evo* 2019

CONFERENCE HANDBOOK

EvoStar conferences held in Leipzig, Germany
24-26 April 2019

SPECIES

Acknowledgements

EvoStar gratefully acknowledges:

Invited speakers

Risto Miikkulainen & Manja Marz

the **Programme Chairs** and **Programme Committees**

of all EvoStar conferences

Hendrik Richter from **HTWK Leipzig** including the local organising team of Natalie Kruck, Jonas Berger, Marcel Meyer, Silvia Paketuris-Scholer and Robert Thiel.
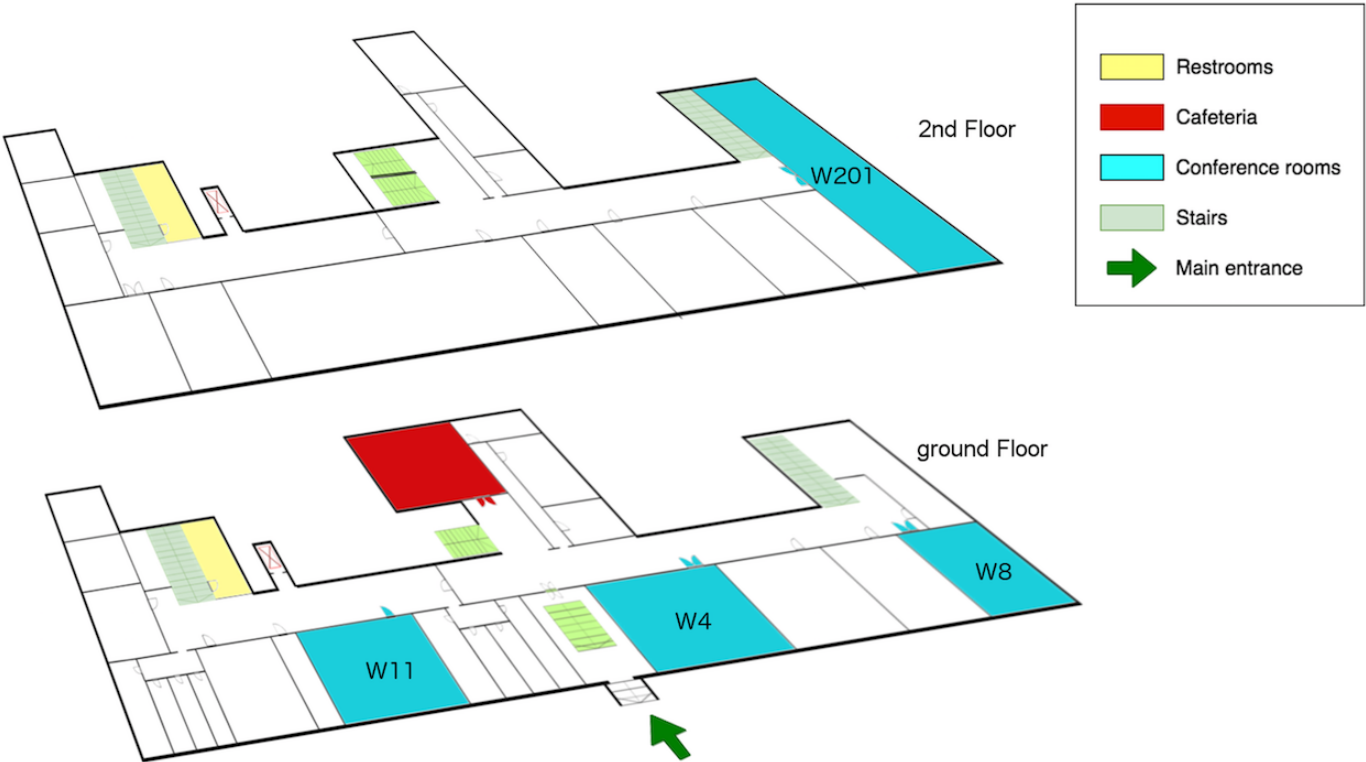
Pablo García Sánchez (Universidad de Cádiz) for EvoStar Website and Publicity

