlearn previous objectives when necessary. We analyze and evaluate LRSAO on the black-box complexity version of the non-monotonic Jump function, with gap parameter ℓ, where each auxiliary objective is beneficial at specific stages of optimization. The Jump function is hard to optimize for evolutionary-based algorithms and the best-known complexity for reinforcement-based selection on Jump was $O(n^2/\log(n)\ell)$. Our approach improves over this result to achieve a complexity of $\Theta(n^2/\ell^2 + n\log(n))$ resulting in a significant improvement, which demonstrates the efficiency and adaptability of LRSAO, highlighting its potential to outperform traditional methods in complex optimization scenarios. Code is available at https://github.com/FAdrien/LRSAO.

Code Evolution Graphs: Understanding Large Language Model Driven Design of Algorithms
Niki van Stein, Anna Kononova, Lars Kotthoff, Thomas Bäck

Large Language Models (LLMs) have demonstrated great promise in generating code, especially when used inside an evolutionary computation framework to iteratively optimize the generated algorithms. However, in some cases they fail to generate competitive algorithms or the code optimization stalls, and we are left with no recourse because of a lack of understanding of the generation process and generated codes. We present a novel approach to mitigate this problem by enabling users to analyze the generated codes inside the evolutionary process and how they evolve over repeated prompting of the LLM. We show results for three benchmark problem classes and demonstrate novel insights. In particular, LLMs tend to generate more complex code with repeated prompting, but additional complexity can hurt algorithmic performance in some cases. Different LLMs have different coding "styles" and generated code tends to be dissimilar to other LLMs. These two findings suggest that using different LLMs inside the code evolution frameworks might produce higher performing code than using only one LLM.

Hybrid Selection Allows Steady-State Evolutionary Algorithms to Control the Selective Pressure in Multimodal Optimisation
Dogan Corus, Pietro S. Oliveto, Feiyang Zheng

Recent work has shown that Inverse Tournament Selection operators within steady-state evolutionary algorithms (EAs) allow to control the selective pressure much more accurately than in generational EAs. However, to achieve low selective pressures, large tournament sizes are required which come at the cost of prohibitive expected times for the population to escape from local optima. To this end, we propose a hybrid selection mechanism that leads to considerable speed-ups in the expected time to escape from local optima while permitting to keep the selective pressure arbitrarily low and the use of large population sizes. The mechanism simply switches between Inverse Elitist selection and Uniform selection when it detects that the population is stuck on local optima, and switches back when an improving solution is found. We prove its effectiveness for the TruncatedTwoMax and RidgeWithBranches benchmarks from the literature by providing super-linear speed-ups over the (μ+1) EA with any fixed selective pressure.

Key Insights into Estimating Nash Equilibria in Simultaneous Continuous Multiplayer Games Using Coevolutionary Algorithms
Rui Leite, Hernan Aguirre, Kiyoshi Tanaka

Game theory is a powerful tool for analyzing strategic interactions between rational agents and has been widely applied across fields such as economics, biology, and cybersecurity. In this paper, we propose a novel approach for estimating solutions to multiplayer games of simultaneous decision with continuous strategy sets, including those with infinitely many Nash Equilibria. Our method leverages the coevolution of multiple Evolutionary Algorithms (EAs): a single-objective EA models a single-objective player, while a Pareto dominance-based EA represents a multi-objective player. Each EA optimizes its player's strategies (decisions) through iterative gameplay. We analyze the key features that enable the proposed algorithm to estimate a Nash Equilibrium with minimal deviation from the analytical solution (which remains unknown to the algorithm) and to maintain stability near this solution. Experimental results show that the proposed algorithm converges to the nearest equilibrium with appropriate parameter tuning, including the secondary parent/survival selection criterion for the multi-objective EA, the fitness computation method, the mutation distribution index, and the mutation rate.

GECH 3

Thursday, July 17, 12:00–13:30 Alcazaba

Analysing the Effectiveness of Mutation Operators for One-Sided Bipartite Crossing Minimisation
Jakob Baumann, Ignaz Rutter, Dirk Sudholt

Graph Drawing aims to make graphs visually comprehensible while faithfully representing their structure. In layered drawings, each vertex is drawn on a horizontal line and edges are drawn as y-monotone curves. We consider a fundamental problem from this domain, the One-Sided Bipartite Crossing Minimisation (OBCM) problem. Given a bipartite graph with two layers and a fixed horizontal order of vertices on the first layer, the objective is to order the vertices on the second layer to minimise the number of edge crossings. We empirically analyse the performance of simple evolutionary algorithms (EAs) for OBCM and compare different mutation operators for the underlying permutation problem: exchanging two elements (exchange), swapping adjacent elements (swap) and jumping an element to a new position

(jump). Our analysis reveals that jump is the most effective operator, with EAs using jumps outperforming all classical algorithms in terms of solution quality within a reasonable number of generations. We also propose hybrid EA variants that reduce the required number of generations by up to a factor of 100. Additionally, we provide theoretical insights and prove a quadratic upper bound on the expected runtime for the most effective EA using jumps for a general class of instances.

Solving the Cubic Knapsack Problem using Quantum-Inspired Digital Annealer Technology

Thiago Alves de Queiroz, Manuel Iori, Alberto Locatelli, Matthieu Parizy

This study investigates the effectiveness of quantum methods in tackling the cubic knapsack problem (CKP). The CKP is not only NP-hard but also extremely difficult to solve in practice. Benchmark instances of small size (including some with only 60 items) remain unsolved to proven optimality. We solve the CKP using the latest Digital Annealer (DA) prototype, an extended Ising machine available through the Quantum-Inspired Integrated Optimization (QIIO) service on Fujitsu's Kozuchi platform. Specifically, we propose two formulations: a higher-order unconstrained binary optimization (HUBO) and a quadratic unconstrained binary optimization. The latter is derived by reformulating the HUBO model into an equivalent quadratic form. These models are solved using the QIIO solver and compared with three state-of-the-art algorithms, a greedy heuristic, and two mixed integer programs. Additionally, we introduce a postprocessing heuristic to ensure the feasibility of solutions generated by the DA solver, as within short time limits, it does not always produce feasible solutions. Computational experiments are conducted on instances with up to 200 items and varying densities of nonzero objective coefficients. The results indicate that the HUBO formulation is highly competitive with state-of-the-art algorithms, achieving the best new solutions for six large instances.

Quantum Circuit Construction and Optimization through Hybrid Evolutionary Algorithms

Leo Sünkel, Philipp Altmann, Michael Kölle, Gerhard Stenzel, Thomas Gabor, Claudia Linnhoff-Popien

We apply a hybrid evolutionary algorithm to minimize the depth of circuits in quantum computing. More specifically, we evaluate two different variants of the algorithm. In the first approach, we combine the evolutionary algorithm with an optimization subroutine to optimize the parameters of the rotation gates present in the quantum circuit. In the second, the algorithm solely relies on evolutionary operations (i.e., mutations and crossover). We approach the problem from two sides: (1) constructing circuits from the ground up by starting with random initializations and (2) initializing individuals with a target circuit in order to optimize it further according to the fitness function. We run experiments on random circuits with 4 and 6 qubits varying in circuit depth. Our results show that the proposed methods are able to significantly reduce the depth of circuits while still retaining a high fidelity to the target state.

Enhancing Quality-Diversity Optimization Through Domain-Specific Dissimilarity as Crowding Distance

Maciej Komosinski, Agnieszka Mensfelt

Quality-diversity algorithms aim to simultaneously optimize solution performance and maintain diversity within a population. In this paper, we explore the use of NSGA-II as a quality-diversity algorithm for the evolutionary design of 3D structures, modifying its crowding distance calculation to utilize dissimilarity measures. While NSGA-II is widely employed for multi-objective optimization, its use of fitness for calculating crowding distance may not be the most effective for tasks requiring solution diversity. We propose leveraging both genetic and phenotypic dissimilarity metrics to improve diversity management. To evaluate this approach, we compare the standard NSGA-II using fitness-based crowding distance and Diversity-Enhancing NSGA-II (DE-NSGA-II) using various combinations of dissimilarity-based metrics for crowding distance and diversity scores. Experiments are conducted using two distinct genetic representations on two optimization tasks: height of the center of gravity of passive structures and velocity of active structures. Results demonstrate the potential of dissimilarity-based crowding distance to enhance the diversity and overall quality of solutions in complex evolutionary design tasks.

Evaluating Mutation Techniques in Genetic-Algorithm-Based Quantum Circuit Synthesis

Michael Kölle, Tom Bintener, Maximilian Zorn, Gerhard Stenzel, Leo Sünkel, Thomas Gabor, Claudia Linnhoff-Popien

Quantum computing leverages the unique properties of qubits and quantum parallelism to solve problems intractable for classical systems, offering unparalleled computational potential. However, optimization of quantum circuits remains critical, especially for noisy intermediate-scale quantum (NISQ) devices with limited qubits and high error rates. Genetic algorithms (GAs) provide a promising approach for efficient quantum circuit synthesis by automating optimization tasks. This work examines the impact of various mutation strategies within a GA framework for quantum circuit synthesis. By analyzing how different mutations transform circuits, it identifies strategies that enhance efficiency and performance. Experiments utilized a fitness function emphasizing fidelity, while accounting for circuit depth and T-operations, to optimize circuits with four to six qubits. Our analysis revealed that, while the "swap, addition" strategy achieved the highest fidelity scores, it consistently increased circuit depth. In contrast, combining "swap, addition, delete" strategies offers a more balanced approach, delivering near-optimal results while also having the potential of reducing circuit depth.

Genetic Programming (GP)

GP 1

Wednesday, July 16, 12:00–13:30 Alborán

Multi-Objective Genetic Programming for Imbalanced Classification with Adaptive Thresholds and a New Fitness Function

Minghui Bai, Xiaoying Gao, Jiaxin Niu, Jianbin Ma

Genetic programming (GP) is widely used for classifier construction due to its flexible representation and feature construction characteristics. Traditional GP methods, however, often rely on a fixed threshold, typically 0, which fails to reflect the true distribution of the data in imbalanced datasets. To overcome this, we propose a multi-objective GP method that adaptively adjusts the threshold during evolution using Youden's Index. This adaptive threshold adjustment allows the classifiers to better fit the data distribution. Additionally, we introduce a class separation metric, dist_t, aimed at enhancing the clarity of the classification boundaries and improving the generalization ability of the evolved classifiers. We use the multi-objective GP, along with the optimal threshold of each classifier, to jointly optimize the accuracy of the minority and majority classes, as well as the class separation metric dist_t, selecting the best classifier from the Pareto front for unseen data. Experiments on 7 imbalanced datasets demonstrate that our method outperforms single-objective GP with fixed thresholds and four GP-based algorithms, showcasing superior performance and improved classification clarity. Furthermore, our proposed clarity metric dist_t improves classification performance, ensuring better generalization and enhanced decision boundaries.

How Neutrality Shapes Evolution: Simplicity Bias and Search

Ting Hu, Wolfgang Banzhaf, Gabriela Ochoa

Neutrality, characterized by pathways in the genotype space that do not alter the phenotype or fitness, enables a broad exploration of evolutionary search. Simplicity bias describes the tendency of evolutionary systems to favor low-complexity solutions. This study investigates how neutrality contributes to simplicity bias in evolutionary systems using a Boolean Linear Genetic Programming framework. We introduce two fitness functions that utilize symmetry in solutions to promote neutrality, to analyze their effects on neutral network connectivity and search dynamics. Our results demonstrate that simpler phenotypes, characterized by lower Kolmogorov complexity, exhibit greater redundancy and connectivity, making them more accessible during neutral exploration. In addition, the proposed fitness functions significantly improve search success rates, especially for complex target phenotypes, by expanding neutral pathways. These findings shed light on the role of neutrality in shaping simplicity bias and provide practical insights to improve the effectiveness of evolutionary algorithms.

A comparison of tournament and lexicase selection paradigms in regression problems: error-based fitness versus correlation fitness

Illya Bakurov, Aidan Murphy, Charles Ofria, Wolfgang Banzhaf

Lexicase parent selection considers training cases separately, postulating that aggregated fitness reduces the information about the behavior of individuals. Originally lexicase was proposed in the context of program synthesis, characterized by uncompromising problems that require qualitatively different actions for different inputs, but it has since been extended to regression problems. To facilitate valley-crossing a relaxation parameter epsilon was added broadening the pass condition at a given training case. Although epsilon-lexicase has demonstrated superior effectiveness, it was compared against selection methods that aggregated squared (or absolute) errors. Recent contributions, however, demonstrate that correlation fitness functions can lead to significant performance gains over the root mean square error (RMSE) in tournament-guided evolution for symbolic regression. Here we compare epsilon-lexicase (with and without down-sampling) against tournament selection using both error- and correlation-based fitness to guide Genetic Programming (GP). We also assess batch epsilon-lexicase selection as an intermediate condition. Finally, we explore different selection pressures to assess the exploration-exploitation trade-off. We analyze the experimental results using different metrics, including code redundancy, sharpness-awareness and selection impact. Our results demonstrate that tournament selection with correlation fitness function significantly outperforms epsilon-lexicase on regression problems and that its batch variant also benefits from correlation-based aggregation.

Desire-Driven Selection: An Epigenetic Experiment in Genetic Programming

José Maria Simões, Penousal Machado, Nuno Lourenço

In nature, survival poses small benefits if one fails to reproduce and spread one's genes. This is particularly relevant in sexually reproductive species, which exerts another pressure dimension on the individual beyond natural selection: Sexual Selection. More often than not, the quality of the chosen mate is a crucial step in reproduction, making all the investment in mate choice worthwhile. This partly explains why partners often prefer certain secondary traits, such as ornaments, particularly if such traits signal good fitness. We hypothesize that the dynamics between mating preferences and fitness-dependent ornaments can act as a filter to find a mate within a population, exploiting good solutions while maintaining high diversity. In this work, we propose a new selection method for Genetic Programming based on these premises, validating our approach on regression problems. Results show that high levels of diversity are maintained when compared against a standard tournament selection with performance gains, reducing the overall error by 16.3% and 13.8% in training and testing respectively, and performing up to par with state-of-the-art Lexicase selection while also providing the best overall solution.

GP 2

Wednesday, July 16, 15:30–17:00 Alborán

Evolutionary Synthesis of Probabilistic Programs

Romina Doz, Francesca Randone, Eric Medvet, Luca Bortolussi

Modeling the relationships between variables through probability distributions lies at the core of probabilistic models, enabling reasoning under uncertainty. Probabilistic programming offers an effective way to represent these models by blending the simplicity of standard programming constructs with the power of automatic inference algorithms. The languages for expressing probabilistic programs are augmented with primitives representing various probability distributions to effectively capture the stochastic behavior inherent in the data. However, writing a probabilistic program is hard, because it typically requires prior knowledge about the data generation mechanism. In this work, we propose a framework for automatically synthesizing probabilistic programs directly from data, thereby learning the underlying relationships between variables and the data-generating process. We adopt an evolutionary approach, specifically grammatical evolution (GE), to extensively explore the space of probabilistic programs, aiming to discover the most likely program that describes the observed data. We experimentally evaluate our method across several benchmarks, incorporating varying levels of prior knowledge through a sketching strategy embedded into the grammar fed to GE, to demonstrate the potential of this evolutionary framework. This evaluation highlights the flexibility and effectiveness of GE in synthesizing probabilistic programs under different informational constraints.

Reaching Meaningful Diversity with Speciation-Novelty in Genetic Improvement for Software

Zsolt Nemeth, Penn Faulkner Rainford, Barry Porter

Genetic Improvement (GI) for software has been used in automated bug fixing and in automated performance improvement. Automated improvement has been targeted at multi-context problems, where one implementation variant might be best at one context, and another might be best at a different context. However, this application of GI generally requires a fresh improvement process for each new context, which can be computationally expensive. We propose a novel application of GI for multi-context problems, in which we aim for a diverse set of individuals in an initial training run for one context. We use a phenotypic speciation metric as a diversity indicator, allowing us to plot a diversity geometry through program search space. When a different context is introduced, as a new optimisation target for GI, we are able to select from one of these diverse individuals as a close starting point for fine-tuning. With a hash table implementation as an example to genetically improve, we show that we can exercise a high degree of control over population diversity, and that this diversity can be a useful starting point for finding individuals in successive alternative contexts.

Coordinate System Extraction as the Search Driver in Test-Based Genetic Programming

Dmytro Vitel, Kok Cheng Tan, Alessio Gaspar, Paul Wiegand

In test-based genetic programming (GP), the evolution is driven by program-test interactions that are naturally multidimensional. Previous works applied dimension reductions to these interaction matrices to form "derived objectives" that guide evolutionary multi-objective optimization (EMO). In this work, we consider tests as separate optimization targets as an alternative to reducing the interaction dimensionality. We compare methods based on different Pareto-front sampling strategies and propose a coevolutionary approach driven by a selection method based on extracting the underlying game structure from the interactions. This structure is a multidimensional coordinate system that maintains domination relations between programs along the axes and facilitates better sampling for breeding. Experimental results in discrete value domains demonstrate that the proposed methods have, in many cases, better performance on benchmarks than methods based on fitness aggregation, including dimensionality reduction.

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Analysis of Memory-Runtime Trade-offs in Caching Strategies for Genetic Programming Symbolic Regression

Jiaming Shi, Kei Sen Fong, Mehul Motani

Genetic Programming Symbolic Regression (GPSR) generates mathematical expressions to model input-output relationships using an evolutionary process. A significant challenge in GPSR lies in the repeated evaluation of entire expressions or their sub-expression, which inflates computational runtime. To address this inefficiency, caching mechanisms have been employed to reduce redundant computations. However, prior studies predominantly employ a single caching strategy, offering limited insights into their comparative performance or memory-runtime trade-offs. In this paper, we present a comprehensive analysis of caching mechanisms for GPSR on synthetic and real-world datasets. We

also include an empirical study of key-value usage frequencies under an infinitely large cache, offering insights into optimal cache sizing. Furthermore, we provide actionable guidelines for configuring caching strategies based on computational and memory constraints. Our findings indicate that complex caching mechanisms necessitate a minimum cache size to achieve computational time reductions. Conversely, lightweight caching strategies, such as Least Recently Used (LRU) and, notably, First-In-First-Out (FIFO), can significantly decrease computation time for fitness evaluations, which are a substantial component of the overall runtime.

GP 3 + Impact

Thursday, July 17, 12:00–13:30 Minotauro

★ An Online Genetic Programming Approach to Dynamic Production Scheduling

Binh Tran, Su Nguyen

Scheduling is an important function in dynamic and complex production systems. Effective scheduling strategies help production systems utilise resources efficiently and improve delivery performance. Due to the production system's complexity and dynamic changes, designing such scheduling strategies is challenging. Recently, advanced machine learning and optimisation methods such as genetic programming (GP) have shown promise in designing sophisticated scheduling strategies. These methods' success relies on accurate data-driven simulation models for evaluating automatically-generated scheduling strategies. However, building a simulation model that accurately predicts complex production system behaviours requires a lot of historical operational data, which may not always be available, especially for new production systems or those adaptive to the market. To overcome this limitation, this study develops the first online GP method called OGP for dynamic production scheduling problems that allows GP to learn and optimise scheduling decisions on the fly without an exact model for fitness evaluations. The experiments with dynamic flexible job shops show that OGP outperforms existing scheduling strategies in the literature when both scheduling and routing decisions are considered. When used as an automated heuristic design method, OGP can generate competitive rules compared to the state-of-the-art GP methods in terms of test performance and rule sizes.

★ Quality Diversity Genetic Programming for Learning Scheduling Heuristics

Meng Xu, Frank Neumann, Aneta Neumann, Yew-Soon Ong

Real-world optimization often demands diverse, high-quality solutions. Quality-Diversity (QD) optimization is a multifaceted approach in evolutionary algorithms that aims to generate a set of solutions that are both high-performing and diverse. QD algorithms have been successfully applied across various domains, providing robust solutions by exploring diverse behavioral niches. However, their application has primarily focused on static problems, with limited exploration in the context of dynamic combinatorial optimization problems. Furthermore, the theoretical understanding of QD algorithms remains underdeveloped, particularly when applied to learning heuristics instead of directly learning solutions in complex and dynamic combinatorial optimization domains, which introduces additional challenges. This paper introduces a novel QD framework for dynamic scheduling problems. We propose a map-building strategy that visualizes the solution space by linking heuristic genotypes to their behaviors, enabling their representation on a QD map. This map facilitates the discovery and maintenance of diverse scheduling heuristics. Additionally, we conduct experiments on both fixed and dynamically changing training instances to demonstrate how the map evolves and how the distribution of solutions unfolds over time. We also discuss potential future research directions that could enhance the learning process and broaden the applicability of QD algorithms to dynamic combinatorial optimization challenges.

★ Transformer Semantic Genetic Programming for Symbolic Regression

Philipp Anthes, Dominik Sobania, Franz Rothlauf

In standard genetic programming (stdGP), solutions are varied by modifying their syntax, with uncertain effects on their semantics. Geometric-semantic genetic programming (GSGP), a popular variant of GP, effectively searches the semantic solution space using variation operations based on linear combinations, although it results in significantly larger solutions. This paper presents Transformer Semantic Genetic Programming (TSGP), a novel and flexible semantic approach that uses a generative transformer model as search operator. The transformer is trained on synthetic test problems and learns semantic similarities between solutions. Once the model is trained, it can be used to create offspring solutions with high semantic similarity also for unseen and unknown problems. Experiments on several symbolic regression problems show that TSGP generates solutions with comparable or even significantly better prediction quality than stdGP, SLIM_GSGP, DSR, and DAE-GP. Like SLIM_GSGP, TSGP is able to create new solutions that are semantically similar without creating solutions of large size. An analysis of the search dynamic reveals that the solutions generated by TSGP are semantically more similar than the solutions generated by the benchmark approaches allowing a better exploration of the semantic solution space.

MAPLE: Multi-Action Programs through Linear Evolution for Continuous Multi-Action Reinforcement Learning

Quentin Vacher, Stephen Kelly, Ali Naqvi, Nicolas Beuve, Tanya Djavaherpour, Mickaël Dardaillon, Karol Desnos

Over the last decades, the need to solve complex tasks using machine learning techniques has grown significantly. Deep learning algorithms achieve state-of-the-art performance in most tasks, but at the cost of high computational complexity and limited interpretability. In domains such as Reinforcement Learning (RL), understanding the agent behavior ensures reliability and safety. In this work, we explore Genetic Programming (GP) as a promising solution for RL tasks, providing simpler and more interpretable solutions. While GP achieves competitive results in low-complexity environments, it struggles in environments with

high-dimensional action spaces. To address this, we propose Multi-Action Programs through Linear Evolution (MAPLE), a GP algorithm in which the agent is a team of multiple Linear Genetic Programs (LGPs), each responsible for an action. MAPLE is evaluated on the MuJoCo suite and outperforms state-of-the-art GP algorithms and a small deep RL model. It achieves comparable performance to a larger deep RL network in low-dimensional environments while maintaining significantly lower complexity. By decomposing the action decision into different programs, it is possible to understand which parts of the states are needed for each action. This demonstrates the potential of MAPLE for interpretable and efficient solutions in RL.

GP 4

Friday, July 18, 10:00–11:30 Minotauro

Improving Genetic Programming for Symbolic Regression with Equality Graphs

Fabrício Olivetti de França, Gabriel Kronberger

The search for symbolic regression models with genetic programming (GP) has a tendency of revisiting expressions in their original or equivalent forms. Repeatedly evaluating equivalent expressions is inefficient, as it does not immediately lead to better solutions. However, evolutionary algorithms require diversity and should allow the accumulation of inactive building blocks that can play an important role at a later point. The equality graph is a data structure capable of compactly storing expressions and their equivalent forms allowing an efficient verification of whether an expression has been visited in any of their stored equivalent forms. We exploit the e-graph to adapt the subtree operators to reduce the chances of revisiting expressions. Our adaptation, called eggp, stores every visited expression in the e-graph, allowing us to filter out from the available selection of subtrees all the combinations that would create already visited expressions. Results show that, for small expressions, this approach improves the performance of a simple GP algorithm to compete with PySR and Operon without increasing computational cost. As a highlight, eggp was capable of reliably delivering short and at the same time accurate models for a selected set of benchmarks from SRBench and a set of real-world datasets.