Marc Schoenauer (INRIA Saclay - Île de France) for continued assistance in providing the MyReview conference management system

HTWK Leipzig for support of student activities

Floor plan

Legend:
- Restrooms
- Cafeteria
- Conference rooms
- Stairs
- Main entrance

2nd Floor — W201

ground Floor — W11, W4, W8

EvoStar 2019 conference programme

Wednesday 24 April

0900-0930	Registrations		
0930-0945	Conference opening by SPECIES Society President Marc Schoenauer and welcome address by Prof. Dr. p.h. habil. Gesine Grande, Rector, HTWK Leipzig University of Applied Sciences (Room W201)		
0945-1045	Plenary invited talk: Risto Miikkulainen - University of Texas, USA *Creative AI through Evolutionary Computation* *Room W201*		
1045-1110	Coffee break		

		Room W11	Room W4	Room W8
1110-1320		EuroGP 1 *Applications of GP*	EvoMusArt 1 Visuals	EvoApplications 1 Short talks (i)
1320-1430	Lunch at Mensa Petersteinweg			
1430-1620		EuroGP 2 Short talks + Panel debate (15:00) *What is the killer application of GP?*	EvoMusArt 2 Audio	EvoApplications 2 Short talks (ii)
1620-1640	Coffee break			
1640-1800		LBA Session TBA	EvoMusArt 3 Short talks	EvoApplications 3 Robots and Engineering Applications
1830-2000	EvoStar poster session and conference reception			

Thursday 25 April

		Room W11	Room W4	Room W8
0930-1110		FET Session TBA		EvoApplications 4 Engineering & Real World Applications (i)
1110-1130	Coffee break			
1130-1315		EvoMusArt 4 Best paper nominations	EvoCOP 1	EvoApplications 5 Engineering & Real World Applications (ii)
1315-1415	Lunch at Mensa Petersteinweg			
1415-1600		EuroGP 3 New techniques in GP	EvoCOP 2	EvoApplications 6 Best paper nominations
1600-1620	Coffee break			
1620-1800		EuroGP 4 Best paper nominations	EvoCOP 3	EvoApplications 7 Misc
1900-2130	Conference dinner: Ratskeller Group departures 18:00 to 18:30			

Friday 26 April

		Room W11	Room W4	Room W8
10:00-1130		LBA Session TBA	EvoCOP 4 Best paper nominations	EvoApplications 8 Neuroevolution
1130-1200	Coffee break			
1200-1300	Plenary invited talk: Manja Marz - *Friedrich Schiller University Jena, Germany* *The discovery of RNA evolution with long read sequencing methods* *Room W201*			
1300-1330	Conference closing, best paper presentations, general announcements including 2020 location			
1330-1415	Lunch at Mensa Petersteinweg			
1415-1515	SPECIES society AGM open to all EvoStar participants (Room W8)			
1515-1800	Optional afternoon social trip : tour of Leipzig			

Contents

6

EvoStar 2019 Organisers

EuroGP
22nd European conference on Genetic Programming
EuroGP programme chairs
>Lukas Sekanina, Brno University of Technology, Czech Republic
>Ting Hu, Memorial University, Canada

EuroGP publication chair
>Nuno Lourenço, University of Coimbra, Portugal

EvoAPPLICATIONS
22nd International Conference on the Applications of Evolutionary Computation
EvoAPPLICATIONS coordinator
>Paul Kaufmann, Mainz University, Germany