Uniform Projection of Program Space Geometry for Genetic Improvement of Software

Benjamin Craine, Barry Porter

Current Genetic Improvement (GI) for software systems use pre- existing program representations, such as abstract syntax trees and bytecode, to apply genetic operations to. These representations, however, were designed for the purpose of translating human readable source code to machine code. When used to underpin GI, these representations have drawbacks, such as the risk of breaking a program when deploying mutations. We present a novel matrix-based program representation which is specifically designed for the purpose of GI. Our representation (i) makes it impossible for mutations or crossover to yield an invalid program, without the need for any syntactic or semantic checks, while still making every valid program reachable by search, and (ii) supports the simple expression of rich, layered probability distributions atop the program matrix to guide a GI search process. We build an end-to-end GI system using this new representation and demonstrate how we can layer a range a probability distribution on top of the representation to gain different effects. We also explore the future research possibilities that this approach to program representation presents.

Slim_gsgp: A Python Library for Non-Bloating GSGP

Liah Rosenfeld, Davide Farinati, Diogo Rasteiro, Gloria Pietropolli, Karina Brotto Rebuli, Sara Silva, Leonardo Vanneschi

This paper presents slim_gsgp: an open-source Python library that provides the first ever framework for the Semantic Learning algorithm based on Inflate and deflate Mutation (SLIM-GSGP). Proposed in 2024, SLIM-GSGP is a promising non-bloating variant of Geometric Semantic Genetic Programming (GSGP). slim_gsgp includes all existing SLIM-GSGP variants, as well as traditional GSGP and standard Genetic Programming (GP), facilitating comparative analysis and benchmarking. Additionally, slim_gsgp's parallel computation and semi-modular architecture renders it not only fast but also user-friendly and easily extensible, thereby serving as a valuable resource for researchers aiming to advance this emerging and promising area of research. The source code and documentation can be accessed at https://github.com/DALabNOVA/slim.

Program Synthesis with LLM-Predicted Minimal Specialized Grammars

David Vella Zarb, Geoff Parks, Timoleon Kipouros

Grammatical evolution (GE) has proven effective at program synthesis. However, its performance is hindered by the exponential growth of search spaces as grammar complexity increases. Methods utilizing recent advances in large language models and genetic programming have outperformed GE on some benchmarks, affirming the need for scalable approaches. This paper addresses the scalability challenge by proposing an in-context learning method to automatically generate minimal specialized grammars (MSGs), which are problem-specific subsets of a larger grammar designed to reduce search space complexity. To the best of our knowledge, this represents the first use of in-context learning for program synthesis within GE. Our approach conditions a language model on examples of Backus-Naur Form grammars to generate MSGs tailored to individual synthesis tasks. We evaluate this framework on a benchmark suite widely used in GE research. Experimental results show our method almost always outperforms the baseline GE approach, improving both the number and frequency of problems solved while reducing computational cost as measured by fitness evaluations.

Learning for Evolutionary Computation (L4EC)

L4EC 1

Wednesday, July 16, 12:00–13:30 Jábega

Residual Learning Inspired Crossover Operator and Strategy Enhancements for Evolutionary Multitasking

Ruilin Wang, Xiang Feng, Huiqun Yu, Edmund M-K Lai

In evolutionary multitasking, strategies such as crossover operators and skill factor assignment are critical for effective knowledge transfer. Existing improvements to crossover operators primarily focus on low-dimensional variable combinations, such as arithmetic crossover or partially mapped crossover, which are insufficient for modeling complex high-dimensional interactions.Moreover, static or semi-dynamic crossover strategies fail to adapt to the dynamic dependencies among tasks. In addition, current Multifactorial Evolutionary Algorithm frameworks often rely on fixed skill factor assignment strategies, lacking flexibility. To address these limitations, this paper proposes the Multifactorial Evolutionary Algorithm-Residual Learning (MFEA-RL) method based on residual learning. The method employs a Very Deep Super-Resolution (VDSR) model to generate high-dimensional residual representations of individuals, enhancing the modeling of complex relationships within dimensions. A ResNet-based mechanism dynamically assigns skill factors to improve task adaptability, while a random mapping mechanism efficiently performs crossover operations and mitigates the risk of negative transfer. Theoretical analysis and experimental results show that MFEA-RL outperforms state-of-the-art multitasking algorithms. It excels in both convergence and adaptability on standard evolutionary multitasking benchmarks, including CEC2017-MTSO and WCCI2020-MTSO. Additionally, its effectiveness is validated through a real-world application scenario.

Learning Graph Configuration Spaces to Support Road Network Design Optimisation

Michael Mittermaier, Takfarinas Saber, Goetz Botterweck

Genetic algorithms (GA) allow us to optimise graphs according to multiple objectives while considering many different constraints. These population-based algorithms assess the fitness of a high number of genomes. In the case of optimising road networks, a high number of fitness assessments leads to high computational costs of traffic simulations. In this work, we explore the application of learning graph configuration spaces to make efficient use of these traffic simulations by using learning model predictions for the majority of fitness assessments. In a controlled experiment, we compare the quality of GA optimisations with and without learning model predictions on the same simulation budget. Our results indicate that although we lose accuracy in the fitness assessments with predictions, the GA reliably finds road networks with better traffic flow and lower overall road length while using the same number of traffic simulations. We show that learning models can support GAs to make efficient use of the simulation budget and thus improve the optimisation. Future work is necessary to confirm these results for larger road networks.

Automatic Design of Specialized Variation Operators for the Multi-Objective Quadratic Assignment Problem

Adrián Isaí Morales-Paredes, Julio Juárez, Jesús Guillermo Falcón-Cardona, Hugo Terashima-Marín, Carlos A. Coello Coello

The development of specialized, domain-specific operators has significantly enhanced the performance of evolutionary algorithms for solving optimization problems. However, creating such operators often requires substantial effort from human experts, making the process slow, resource-intensive, and heavily reliant on domain knowledge. To overcome these limitations, generation hyper-heuristics provide a framework for automating the design of variation operators by evolving combinations of heuristic components without direct expert input. In this work, we propose a generation hyper-heuristic method based on grammatical evolution to automatically design variation operators (crossover and mutation) tailored to the multi-objective quadratic assignment problem (mQAP)—a challenging combinatorial optimization problem with many real-world applications. Using the proposed method, variation operators were generated considering six mQAP instances with two and three objectives, leveraging MOEA/D as a multi-objective optimizer. For validation, the generated operators were evaluated on unseen instances. Our experimental results indicate that the evolved operators enhance the performance of MOEA/D compared to standard crossover operators. Furthermore, the top-performing operator in training did not always generalize best to larger instances, while some lower-ranked operators showed better adaptability. These results highlight the potential of automated operator design in effectively tackling complex optimization problems like the mQAP.

Greedy Restart Schedules: A Baseline for Dynamic Algorithm Selection on Numerical Black-box Optimization Problems

Lennart Schäpermeier

In many optimization domains, there are multiple different solvers that contribute to the overall state-of-the-art, each performing better on some, and worse on other types of problem instances. Meta-algorithmic approaches, such as instance-based algorithm selection, configuration and scheduling, aim to close this gap by extracting the most performance possible from a set of (configurable) optimizers. In this context, the best performing individual algorithms are often hand-crafted hybrid heuristics which perform many restarts of fast local optimization approaches. However, data-driven techniques to create optimized restart schedules have not yet been extensively studied. Here, we present a simple scheduling approach that iteratively selects the algorithm performing best on the distribution of unsolved training problems at time of selection, resulting in a problem-independent solver schedule. We demonstrate our approach

using well-known optimizers from numerical black-box optimization on the BBOB testbed, bridging much of the gap between single and virtual best solver from the original portfolio across various evaluation protocols. Our greedy restart schedule presents a powerful baseline for more complex dynamic algorithm selection models.

L4EC 2

Wednesday, July 16, 15:30–17:00 Jábega

Accurate Peak Detection in Multimodal Optimization via Approximated Landscape Learning

Zeyuan Ma, Hongqiao Lian, Wenjie Qiu, Yue-Jiao Gong

Detecting potential optimal peak areas and locating the accurate peaks in these areas are two major challenges in Multimodal Optimization problems (MMOPs). To address them, much efforts have been spent on developing novel searching operators, niching strategies and multi-objective problem transformation pipelines. Though promising, existing approaches more or less overlook the potential usage of landscape knowledge. In this paper, we propose a novel optimization framework tailored for MMOPs, termed as APDMMO, which facilitates peak detection via fully leveraging the landscape knowledge and hence capable of providing strong optimization performance on MMOPs. Specifically, we first design a novel surrogate landscape model which ensembles a group of non-linear activation units to improve the regression accuracy on diverse MMOPs. Then we propose a free-of-trial peak detection method which efficiently locates potential peak areas through back-propagation on the learned surrogate landscape model. Based on the detected peak areas, we employ SEP-CMAES for local search within these areas in parallel to further improve the accuracy of the found optima. Extensive benchmarking results demonstrate that APDMMO outperforms several up-to-date baselines. Further ablation studies verify the effectiveness of the proposed novel designs. The source-code is available at https://github.com/GMC-DRL/APDMMO.

Instance Space Analysis for the Capacitated Vehicle Routing Problem with Mixture Discriminant Analysis

Danielle Notice, Hamed Soleimani, Nicos G. Pavlidis, Ahmed Kheiri, Mario Andrés Muñoz

In this paper, we attempt a deeper understanding of the relative performance of two state-of-the-art metaheuristic solvers for the capacitated vehicle routing problem (CVRP). To this end, we employ a novel CVRP instance generator to expand the set of CVRP instances used to assess heuristics. This generator modifies existing problem instances using the outliers of node clusters to produce relevant new CVRP instances. We consider a large number of features to characterise each problem instance, and propose to use mixture discriminant analysis (MDA) to obtain both a low dimensional representation of the instance space and a classifier of algorithm performance. MDA has not been previously used in instance space analysis, and as a supervised dimension reduction method has the advantage that the tasks of dimension reduction and classification are handled in a unified framework (rather than two separate steps). The resulting predictive models perform as well as more complex classifiers that involve more tuning parameters and are computationally more expensive (like support vector machines). Our analysis highlights that the performance comparison between the two CVRP metaheuristics is nuanced and the best algorithm depends on the time budget, as well as certain key characteristics of the problem instance.

Learning Adaptive Neighborhood Search with Dual Operator Selection for Capacitated Vehicle Routing Problem

Xiang-Ling Chen, Yi Mei, Mengjie Zhang

The Capacitated Vehicle Routing Problem (CVRP) is a classic optimization problem with widespread applications in real-world scenarios. Existing research has developed numerous neighborhood operators capable of generating high-quality solutions. However, most neighborhood search algorithms either apply all operators in a predefined/random sequence or adaptively adjust only improvement operators, neglecting the learning of perturbation operators. This limitation often results in suboptimal performance. To address this issue, this paper proposes Learning Adaptive Neighborhood Search with Dual operator Selection (LANDS), an algorithm that integrates two RL-based controllers to adaptively select both improvement and perturbation operators simultaneously. Within this framework, the two controllers act as high-level guides, collaboratively directing the optimization process by selecting appropriate operators. Additionally, to reduce resource waste, a filtering mechanism is introduced to exclude operators deemed ineffective within the same improvement iteration, enhancing the algorithm's efficiency. The effectiveness of the proposed LANDS method is verified by a series of experiments.

Interpretable Decision Trees to Predict Solution Fitness

GianCarlo Antonino Pasquale Ignazio Catalano, Alexander Brownlee, David Cairns, Russell Ainslie, John McCall

Metaheuristic algorithms are powerful tools for tackling complex optimization problems, but their black-box nature often hinders user trust and understanding. This paper presents a novel methodology for enhancing the explainability of metaheuristics by employing decision trees with splitting criteria based on Partial Solutions. These represent beneficial sub-structures of solutions and provide insights into the problem landscape and solution characteristics. By constructing decision trees that consider the presence or absence of specific patterns in solutions, we produce a transparent model capable of predicting solution fitness. The proposed methodology is evaluated on a diverse set of benchmark problems and metaheuristic algorithms, demonstrating its effectiveness and flexibility as a post-hoc explainability tool. Our results show that our decision trees can match and usually surpass traditional methods in predicting the fitness of candidate solutions for the tested benchmark problems, with one of our methods demonstrating an improvement between 3.5% and 8% in R^2 predictive performance for shallower trees trained on a Genetic Algorithm's data. These trees are able to maintain competitive predictive performance while using more interpretable splitting criteria.

L4EC 3

Wednesday, July 16, 17:30–19:00 Jábega

Reinforcement Learning-Based Self-Adaptive Differential Evolution through Automated Landscape Feature Learning

Hongshu Guo, Sijie Ma, Zechuan Huang, Yuzhi Hu, Zeyuan Ma, Xinglin Zhang, Yue-Jiao Gong

Recently, Meta-Black-Box-Optimization (MetaBBO) methods significantly enhance the performance of traditional black-box optimizers through meta-learning flexible and generalizable meta-level policies that excel in dynamic algorithm configuration (DAC) tasks within the low-level optimization, reducing the expertise required to adapt optimizers for novel optimization tasks. Though promising, existing MetaBBO methods heavily rely on human-crafted feature extraction approach to secure learning effectiveness. To address this issue, this paper introduces a novel MetaBBO method that supports automated feature learning during the meta-learning process, termed as RLDE-AFL, which integrates a learnable feature extraction module into a reinforcement learning-based DE method to learn both the feature encoding and meta-level policy. Specifically, we design an attention-based neural network with mantissa-exponent based embedding to transform the solution populations and corresponding objective values during the low-level optimization into expressive landscape features. We further incorporate a comprehensive algorithm configuration space including diverse DE operators into a reinforcement learning-aided DAC paradigm to unleash the behavior diversity and performance of the proposed RLDE-AFL. Extensive benchmark results show that co-training the proposed feature learning module and DAC policy contributes to the superior optimization performance of RLDE-AFL to several advanced DE methods and recent MetaBBO baselines over both synthetic and realistic BBO scenarios.

Surrogate Learning in Meta-Black-Box Optimization: A Preliminary Study

Zeyuan Ma, Zhiyang Huang, Jiacheng Chen, Zhiguang Cao, Yue-Jiao Gong

Recent Meta-Black-Box Optimization (MetaBBO) approaches have shown possibility of enhancing the optimization performance through learning meta-level policies to dynamically configure low-level optimizers. However, existing MetaBBO approaches potentially consume massive function evaluations to train their meta-level policies. Inspired by the recent trend of using surrogate models for cost-friendly evaluation of expensive optimization problems, in this paper, we propose a novel MetaBBO framework which combines surrogate learning process and reinforcement learning-aided Differential Evolution algorithm, namely Surr-RLDE, to address the intensive function evaluation in MetaBBO. Surr-RLDE comprises two learning stages: surrogate learning and policy learning. In surrogate learning, we train a Kolmogorov-Arnold Networks (KAN) with a novel relative-order-aware loss to accurately approximate the objective functions of the problem instances used for subsequent policy learning. In policy learning, we employ reinforcement learning (RL) to dynamically configure the mutation operator in DE. The learned surrogate model is integrated into the training of the RL-based policy to substitute for the original objective function, which effectively reduces consumed evaluations during policy learning. Extensive benchmark results demonstrate that Surr-RLDE not only shows competitive performance to recent baselines, but also shows compelling generalization for higher-dimensional problems. Further ablation studies underscore the effectiveness of each technical components in Surr-RLDE.

L4EC 4

Thursday, July 17, 15:30–17:00 Mena

★ Deep reinforcement learning for instance-specific algorithm configuration

Elias Schede, Moritz Vinzent Seiler, Kevin Tierney, Heike Trautmann

Optimization algorithms contain parameters that greatly influence their behavior. Finding the right settings for parameters through automated algorithm configuration has become a critical component of designing competitive algorithms. While traditional offline configurators tackle this problem by finding one configuration that works well for a set of instances, instance-specific algorithm configuration utilizes features of the instances to provide configurations that are tailored to each instance to maximize performance. We provide the first instance-specific algorithm configurator based on deep reinforcement learning that can be used in general algorithm configuration settings. Our method is able to handle large, mixed discrete and continuous search spaces and only requires a small number of instances for training. We can show that our configurator provides improvements over the state-of-the-art instance-specific configurators ISAC and Hydra on a wide range of problem domains.

★ The Pitfalls of Benchmarking in Algorithm Selection: What We Are Getting Wrong

Gašper Petelin, Gjorgjina Cenikj

Algorithm selection, aiming to identify the best algorithm for a given problem, plays a pivotal role in continuous black-box optimization. A common approach involves representing optimization functions using a set of features, which are then used to train a machine learning meta-model for selecting suitable algorithms. Various approaches have demonstrated the effectiveness of these algorithm selection meta-models. However, not all evaluation approaches are equally valid for assessing the performance of meta-models. We highlight methodological issues that frequently occur in the community and should be addressed when evaluating algorithm selection approaches. First, we identify flaws with the "leave-instance-out" evaluation technique. We show that non-informative features and meta-models can achieve high accuracy, which should not be the case with a well-designed evaluation framework. Second, we demonstrate that measuring the performance of optimization algorithms with metrics sensitive to the scale of the objective function requires careful consideration of how this impacts the construction of the meta-model, its predictions, and the model's error. Such metrics can falsely present overly optimistic performance assessments of the meta-models. This paper emphasizes the impor-

tance of careful evaluation, as loosely defined methodologies can mislead researchers, divert efforts, and introduce noise into the field.

★ On the Importance of Reward Design in Reinforcement Learning-based Dynamic Algorithm Configuration: A Case Study on OneMax with (1+(λ,λ))-GA

Tai Nguyen, Phong Le, André Biedenkapp, Carola Doerr, Nguyen Dang

Dynamic Algorithm Configuration (DAC) has garnered significant attention in recent years, particularly in the prevalence of machine learning and deep learning algorithms. Numerous studies have leveraged the robustness of decision-making in Reinforcement Learning (RL) to address the optimization challenges associated with algorithm configuration. However, making an RL agent work properly is a non-trivial task, especially in reward design, which necessitates a substantial amount of handcrafted knowledge based on domain expertise. In this work, we study the importance of reward design in the context of DAC via a case study on controlling the population size of the $(1 + (\lambda, \lambda))$-GA optimizing OneMax. We observed that a poorly designed reward can hinder the RL agent's ability to learn an optimal policy because of a lack of exploration, leading to both scalability and learning divergence issues. To address those challenges, we propose the application of a reward shaping mechanism to facilitate enhanced exploration of the environment by the RL agent. Our work not only demonstrates the ability of RL in dynamically configuring the $(1 + (\lambda, \lambda))$-GA, but also confirms the advantages of reward shaping in the scalability of RL agents across various sizes of OneMax problems.

Neuroevolution (NE)

CS 1 + NE 1

Thursday, July 17, 12:00–13:30 Mena

★ Competition and Attraction Improve Model Fusion

João Abrantes, Robert Tjarko Lange, Yujin Tang

Model merging is a powerful technique for integrating the specialized knowledge of multiple machine learning models into a single model. However, existing methods require manually partitioning model parameters into fixed groups for merging, which restricts the exploration of potential combinations and limits performance. To overcome these limitations, we propose Model Merging of Natural Niches (M2N2), an evolutionary algorithm with three key features: (1) dynamic adjustment of merging boundaries to progressively explore a broader range of parameter combinations; (2) a diversity preservation mechanism inspired by the competition for resources in nature, to maintain a population of diverse, high-performing models that are particularly well-suited for merging; and (3) a heuristic-based *attraction* metric to identify the most promising pairs of models for fusion. Our experimental results demonstrate, for the first time, that model merging can be used to evolve models entirely from *scratch*. Specifically, we apply M2N2 to evolve MNIST classifiers from scratch and achieve performance comparable to CMA-ES, while being computationally more efficient. Furthermore, M2N2 scales to merge specialized language and image generation models, achieving state-of-the-art performance. Notably, it preserves crucial model capabilities beyond those explicitly optimized by the fitness function, highlighting its robustness and versatility. Our code is available at https://github.com/AnonScientist/natural_niches.

★ Evolving Comprehensive Proxies for Zero-Shot Neural Architecture Search

Junhao Huang, Bing Xue, Yanan Sun, Mengjie Zhang

Neural architecture search (NAS) has emerged as a promising technology for automatically designing deep neural network (DNN) architectures. However, its development is significantly constrained by the prohibitively high computational cost of architecture evaluations. Recently, zero-shot NAS has addressed this challenge by employing zero-cost proxies to evaluate candidate architectures without expensive gradient training, effectively mitigating the time-intensive nature of NAS. However, a major limitation is that most existing zero-cost proxies focus narrowly on a single aspect of DNNs, resulting in biased evaluations with generally weak correlations to the network's performance. In this work, we address this issue by assembling four distinct zero-cost proxies in a nonlinear fashion to provide a comprehensive evaluation of DNNs across multiple dimensions, including expressivity, convergence, generalization, and parameter saliency. Furthermore, we develop an adaptive particle swarm optimization-based approach to effectively evolve the coefficients of each base proxy in the ensemble for task-specific optimization. Extensive experimental results on various NAS benchmarks and open-domain search spaces demonstrate the effectiveness of the proposed method. Our findings show that the complementarity of zero-cost proxies greatly improves the reliability of performance evaluation, thereby enabling zero-shot NAS to identify more promising network architectures.

★ Visualizing the Dynamics of Neuroevolution with Genetic Distance Projections

Evan Hayden Patterson, Joshua Karns, Zimeng Lyu, Travis Desell

Evolutionary algorithms have shown substantial progress in recent years, especially in neural architecture search applications, or neuroevolution. Despite their effectiveness, analyzing and understanding the evolutionary paths these algorithms traverse to reach solutions remains challenging. Often these algorithms involve distributed computing strategies, which can include subpopulations or islands, and they explore massive or even unbounded search spaces which can include both weights and architecture, in both continuous and non-continuous domains. Manually ex-

amining individual solutions to understand the evolutionary dynamics is often infeasible due to large population sizes, large genome sizes, and high generation counts. This work introduces a new methodology for visualizing neuroevolution population dynamics called genetic distance projections, along with a novel neural network based method for generating these representations. We evaluate this methodology empirically and find it performs better than other traditional methods in generating these representations. We further validate the usefulness of these visualizations using case studies from EXAMM, a long standing neuroevolution algorithm, in which one case study even led to finding and fixing a bug in EXAMM's algorithm.

NE 2

Thursday, July 17, 15:30–17:00 Gibralfaro

Neuroevolution of Self-Attention Over Proto-Objects

Rafael Coimbra Pinto, Anderson Rocha Tavares

Proto-objects – image regions that share common visual properties – offer a promising alternative to traditional attention mechanisms based on rectangular-shaped image patches in neural networks. Although previous work demonstrated that evolving a patch-based hard-attention module alongside a controller network could achieve state-of-the-art performance in visual reinforcement learning tasks, our approach leverages image segmentation to work with higher-level features. By operating on proto-objects rather than fixed patches, we significantly reduce the representational complexity: each image decomposes into fewer proto-objects than regular patches, and each proto-object can be efficiently encoded as a compact feature vector. This enables a substantially smaller self-attention module that processes richer semantic information. Our experiments demonstrate that this proto-object-based approach matches or exceeds the state-of-the-art performance of patch-based implementations with 62% less parameters and 2.6 times less training time.