EvoAPPLICATIONS publication chair
>Pedro Castillo, University of Granada, Spain

EvoAPPLICATIONS Area Chairs

Engineering & Real world applications	Emma Hart, Sara Silva
Games	Julian Togelius, Alberto Tonda
Image & Signal Processing, Vision & Pattern recognition	Stephen Smith, Monica Mordonini
Life sciences	James Foster, Jaume Bacardit
Networks	JJ Merelo, Juan Luis (Juanlu) Jiménez-Laredo
Neuroevolution	Julian Miller, Sebastian Risi
Numerical optimization	Günter Rudolph, Oliver Kramer
Robotics	Gusz Eiben, Kyrre Glette
General	Carlos Cotta, Francisco Fernández de Vega, Giovanni Iacca, Trung Thanh Nguyen

EvoAPPLICATIONS steering committee
>Stefano Cagnoni, Anna I Esparcia-Alcázar, Mario Giacobinni, Antonio Mora, Günther Raidl, Franz Rothlauf, Kevin Sim, Giovanni Squillero. Honorary member: Cecilia di Chio

EvoCOP
18th European conference on Evolutionary Computation in Combinatorial Optimisation
EvoCOP programme chairs
>Arnaud Liefooghe, University of Lille, France
>Luís Paquete, University of Coimbra, Portugal

EvoMUSART
7th International Conference on Computational Intelligence in Music, Sound, Art and Design

EvoMUSART programme chairs
>Antonios Liapis, Institute of Digital Games, University of Malta
>Aniko Ekárt, Aston University, UK

EvoMUSART publication chair
>Luz Castro, Universidade da Coruña, Spain

EvoStar 2019 Team

EvoStar 2019 local chair
Hendrik Richter, HTWK Leipzig

EvoStar 2019 publicity chair
Pablo García Sánchez, University of Cádiz, Spain

EvoStar 2019 MyReview System coordinator
Marc Schoenauer, INRIA-Saclay, France

EvoStar 2019 coordinator
Anna I Esparcia-Alcázar, UPV, Spain

EvoStar 2019 helpers
Natalie Kruck, Jonas Berger, Marcel Meyer,
Silvia Paketuris-Scholer, Misha Paauw and Robert Thiel.

SPECIES Executive Board

Marc Schoenauer	Anna Esparcia-Alcázar	Wolfgang Banzhaf	Stefano Cagnoni
Ernesto Costa	J. Ignacio Hidalgo	Penousal Machado	Gabriela Ochoa
Giovanni Squillero	Neil Urquhart	Leonardo Vanneschi	

Welcome to EvoStar

On behalf of all the EvoStar 2019 organisers, we are pleased to welcome you to Leipzig for the four co-located EvoStar conferences of EuroGP, EvoAPPs, EvoCOP and EvoMUSART. This is the 22nd edition of evoStar, with the first EuroGP and EvoROB workshops being held in Paris in 1998. Many of the people originally participating then still continue to come to EvoStar, or are now represented by their students! Many come from the hundreds attending EvoStar conferences over the years have subsequently become programme chairs or local chairs in later years, and this contributes to a rich and vibrant community.

This year we are presenting a total of 22 conference sessions plus a general poster session, with 98 papers, short papers and late-breaking abstracts presented over two and a half days. In addition we are pleased to have two eminent invited speakers for the opening and closing talks, Risto Miikkulainen and Manja Marz. We offer an exciting programme with many high-quality contributions from the diverse fields within bio-inspired computation. The EvoStar events provide excellent opportunities to meet friends and establish new collaborative relationships within enjoyable social settings. Please do enjoy EvoSar2019 and if you want more information or need any help, do not hesitate to ask at the conference desk or any of the local organisers.

EvoStar arose out of workshops originally developed by EvoNet, the Network of Excellence in Evolutionary Computing, established by the European Commission and coordinated at Edinburgh Napier University in the UK. These events now represent a continuity of research collaboration stretching back over 20 years.

SPECIES was formally set up in 2014 to provide an appropriate legal structure for future organisation and support of the EvoStar conferences. SPECIES stands for the Society for the Promotion of Evolutionary Computation in Europe and its Surroundings, and its goal is to promote evolutionary algorithmic thinking.