SiamNAS: Siamese Surrogate Model for Dominance Relation Prediction in Multi-objective Neural Architecture Search

Yuyang Zhou, Ferrante Neri, Yew-Soon Ong, Ruibin Bai

Modern neural architecture search (NAS) is inherently multi-objective, balancing trade-offs such as accuracy, parameter count, and computational cost. This complexity makes NAS computationally expensive and nearly impossible to solve without efficient approximations. To address this, we propose a novel surrogate modelling approach that leverages an ensemble of Siamese network blocks to predict dominance relationships between candidate architectures. Lightweight and easy to train, the surrogate achieves 92% accuracy and replaces the crowding distance calculation in the survivor selection strategy with a heuristic rule based on model size. Integrated into a framework termed SiamNAS, this design eliminates costly evaluations during the search process. Experiments on NAS-Bench-201 demonstrate the framework's ability to identify Pareto-optimal solutions with significantly reduced computational costs. The proposed SiamNAS identified a final non-dominated set containing the best architecture in NAS-Bench-201 for CIFAR-10 and the second-best for ImageNet, in terms of test error rate, within 0.01 GPU days. This proof-of-concept study highlights the potential of the proposed Siamese network surrogate model to generalise to multi-tasking optimisation, enabling simultaneous optimisation across tasks. Additionally, it offers opportunities to extend the approach for generating Sets of Pareto Sets (SOS), providing diverse Pareto-optimal solutions for heterogeneous task settings.

CPPN2WFC: Extending Wave Function Collapse to Generate Globally Coherent Content

Oleg Jarma Montoya, František Srb, Djordje Grbic, Sebastian Risi

Procedural content generation (PCG) enables the creation of vast, varied, and aesthetically rich environments with minimal manual effort. One of the most widely used techniques for procedural map generation is Wave Function Collapse (WFC), a constraint-based algorithm that synthesizes game maps by propagating local patterns while ensuring global consistency. However, despite its effectiveness, WFC often produces repetitive structures and lacks the ability to introduce higher-order spatial coherence or emergent design patterns. This paper explores whether combining Compositional Pattern Producing Networks (CPPN) and WFC – a hybrid method we term CPPN2WFC – leads to more structured and visually compelling game maps compared to using WFC or CPPNs alone. CPPNs, which are artificial neural networks with a selection of different activation functions, have been shown to generate intricate patterns and organic-like structures when evolved through NEAT, a method that dynamically evolves both network topology and weights over generations. By integrating CPPNs into the WFC framework, we introduce an additional layer of flexibility, allowing both constraint satisfaction and high-level structural control. We conduct comparative experiments through an Interactive Evolutionary interface and user study. Main results show that compared to CPPNs or WFC alone, CPPN2WFC strikes a balance between producing global and local patterns.

Integrating Neural Architecture Search and Rematerialization for Efficient On-Device Learning

Chih-Ling Chen, Kai-Chiang Wu, Ning-Chi Huang

Deep neural networks (DNNs) have notable performance in many fields, such as computer vision. Training a neural network on an edge device, commonly called on-device learning, has grown crucial for applications demanding real-time processing and enhanced privacy. However, existing on-device learning methods often face limitations, such as decreasing application accuracy, causing complexity in design and implementation, and increasing computational overhead, all of which hinder their effectiveness in reducing memory usage. In this paper, we address the issue by inspecting the memory usage of training a DNN, analyzing the effects of different on-device learning strategies, and introducing a framework that integrates neural architecture search (NAS) and rematerialization. The supernet of NAS can provide a population of compressed subnets/architectures to be trained without additional computational overhead, while rematerialization can mitigate memory consumption without

accuracy loss. By leveraging the memory-saving effect of both supernet-based model compression and rematerialization, our proposed method can obtain suitable models that fit within the memory constraint while achieving a better trade-off between training time and model performance. In the experiments, we utilized complex datasets (CIFAR-100 and CUB-200) to fine-tune models on Raspberry Pi. The experimental results represent the effectiveness of our method in real-world on-device learning scenarios.

NE 3

Friday, July 18, 10:00–11:30 Gibralfaro

A Multi-Objective Approach to Optimizing Kolmogorov-Arnold Networks

Quan Long, Bin Wang, Bing Xue, Mengjie Zhang

Kolmogorov-Arnold Network (KAN) has recently gained attention for its strong performance in both accuracy and interoperability. However, a trade-off often exists between these two objectives. To address this challenge, we propose MO-KAN, a novel multi-objective optimization framework based on the NSGA-II algorithm. MO-KAN optimizes the trade-off between accuracy and interpretability by leveraging NSGA-II to generate Pareto-optimal solutions, from which the most suitable solution is selected. Additionally, MO-KAN introduces a novel interpretability metric that quantifies the interpretability of KAN models by evaluating their simplicity, based on connection count and structural complexity, with the assumption that simpler models are more interpretable. Experimental results validate MO-KAN's effectiveness on four toy datasets from the original KAN study, achieving optimal structures while maintaining interpretability. Furthermore, experiments on five classification datasets from the UCI repository demonstrate that MO-KAN outperforms existing methods in achieving a better trade-off. By slightly compromising accuracy, MO-KAN identifies significantly more interpretable solutions, highlighting its potential for applications where interpretability is critical.

Neuro-Evolutionary Approach to Physics-Aware Symbolic Regression

Jiří Kubalík, Robert Babuska

Symbolic regression is a technique that can automatically derive analytic models from data. Traditionally, symbolic regression has been implemented primarily through genetic programming that evolves populations of candidate solutions sampled by genetic operators, crossover and mutation. More recently, neural networks have been employed to learn the entire analytical model, i.e., its structure and coefficients, using regularized gradient-based optimization. Although this approach tunes the model's coefficients better, it is prone to premature convergence to suboptimal model structures. Here, we propose a neuro-evolutionary symbolic regression method that combines the strengths of evolutionary-based search for optimal neural network (NN) topologies with gradient-based tuning of the network's parameters. Due to the inherent high computational demand of evolutionary algorithms, it is not feasible to learn the parameters of every candidate NN topology to the full convergence. Thus, our method employs a memory-based strategy and population perturbations to enhance exploitation and reduce the risk of being trapped in suboptimal NNs. In this way, each NN topology can be trained using only a short sequence of backpropagation iterations. The proposed method was experimentally evaluated on three real-world test problems and has been shown to outperform other NN-based approaches regarding the quality of the models obtained.

Diversity in Reinforcement Learning Through the Occupancy Measure

Arno Feiden, Jochen Garcke

Quality-Diversity algorithms search for a set of diverse, high-performing solutions to optimization problems, including reinforcement learning problems. In the case of reinforcement learning problems, Quality-Diversity algorithms foster diversity by differentiating solutions using behaviour descriptors. We introduce a straightforward, powerful approach to generically characterise behaviour using the so-called occupancy measure. Our approach avoids the manual definition of behaviour descriptors and does not rely on further black-box learning. We investigate four established benchmark problems inspired by robotics, concerning locomotion and maze navigation. To measure the ability to overcome local optima we consider the number of solved configurations and the maximum average score. The use of the occupancy measure is competitive with problem-specific, custom behaviour descriptors and superior to an established generic behaviour descriptor. Our work contributes to the establishment of MAP-Elites as a versatile, robust, out-of-the-box solver for complex non-convex reinforcement learning scenarios.

Scaling Policy Gradient Quality-Diversity with Massive Parallelization via Behavioral Variations

Konstantinos Mitsides, Maxence Faldor, Antoine Cully

Quality-Diversity optimization comprises a family of evolutionary algorithms aimed at generating a collection of diverse and high-performing solutions. MAP-Elites (ME), a notable example, is used effectively in fields like evolutionary robotics. However, the reliance of ME on random mutations from Genetic Algorithms limits its ability to evolve high-dimensional solutions. Methods proposed to overcome this include using gradient-based operators like policy gradients or natural evolution strategies. While successful at scaling ME for neuroevolution, these methods often suffer from slow training speeds, or difficulties in scaling with massive parallelization due to high computational demands or reliance on centralized actor-critic training. In this work, we introduce a fast, sample-efficient ME based algorithm capable of scaling with massive parallelization, significantly reducing runtimes without compromising performance. Our method, ASCII-ME, unlike existing policy gradient quality-diversity methods, does not rely on centralized actor-critic training. It performs behavioral variations based on time step performance metrics and maps these variations to solutions using policy gradients. Our experiments show that ASCII-ME can generate a diverse collection of high-performing deep neural network policies in less than 250 seconds on a single GPU. Additionally, it operates on average, five times faster than state-of-the-art algorithms while maintaining competitive sample efficiency.

Real World Applications (RWA)

RWA 1

Wednesday, July 16, 12:00–13:30 Minotauro

★ Sequence Optimization of Multispacecraft Multitarget Rendezvous Missions with a Coevolutionary Algorithm

Yu Zhang, Yuehe Zhu, Jiacheng Zhang, Yazhong Luo

The optimization of multispacecraft multitarget rendezvous sequences is a critical component of mission planning for endeavors such as space debris removal and multi-asteroid exploration. This approach has significant implications for improving mission efficiency and resource utilization. In this paper, a coevolutionary algorithm that synergistically combines a genetic algorithm (GA) with ant colony optimization (ACO) is proposed to solve a multispacecraft multitarget rendezvous sequence planning problem. The proposed algorithm employs a hierarchical strategy for target allocation and sequence planning, seamlessly integrating these two layers into a unified coevolutionary framework. To address the time-dependent challenges in space target rendezvous sequence planning, the ACO algorithm incorporates a time-local search strategy to optimize the rendezvous sequence and rendezvous time. Two local search strategies, which are called tail addition and sequence replanning, are further proposed to address the challenge associated with remaining targets in fuel-constrained missions. The experimental results highlight the effectiveness of the coevolutionary algorithm in solving the multispacecraft multitarget rendezvous sequence planning problem, with performance improvements of 8.4–10.2% in optimality over traditional methods. In the modified scenarios of the 12th Global Trajectory Optimization Competition, the algorithm's optimization results are superior to those of the winning team, highlighting its exceptional optimization capabilities.

★ Tomographic Reconstruction with Real-time a priori Acquistion

Muhammad Wishal Khan, Hooman Oroojeni, Bal Sanghera, Tim Blackwell, Mohammad Majid al-Rifaie

An a priori construction technique is proposed, utilizing a minimal swarm optimizer to achieve enhanced reconstruction accuracy. Central to the method is the incorporation of a priori information, constructed dynamically without prior knowledge of material properties, positions, or structural details. Instead, this a priori information is derived directly from sinogram projections for each defined angle in the set. A novel dynamic masking strategy leverages these sinogram-derived values to identify certain entries, generating a priori data structure that removes regions in the reconstructed image corresponding to zero sinogram values, thereby achieving theoretical dimensionality reduction. This approach effectively eliminates noise and artifacts, resulting in significantly lower reconstruction and reproduction errors.

★ Differential Evolution for Infeasible Circumstances in Network-Assisted Full-Duplex Cell-Free Massive MIMO

Trinh Van Chien, Bui Trong Duc, Mohammadali Mohammadi, Hien Quoc Ngo, Michail Matthaiou

This paper presents an application of differential evolution in optimizing the exploitation of full-duplex communication for Cell-Free Massive Multiple Input Multiple Output (CF-mMIMO), a potential candidate for 6G networks. This paper proposes a new dynamic network-assisted full-duplex CF-mMIMO network, where access points can operate in either half-duplex or full-duplex mode, and each full-duplex access point can serve uplink and downlink users simultaneously. A long-term total spectral efficiency maximization problem is formulated subject to a network operation model and individual spectral efficiency requirements with a limited power budget. Due to the intrinsic nonconvexity and infeasible circumstances where some users might not achieve the rate requirements, we adapt differential evolution to design a low computational complexity algorithm, attaining good power allocation and network operation mode in polynomial time. We further analytically investigate the number of generations required to reach the optimal solution. Numerical results demonstrate the effectiveness of our system design and proposed algorithm over state-of-the-art benchmarks. The network can offer satisfactory service to most users, although several may be unscheduled under harsh conditions.

RWA 2

Wednesday, July 16, 15:30–17:00 Malagueta

Navigating Path-Influenced Environments using Evolutionary Multi-Objective Optimization

Carlo Nübel, Malte Florim Speidel, Sanaz Mostaghim

This paper explores multi-objective pathfinding in path-influenced environments. These environments contain movable obstacles which can be shifted by the agents. This way, the agents actively change their environment while traversing on their path. Therefore, pathfinding takes on a new dimension. While it has been extensively studied across various domains, finding an optimal path in a path-influenced environment introduces new challenges. In this paper, we propose several real-world inspired problem instances. Then we formally describe this sort of problem as a multi-objective optimization problem and finally evaluate the performance of seven state-of-the-art multi-objective evolutionary algorithms on our problem instances. The results indicate that the evolutionary approach can generate sets of non-dominated solutions for this new problem. The performance of the algorithms in terms of convergence and diversity of the Pareto front highly depends on the way the encountered obstacles are handled, as well as the obstacle distribution on the map. Among the algorithms, AGE-MOEA and SPEA-II demonstrate the best convergence across the majority of problem instances.

Optimization of Unequal-Area Facility Layouts for Mass-Customization Assembly Systems with AGV

Material Handling

Thomas Seidelmann, Sanaz Mostaghim

Traditional facility layout planning (FLP) typically assumes predictable, static or periodic material flows, which no longer applies to modern mass-customization assembly systems. Optimizing these systems requires a complex integration of unequal-area FLP with the dynamic flexible assembly job-shop scheduling problem (DFAJSP), and adaptable material handling provided by multiple-load automated guided vehicle (AGV) dispatching. Due to high variability in material flows, stochastic processing times, and dynamic AGV availability, traditional methods fail to address the new problem effectively. This paper introduces the first solution approach to integrate these three NP-hard problems through a combination of multi-objective evolutionary algorithms and advanced dispatching rule systems, thus offering a significant advancement in addressing the planning challenges of mass-customization assembly systems. We evaluate three optimization architectures in 12 configurations and demonstrate that a mutation-only NSGA-II with adaptive parameter adjustment outperforms multi-stage optimization slightly, and cooperative coevolution approaches substantially on this problem. The results suggest that transitioning between early exploration and late exploitation is essential for optimal results, while coevolutionary search space division has little benefit. For the same scenario and budget, the proposed algorithm improves flow time by approximately 5% and reduces idle time by 9% compared to the coevolutionary algorithms.

Exploring the Expressive Space of an Articulatory Vocal Modal using Quality-Diversity Optimization with Multimodal Embeddings

Joris Grouwels, Nicolas Jonason, Bob L. T. Sturm

Knowing which sounds can be produced by a simulated vocal model and how they are connected to its articulatory behavior is not trivial. Being able to map this out can be interesting for applications that make use of the extended capabilities of a voice, e.g., singing or vocal imitations. We present a method that achieves this for a state-of-the-art articulatory vocal model (VocalTractLab) by combining it with a recent Quality-Diversity algorithm (CMA-MAE) and audio embeddings obtained through a multi-modal pretrained model (CLAP). The text-capabilities of CLAP make it possible to steer the exploration through a text prompt. We show that the method explores more efficiently than a random sampling baseline, covering more of the measure space and achieving higher objective scores. We provide several listening examples and the source code for a scalable implementation.

Orthogonal Genetic Algorithm for Efficient Delivery Route Planning in TSP-D

Iyed Nasra, Hervé Camus, Ghaith Manita, Amine Dhraief, Ouajdi Korbaa

In this study, we propose an advanced Orthogonal Genetic Algorithm (OGA) specifically developed to tackle the Traveling Salesman Problem with Drones (TSP-D), a multifaceted optimization challenge that necessitates precise synchronization between a truck and a drone for effective delivery tasks. The OGA integrates Orthogonal Crossover and Region-Based Mutation strategies, thereby enhancing the algorithm's proficiency in optimizing drone routing in a range of TSP-D scenarios. This novel approach significantly augments the algorithm's adaptability and exploratory capabilities within the intricate search space. Our comprehensive experimental analysis rigorously evaluates the performance of the proposed OGA against established algorithms in a variety of TSP-D instances. The results from these evaluations reveal that our approach substantially surpasses conventional algorithms in terms of both convergence speed and solution quality. This enhanced performance underscores the OGA's efficacy and robustness in optimizing complex paths in TSP-D scenarios.

RWA 3

Wednesday, July 16, 17:30–19:00 Malagueta

CLEAR: Cue Learning using Evolution for Accurate Recognition Applied to Sustainability Data Extraction

Peter Bentley, Soo Ling Lim, Fuyuki Ishikawa

Large Language Model (LLM) image recognition is a powerful tool for extracting data from images, but accuracy depends on providing sufficient cues in the prompt – requiring a domain expert for specialized tasks. We introduce Cue Learning using Evolution for Accurate Recognition (CLEAR), which uses a combination of LLMs and evolutionary computation to generate and optimize cues such that recognition of specialized features in images is improved. It achieves this by auto-generating a novel domain-specific representation and then using it to optimize suitable textual cues with a genetic algorithm. We apply CLEAR to the real-world task of identifying sustainability data from interior and exterior images of buildings. We investigate the effects of using a variable-length representation compared to fixed-length and show how LLM consistency can be improved by refactoring from categorical to real-valued estimates. We show that CLEAR enables higher accuracy compared to expert human recognition and human-authored prompts in every task with error rates improved by up to two orders of magnitude and an ablation study evincing solution concision.

Feature Selection Using Genetic Algorithm for Intrusion Detection on Resource-Constrained Edge Devices

Tijana Markovic, Pontus Lidholm, Per Erik Strandberg, Miguel Leon

Intrusion Detection (ID) systems play a crucial role in protecting computer networks from growing number of cyber threats, with Machine Learning (ML) algorithms emerging as highly effective tools in strengthening ID performance. In recent years, there has been a notable shift towards deploying ML algorithms for ID directly on edge devices, to enhance performance and increase data privacy. However, this requires ML models to be optimized for resource-constrained devices. This paper is focused on applying genetic algorithm for feature selection in ML-based ID systems deployed on edge devices. It investigates how feature selection impacts the performance of various ML algorithms, including decision tree, random forest, and artificial neural network. The study is conducted using publicly available Westermo network traffic dataset and evaluated for live network traf-

fic classification on an edge device manufactured by Westermo Network Technologies. Using only features selected by genetic algorithm resulted in a reduction of 14-26% for peak memory consumption and 23-40% for total memory consumption and decreased detection time by 24-69%, depending on the algorithm, while maintaining system classification performance. Together with the increasing computational power of edge devices, these results facilitate the application of edge ML by reducing system requirements concerning memory and processing time.

Contribution of Probabilistic Structured Grammatical Evolution to efficient exploration of the search space. A case study in glucose prediction

Jessica Mégane, Nuno Lourenço, J. Ignacio Hidalgo, Penousal Machado

People with Type 1 diabetes need to predict their blood glucose levels regularly to keep them within a safe range. Accurate predictions help prevent short-term issues like hypoglycemia and reduce the risk of long-term complications. Evolutionary algorithms have shown potential for this task by generating reliable models for glucose prediction. This work compares four evolutionary approaches: Structured Grammatical Evolution (SGE), a float-based variant (SGEF), and two probabilistic methods, Probabilistic SGE (PSGE) and Co-evolutionary PSGE (Co-PSGE). These methods are tested on their ability to predict glucose levels two hours ahead in individuals with diabetes. Two aspects are examined: predictive performance and the diversity of the phenotypes produced by each approach. Results indicate that SGEF provides statistically better performance than the other methods. Although PSGE and Co-PSGE do not show statistically significant improvements in prediction accuracy, they generate a broader set of solutions and explore more distinct areas of the search space.

Seeking and leveraging alternative variable dependency concepts in gray-box-elusive bimodal land-use allocation problems

Jakub Maciążek, Michal Witold Przewoźniczek, Jonas Schwaab

Solving land-use allocation problems can help us to deal with some of the most urgent global environmental issues. Since these problems are NP-hard, effective optimizers are needed to handle them. The knowledge about variable dependencies allows for proposing such tools. However, in this work, we consider a real-world multi-objective problem for which standard variable dependency discovery techniques are inapplicable. Therefore, using linkage-based variation operators is unreachable. To address this issue, we propose a definition of problem-dedicated variable dependency. On this base, we propose obtaining masks of dependent variables. Using them, we construct three novel crossover operators. The results concerning real-world test cases show that introducing our propositions into two well-known optimizers (NSGA-II, MOEA/D) dedicated to multi-objective optimization significantly improves their effectiveness.

RWA 4

Thursday, July 17, 12:00–13:30 Malagueta

Symbolic Pricing Policies for Attended Home Delivery – the Case of an Online Retailer

Miguel Lunet, Daniela Fernandes, Fábio Neves-Moreira, Pedro Amorim

To get products delivered, clients and retailers agree on a delivery time window. We collaborated with an online retailer to develop a real-world application aimed at dynamically determining the delivery fee for each time window while ensuring the explainability of the pricing policy. This sequential decision-making problem arises as new customers continuously arrive. The objective is to maximize the final profit, given by the sum of baskets and delivery fees, discounted by the transportation and fleet costs. As multiple customers share the same delivery route, the costs are distributed among them, complicating the calculation of the marginal cost of each customer. Our study employs Genetic Programming (GP) to create explainable and easy-to-compute pricing policies to determine the delivery fees. These policies, expressed as mathematical formulas, rank price panels – combinations of time slots and corresponding fees – to identify optimal prices for each customer. The inputs to the GP algorithm capture the current state of the system, including factors such as capacity, customer location, and basket value. The resulting expressions offer operational managers a transparent pricing policy that allows them to maximize total profit.

Multi-Agent Swarm Optimization for Decentralized Energy Management Considering Game Behaviors of Electric Vehicles

Tai-You Chen, Feng-Feng Wei, Wei-Neng Chen

With the rapid growth of electric vehicles (EVs) in modern cities, it is worth studying the distributed energy management with EV charging. Due to the autonomous decision making behaviors of EVs, it is challenging to optimize the global objective and balance the supply and demand without a central node. In this work, we propose a multi-agent particle swarm optimization algorithm (MASOIE-G) for the problem. In MASOIE-G, each agent maintains a particle swarm, and each particle in the swarm represents a candidate energy management solution. Through peer-to-peer communication, agents collaboratively evolve their particle swarms and optimize the global objective. To balance the supply and demand for the power grid with the participation of EVs, we develop an evolutionary game strategy for adaptive pricing at the phase of internal learning. To make agents cooperate to optimize the global objective with limited data and communication range, we design an external learning method with variable neighbor weights to help agents learn effective knowledge from multiple neighbors. Experimental validation on the IEEE 39-bus system shows that our algorithm can effectively respond to various conditions of supply and demand, achieving better performance than existing distributed evolutionary algorithms.

Ensemble Phased Genetic Programming for

Roundabout Turn Restriction Prediction
Darren Chitty, Ayah Helal, Sareh Rowlands, Craig Willis, Christopher Underwood, Edward Keedwell

Ensemble methods are among the best performing in the machine learning literature, often outperforming single methods in training accuracy and the prevention of overfitting. This work builds on the previously successful phased genetic programming (GP) approach to build ensembles of GP trees to create ensemble phased GP (EPGP). The method is tested in a real-world transportation modelling problem, the roundabout (traffic circle, rotary) turn restriction problem using data from OpenStreetMap, an important and time-consuming element of the traffic modelling process. EPGP is compared with standard and phased GP formulations and representative algorithms from the machine learning literature and is found to outperform them on this task.

A Dijkstra Seeded Evolutionary Multiobjective Optimization System for a Sustainable User Multimodal Transport Routing
Guilherme Barbosa, Pedro José Pereira, Vasco Abelha, Rui Mendes, Paulo Cortez

Assuming a Mobility as a Service (MaaS) concept, this paper presents a sustainable user multimodal public transport query system that minimizes both the travel time and carbon footprint (CO_2). In particular, we propose a novel Dijkstra (DJ) Seeded Non-dominated Sorting Genetic Algorithm II (NSGA-II) that is termed DS-NSGA-II. Our DS-NSGA-II method adopts multigraph data and a flexible integer solution representation that can be applied to any metropolitan area and set of public transports (including the walking option). Also, it assumes real-world transport time schedules and other realistic estimates (e.g., transport transit times). As a use case, we explore real-world data from the Oporto city, corresponding to a large multigraph with about 2,500 geographic nodes and 287,000 transportation edges regarding bus, metro and walking connections. Several experiments were held, assuming three types of realistic routing query categories (easy, medium, hard). Overall, competitive results were obtained by the proposed DS-NSGA-II method when compared with a standard NSGA-II and DJ approaches.

RWA 5

Thursday, July 17, 15:30–17:00 Malagueta

Evolutionary Algorithms for Metabolic Transformation through Multi-gene Knockout Optimization
Bruno Sá, Alexandre Oliveira, Miguel Rocha

The Metabolic Transformation Algorithm (MTA) leverages constraint-based modeling to identify metabolic interventions capable of shifting a biological system from an undesired to a desired state. Its robust extension (rMTA) strengthens predictive accuracy through worst-case scenario analyses and the integration of Minimization Of Metabolic Adjustment (MOMA) algorithm. In this work, we applied Robust Metabolic Transformation Algorithm (rMTA) to an aging-related scenario in Caenorhabditis elegans, focusing on unc-62, a gene implicated in longevity and age-associated metabolic pathways. Building on rMTA derived insights, we developed Evolutionary Algorithms (EAs) that systematically explore combinatorial gene interventions by encoding multi-gene knockouts as binary vectors and using Robust Transformation Score (rTS) to build the objective function. Through this approach, we uncovered synergistic deletions that significantly outperform single-gene knockouts in redirecting the metabolic network toward a healthier phenotype. By expanding beyond single-gene modifications, our integrated rMTA–EA framework enables a more comprehensive search for metabolic targets that drive phenotype reversion. Although demonstrated here in C. elegans, this method is broadly applicable to other organisms and complex diseases, providing a scalable platform for discovering multi-gene strategies in systems biology and metabolic engineering.

Search-based Generation of Waypoints for Triggering Self-Adaptations in Maritime Autonomous Vessels
Karoline Nylænder, Aitor Arrieta, Shaukat Ali, Paolo Arcaini

Self-adaptation in maritime autonomous vessels (AVs) enables them to adapt their behaviors to address unexpected situations while maintaining dependability requirements. During the design of such AVs, it is crucial to understand and identify the settings that should trigger adaptations, enabling validation of their implementation. To this end, we focus on the navigation software of AVs, which must adapt their behavior during operation through adaptations. AVs often rely on predefined waypoints to guide them along designated routes, ensuring safe navigation. We propose a multi-objective search-based approach, called WPgen, to generate minor modifications to the predefined set of waypoints, keeping them as close as possible to the original waypoints, while causing the AV to navigate inappropriately when navigating with the generated waypoints. WPgen uses NSGA-II as the multi-objective search algorithm with three seeding strategies for its initial population, resulting in three variations of WPgen. We evaluated these variations on three AVs (one overwater tanker and two underwater). We compared the three variations of WPgen with Random Search as the baseline and with each other. Experimental results showed that the effectiveness of these variations varied depending on the AV. Based on the results, we present the research and practical implications of WPgen.

A Quality Diversity Approach to Evolving Model Rockets
Jacob Schrum, Cody Crosby

Model rocketry presents a design task accessible to undergraduates while remaining an interesting challenge. Allowing for variation in fins, nose cones, and body tubes presents a rich design space containing numerous ways to achieve various altitudes. Therefore, when exploring possible designs computationally, it makes sense to apply a method that produces various possibilities for decision-makers to choose from: Quality Diversity (QD). The QD methods MAP-Elites, CMA-ME, and CMA-MAE are applied to model rocket design using the open-source OpenRocket software to characterize the behavior and determine the fitness of evolved designs. Selected rockets were manufactured and launched to evaluate them in the real world. Simulation results demon-

strate that CMA-ME produces the widest variety of rocket designs, which is surprising given that CMA-MAE is a more recent method designed to overcome shortcomings with CMA-ME. Real-world testing demonstrates that a wide range of standard and unconventional designs are viable, though issues with the jump from simulation to reality cause some rockets to perform unexpectedly. This paper provides a case study on applying QD to a task accessible to a broader audience than industrial engineering tasks and uncovers unexpected results about the relative performance of different QD algorithms.

Unveiling the dynamics of NOx pollution in internal combustion engines by Structured Grammatical Evolution

Marcos Llamazares López, Daniel Parra, Jose Manuel Velasco Cabo, Óscar Garnica, Rafael Jacinto Villanueva Micó, J. Ignacio Hidalgo

The formation of nitrogen oxides (NOx) in combustion systems is notable for its harmful impact on public health and the environment. Therefore, it is imperative to develop models to predict NOx formation in different situations. These models are designed to capture the characteristics of three distinct engine operating states: nominal, startup, and saturation. The nominal state represents the typical operating conditions, the startup state refers to the initial phase of the operation of the engine, and the saturation state corresponds to the operation of the engine at its maximum capacity. We applied dynamic structured grammatical evolution to obtain a set of interpretable expressions, which are mathematical representations capable of capturing the dynamics of NOx formation in combustion systems and that can be easily interpreted. These models were compared with traditional differential equation-based models to assess their interpretability and predictive accuracy for the three scenarios. Through our approach, we obtained a set of interpretable expressions that improved those obtained by a differential equation-based mathematical model, providing a more transparent and intuitive understanding of the system's behavior. Our technique seeks to unveil the dynamics of NOx formation processes that could significantly reduce NOx emissions and mitigate their impact on global environmental pollution.

RWA 6

Friday, July 18, 10:00–11:30 Malagueta

Bayesian Optimization for CVaR-based portfolio optimization

Robert Millar, Jinglai Li

Optimal portfolio allocation is often formulated as a constrained risk problem, where one aims to minimize a risk measure subject to some performance constraints. This paper presents new Bayesian Optimization (BO) algorithms for such constrained minimization problems, seeking to minimize the conditional value-at-risk (a computationally intensive risk measure) under a minimum expected return constraint. The proposed algorithms utilize a new acquisition function, which drives sampling towards the optimal region. Additionally, a new two-stage procedure is developed, which significantly reduces the number of evaluations of the expensive-to-evaluate objective function. The proposed algorithm's competitive performance is demonstrated through practical examples.

Optimization of Conformal Cooling Channels for Injection Molding Using Multi-Objective Artificial Intelligence Techniques

Antonio Gaspar-Cunha, João Melo, Tomás Marques, António Pontes

The injection molding process is widely utilized for manufacturing plastic components, where proper mold design is crucial to minimize defects. This study explores the optimization of conformal cooling channels (CCC) using artificial intelligence (AI) techniques, including principal component analysis (PCA), multi-objective evolutionary algorithms (MOEA) and artificial neural networks (ANN), integrated with numerical simulations. The methodology enhanced thermal efficiency and reduced cycle time in a cylindrical part with complex cooling requirements. Results demonstrated significant improvements in temperature uniformity and defect reduction, underscoring the potential of AI-driven optimization in advanced mold design. Furthermore, this study addresses a critical gap in existing optimization methodologies: selecting objectives. Leveraging Nonlinear Principal Component Analysis (NL-PCA), the approach identifies and prioritizes key objectives, enabling a focused and computationally efficient optimization process. Additionally, the study highlights the integration of data-driven approaches to streamline decision-making, ensuring a balance between computational efficiency and practical feasibility. The presented approach also serves as a stepping stone for integrating sustainability metrics, making it a critical contribution to the evolution of manufacturing technologies.

GA-PRE: A Genetic Algorithm-Based Automatic Data Preprocessing Algorithm

Jian Jiao, Liu Yuan

In the fields of data mining and machine learning, data preprocessing is a critical step in improving model performance. Traditional preprocessing methods are based on expert experience and manual adjustment. Although experienced data analysts can effectively preprocess data, individual experiences are difficult to quantify,leading to inconsistent data quality and a time-consuming process.To address this issue, this study proposes an automatic data preprocessing algorithm based on genetic algorithms (GA-PRE). The algorithm optimizes the accuracy of machine learning models as a fitness metric, exploring the search space of preprocessing steps to automatically select the most suitable combination of preprocessing methods. Automatically performs preprocessing tasks including data imputation, feature selection, duplicate value handling, and standardization. The algorithm has been extensively tested on multiple public datasets, and the experimental results demonstrate that, compared to three other preprocessing methods, the genetic algorithm-based preprocessing algorithm can significantly improve the accuracy of the model and the quality of the dataset.

Swarm Intelligence (SI)

SI 1

Wednesday, July 16, 12:00–13:30 Gibralfaro

Evolving Neural Controllers for Adaptive Visual Pattern Formation by a Swarm of Robots
Alessia Loi, Nicolas Bredeche

In this work, we explore the evolution of neural controllers to coordinate a swarm of robotic agents that dynamically adjust their state to match a target pattern defined at the macroscopic level (e.g. each robot should display a specific color so that an external observer sees a coherent picture from the swarm). Inspired by the multi-cellular flag problem, we compare static and dynamic swarm setups using a sliding puzzle-inspired grid environment. We use evolutionary learning to optimize artificial neural network (ANN) controllers that regulate agent behaviors based on local communication. We analyze the impact of agent density and movement fluidity on pattern formation, and we demonstrate that allowing controlled movement can enhance adaptability while preserving global structure. Post-mortem analyses reveal key differences in learned strategies between static and dynamic configurations regarding generalization to varying swarm density, including validation with real robots. We also reveal how communication speed is critical when the swarm configuration changes over time.

Lifelong Evolution of Swarms
Lorenzo Leuzzi, Davide Bacciu, Sabine Hauert, Simon Jones, Andrea Cossu

Adapting to task changes without forgetting previous knowledge is a key skill for intelligent systems, and a crucial aspect of lifelong learning. Swarm controllers, however, are typically designed for specific tasks, lacking the ability to retain knowledge across changing tasks. Lifelong learning, on the other hand, focuses on individual agents with limited insights into the emergent abilities of a collective like a swarm. To address this gap, we introduce a lifelong evolutionary framework for swarms, where a population of swarm controllers is evolved in a dynamic environment that incrementally presents novel tasks. This requires evolution to find controllers that quickly adapt to new tasks while retaining knowledge of previous ones, as they may reappear in the future. We discover that the population inherently preserves information about previous tasks, and it can reuse it to foster adaptation and mitigate forgetting. In contrast, the top-performing individual for a given task catastrophically forgets previous tasks. To mitigate this phenomenon, we design a regularization process for the evolutionary algorithm, reducing forgetting in top-performing individuals. Evolving swarms in a lifelong fashion raises fundamental questions on the current state of deep lifelong learning and on the robustness of swarm controllers in dynamic environments.

Minimalist exploration strategies for robot swarms at the edge of chaos
Vinicius Sartorio, Luigi Feola, Vito Trianni, Jonata Tyska Carvalho

Effective exploration abilities are fundamental for robot swarms, especially when small, inexpensive robots are employed (e.g., micro- or nano-robots). Random walks are often the only viable choice if robots are too constrained regarding sensors and computation to implement state-of-the-art solutions. However, identifying the best random walk parameterisation may not be trivial. Additionally, variability among robots in terms of motion abilities—a very common condition when precise calibration is not possible—introduces the need for flexible solutions. This study explores how random walks that present chaotic or edge-of-chaos dynamics can be generated. We also evaluate their effectiveness for a simple exploration task performed by a swarm of simulated Kilobots. First, we show how Random Boolean Networks can be used as controllers for the Kilobots, achieving a significant performance improvement compared to the best parameterisation of a Lévy-modulated Correlated Random Walk. Second, we demonstrate how chaotic dynamics are beneficial to maximise exploration effectiveness. Finally, we demonstrate how the exploration behavior produced by Boolean Networks can be optimized through an Evolutionary Robotics approach while maintaining the chaotic dynamics of the networks achieving 7.6% of improvement compared to the baseline.

HSEPSO: A Hierarchical Self-Evolutionary PSO Approach for UAV Path Planning
Jie Wei, Yuhui Zhang, Wenhong Wei

This paper proposes a Hierarchical Self-Evolutionary PSO (HSEPSO) Approach for UAV Path Planning to address the challenges faced by traditional Particle Swarm Optimization (PSO), such as high sensitivity to parameters, the tendency to become trapped in local optima, and slow convergence in later stages. Additionally, existing improvements to PSO lack the ability to dynamically adjust evolution strategies based on the current state of particles. HSEPSO employs a hybrid clustering strategy combining K-Means and DBSCAN for population initialization, followed by population division based on clustering results. This ensures diversity within the population while enabling particles to focus their search on regions more likely to contain the optimal solution. The algorithm also dynamically adjusts the learning factors and inertia weights through a nonlinear adaptive update strategy, effectively balancing global search and local exploitation. Moreover, based on the real-time state of the particles, HSEPSO incorporates different evolutionary strategies to accelerate convergence, optimize the search for solutions, and enhance algorithm robustness. Experimental results demonstrate that, compared to traditional PSO and other improved algorithms (such as MFIPSO, SDPSO, and SA²PSO), HSEPSO shows notable improvements in optimization performance, convergence speed, and robustness.

SI 2

Wednesday, July 16, 15:30–17:00 Gibralfaro

Learning Grouping Heuristics in Ant Colony

Optimization for Combinatorial Problems
Aseel Ismael Ali, Edward Keedwell, Ayah Helal

Ant colony optimisation (ACO) has demonstrated good performance on a number of combinatorial optimisation tasks. A recent advance demonstrated the successful addition of a grouping heuristic used information from the objective function to prioritise solutions with full bins. This method increased performance further and established grouping-ACO among the state-of-the-art approaches to bin packing. In this paper, we develop a method to learn and apply decision variable groupings during the ACO algorithm run with no additional information from the objective function. This enables the approach to be generalised to any combinatorial problems for which an ACO representation can be formulated. Experimentation is conducted on a number of instances of the bin packing, knapsack and travelling salesman problems and shows improved performance over standard ACO in all cases, and performance approaching grouping-ACO on the bin packing problem.

Adaptive Multi-Population Dynamic Optimization for Multimodal Dynamic Function Optimization
Shoei Fujita, Ryuki Ishizawa, Hiroyuki Sato, Keiki Takadama

To tackle the dynamic optimization problem where the location and number of optimal solutions frequently change, this paper proposes NDSOT (Niching Swarm Dynamic Optimization with TCMA-ES) which can continuously track the multiple moving optimal solutions each of which is generated or eliminated as time goes on. For this purpose, the proposed algorithm integrates Tracking CMA-ES (TCMA-ES) with NMMSO (Niching Migratory Multi-Swarm Optimization), where the former aims to locally track the multiple moving optimal solutions with globally estimating their movement direction, while the latter aims to estimate the number of the multiple optimal solutions by adjusting the number of swarms composed of individuals. The intensive experiments of the three dynamic multimodal functions in 2D and 5D from the Moving Peaks Benchmark (MPB) have revealed that NDSOT succeeded to track the multiple moving and generated/eliminated optimal solutions. In detail, (1) the Offline-Error and Relative Error Distance of NDSOT is lowest and (2) the Peak Found Ratio of NDSOT is highest in comparison with the conventional methods of multiswarm-Quantum Particle Swarm Optimization (QPSO) and TSOPC

An Ensemble Ant Colony Optimization Algorithm with a Hybrid Pheromone Model for Learning Rule Lists.
James Brookhouse, Ayah Helal, Fernando E.B. Otero

In this paper, we present an ensemble hybrid pheromone Ant-Miner based algorithm, *e*Ant-MinerPB+HMA, which benefits from a new hybrid pheromone model to improve the computational and execution time of the algorithm, along with ensemble methods to boost predictive performance. Ant Colony Optimization (ACO) based rule induction algorithms have proven to be successful in producing classification rules. Ensemble methods have also been shown to boost the predictive performance of individual learners, leading to better models. *e*Ant-MinerPB+HMA creates multiple colonies to build a set of classifiers through feature and instance bagging. *e*Ant-MinerPB+HMA shows competitive accuracy compared to traditional Ant-Miner variants, while also improving its execution speed—more noticeably in larger data sets.

GA 1 + SI 3
Wednesday, July 16, 17:30–19:00 Minotauro

★ Congestion-Aware Multi-Agent Path Planning for Pick-Up and Delivery Tasks
Mehrdad Asadi, Ann Nowé, Javad Ghofrani

Mobile robotic systems play a pivotal role in logistics, particularly in warehouse operations, where efficient and collision-free navigation is essential for completing tasks. However, managing a large number of robots often leads to congestion, causing delays and adversely affecting system scalability. This paper proposes a novel online algorithm for solving the Multi-Agent Pickup and Delivery (MAPD) problem. The algorithm addresses local collision detection and global congestion avoidance by integrating a congestion prediction model to enhance process efficiency. A deep neural network is employed to approximate congestion predictions independently of the number of agents, reducing computational complexity. Simulation experiments demonstrate that the proposed approach significantly improves system throughput and scalability, with a notable average doubling of throughput in specific scenarios. The findings provide a foundation for advanced congestion management strategies in multi-agent systems, paving the way for efficient and scalable deployment in logistics and beyond.

Theory

Theory 1
Wednesday, July 16, 12:00–13:30 Alcazaba

A Royal Road Function for Permutation Spaces: an Example Where Order Crossover is Provably Essential
Andre Opris, Sebastian Sonntag, Dirk Sudholt

Permutation spaces represent a wide range of important problems in domains such as scheduling, routing, sequencing, and assignment. Despite the frequent application of evolutionary algorithms to permutation-based problems, the theory of evolutionary computing in permutation spaces is in its infancy. Many fundamental questions remain open, particularly regarding the effectiveness of various mutation and crossover operators designed for permutation spaces. While there is a substantial body of runtime analyses demonstrating the benefits of crossover in pseudo-Boolean optimisation, there is no such work for permutation spaces. We present

the first example of a permutation problem in which the use of crossover is proven to be beneficial. Mutation-only evolutionary algorithms, such as the (1+1)EA with swaps, exchanges, or jumps as mutation operators, require exponential time to find the global optimum with high probability. In contrast, an island model and a $(\mu + 1)$EA with fitness sharing both leverage order crossover to achieve polynomial runtimes. These stark performance differences highlight the potential advantages of crossover and pave the way for systematically exploring its effectiveness in permutation spaces.

Runtime Analysis of Evolutionary Multitasking for Classical Benchmark Problems
Johannes Lengler, Aneta Neumann, Frank Neumann

Evolutionary multitasking has gained significant attention in the evolutionary computation literature in recent years. Here an evolutionary algorithm is used to compute good or optimal solutions for not just a single but several (possibly related) tasks. We provide a first runtime analysis of evolutionary multitask algorithms and investigate generalized versions of OneMax, LeadingOnes, and Jump which are classical benchmark functions frequently studied in the area of runtime analysis. Our theoretical investigations point out significant speed ups when using evolutionary multitasking instead of several runs of the classical (1+1) EA. In particular, our analysis reveals how progress is shared between the different tasks using uniform crossover in an evolutionary multitasking algorithm. We complement our asymptotic theoretical analysis by experimental investigations which provide further insights into the actual speed ups dependent on the similarity of the given tasks for realistic problem sizes.

A General Upper Bound for the Runtime of a Coevolutionary Algorithm on Impartial Combinatorial Games
Alistair Benford, Per Kristian Lehre

Due to their complex dynamics, combinatorial games are a key test case and application for algorithms that train game playing agents. Among those algorithms that train using self-play are coevolutionary algorithms (CoEAs). However, the successful application of CoEAs for game playing is difficult due to pathological behaviours such as cycling, an issue especially critical for games with intransitive payoff landscapes. Insight into how to design CoEAs to avoid such behaviours can be provided by runtime analysis. In this paper, we push the scope of runtime analysis for CoEAs to combinatorial games, proving a general upper bound for the number of simulated games needed for UMDA to discover (with high probability) an optimal strategy. This result applies to any impartial combinatorial game, and for many games the implied bound is polynomial or quasipolynomial as a function of the number of game positions. After proving the main result, we provide several applications to simple well-known games: Nim, Chomp, Silver Dollar, and Turning Turtles. As the first runtime analysis for CoEAs on combinatorial games, this result is a critical step towards a comprehensive theoretical framework for coevolution.

Random Gradient Hyper-heuristics Can Learn to Escape Local Optima in Multimodal Optimisation
Yuxuan Ma, Pietro S. Oliveto, John Alasdair Warwicker

Selection hyper-heuristics (SHHs) select from a set of low-level heuristics which to apply during the optimisation process. One such approach, namely the random gradient SHH, which continues to apply a randomly selected heuristic as long as it remains successful, has been shown to be able to effectively select heuristics leading to optimal expected runtimes on a range of unimodal functions. In this work, we extend the analysis of the random gradient SHH to multimodal optimisation problems to assess their performance at escaping from local optima. We consider the TwoRates benchmark function which includes several consecutive local optima separated by gaps of two alternating different sizes. The function was recently introduced to assess the performance of the flex-EA that uses an archive to store and re-apply the two most suitable Randomized Local Search (RLSk) operators to make the jumps of different lengths. We show that the SHH can optimise the function considerably faster by identifying and consecutively re-applying the single best heuristic to overcome all of the local optima. This performance also holds when the set of low-level heuristics contains all the n possible RLSk operators, where n is the problem size.

GECH 1 + Theory 2

Wednesday, July 16, 15:30–17:00 Mena

★ Improved Runtime Analysis of a Multi-Valued Compact Genetic Algorithm on Two Generalized OneMax Problems
Sumit Adak, Carsten Witt

Recent research in the runtime analysis of estimation of distribution algorithms (EDAs) has focused on univariate EDAs for multi-valued decision variables. In particular, the runtime of the multi-valued cGA (r-cGA) and UMDA on multi-valued functions has been a significant area of study. Adak and Witt (PPSN 2024) and Hamano et al. (ECJ 2024) independently performed a first runtime analysis of the r-cGA on the r-valued OneMax function (r-OneMax). Adak and Witt also introduced a different r-valued OneMax function called G-OneMax. However, for that function, only empirical results were provided so far due to the increased complexity of its runtime analysis, since r-OneMax involves categorical values of two types only, while G-OneMax encompasses all possible values. In this paper, we present the first theoretical runtime analysis of the r-cGA on the G-OneMax function. We demonstrate that the runtime is $O(nr^3 \log^2 n \log r)$ with high probability. Additionally, we refine the previously established runtime analysis of the r-cGA on r-OneMax, improving the previous bound to $O(nr \log n \log r)$, which improves the state of the art by an asymptotic factor of $\log n$ and is tight for the binary case. Moreover, we for the first time include the case of frequency borders.

★ Why Dominance Is Not Enough: Lessons from Practical Evolutionary Multi-Objective Algorithms
Duc-Cuong Dang, Andre Opris, Dirk Sudholt

Practical EMO algorithms like NSGA-II, NSGA-III, and SMS-EMOA combine the dominance relation with diversity criteria to identify promising solutions. Despite many suc-

cess stories, their theoretical foundation remains underdeveloped, with key questions still unanswered—such as which information obtained throughout the evolution is critical for their success. We explore the limitations of the information provided by the dominance relation between search points encountered so far. We construct an artificial problem with a small Pareto set where almost all pairs of search points are incomparable. For this problem, we prove that any black-box EMO algorithm that only relies on the dominance relation for making decisions and only use variation operators that are invariant to bit values, fails spectacularly, requiring exponential time with high probability. In stark contrast, NSGA-II, NSGA-III, and SMS-EMOA efficiently cover the Pareto front in expected quadratic time by incorporating additional information, such as objective values. Our results highlight the superiority of practical EMO algorithms and the necessity of using information beyond dominance for effective multi-objective optimisation.

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