The SPECIES Annual General Meeting will take place in Room W8 immediately after lunch on Friday 26, at 14:15 and an Executive Board will be duly elected. Your conference registration includes SPECIES membership if you agreed to it, so we hope you will come to the AGM and contribute to the well-being of our society.

Useful information

The EvoStar conference will be held in the building of the **Faculty of Electrical Engineering and Information Technology of HTWK Leipzig University of Applied Sciences** at Wächterstrasse 13 (04107 Leipzig), close to the historic city center of Leipzig. The building is called Wiener-Bau to honor the American mathematician Nobert Wiener (1894-1964) who established cybernetics as a concept of regulatory systems, which had fundamental implications for engineering, systems control and computer science. The Wiener-Bau, where the conference is held, is part of an ensemble of building attached to the historic city center at the end of the 19th century and dedicated to education. Right next to the Wiener-Bau, we find the Academy of Fine Arts (Hochschule für Grafik und Buchkunst), the University of Music and Theatre (Hochschule für Musik und Theater) and the University Library (Universitätsbibliothek).

Pick up your registration materials when you arrive and be sure to **wear your conference badge visibly at all times** so university staff can recognise you as belonging to the EvoStar conference. This also entitles you to lunches, coffee breaks and the conference reception, so do not lose your badge or leave it at your hotel.

Lunches

Lunches will be held at **Mensa und Cafeteria Petersteinweg** (Strasse des 17. Juni 2, 04107 Leipzig), which is an 8 minute (650m) walk. Turn right outside the main entrance of the conference venue, turn right at the next corner into Grassistrasse, turn left at the next corner into Beethovenstrasse, go on straight and cross Harkortstrasse into Strasse des 17 Juni. The Mensa und Cafeteria Petersteinweg is right before the next corner on the left hand side.

In your conference badge you will find your tickets for the Mensa (They have different colors for regular and student participants, but this makes no difference to you.) Each ticket is valid for your choice of main course, plus salad, dessert and soft drink. Vegetarian options are available. The EvoStar lunch service runs from 13.15 – 14.30 on Wednesday, Thursday and Friday. Student helpers will assist you getting to the Mensa and ordering your meal.

Conference Dinner

The conference dinner will take place on Thursday, 25. April 2019, 19:30-22:00 at the historic **Ratskeller** (Lotterstrasse 1, 04109 Leipzig) in the basement of the New Town Hall (Neues Rathaus). The conference dinner will be held as a buffet dinner, comprising of typical dishes from Leipzig and the region. Vegetarian options are available and each dish will be labelled, including

potential food allergens. Thus, if you require any special diets it should be easy to find something suitable. If in doubt, contact the staff at the Ratskeller, or one of the student helpers, or the local organizer Hendrik Richter.

Before the conference dinner there is the opportunity to visit the New Town Hall (Neues Rathaus) and ride up to the 114m tower for a view over the historic city center of Leipzig. From the conference venue the New Town Hall is a 10 minutes' walk (700m). We start in groups from the conference venue between 18:00 and 18:30. After the visit, we go on to the Ratskeller, which is in the same building (but around the corner)

It is important to remember that **YOU MUST BRING YOUR DINNER TICKET WITH YOU**. If you cannot attend the dinner, we kindly ask that you return your dinner ticket to the conference desk so that it can be recycled to others wanting to join the dinner; this is greatly appreciated.

Poster session and Conference Reception

The Evostar conference reception will be held in the **MAIN CORRIDOR on the Ground Floor**, on Wednesday evening from 18:30-20:00 in conjunction with the EvoStar poster session. All posters presented will be candidates to the **Best Poster Prize**. Outstanding Students will also candidate to the Best Student Paper award. Both prizes will be voted by the attendees to the Poster Session
Light refreshments will be served.

Optional local tour on Friday afternoon

For those staying on Friday afternoon, an optional walking tour through the city center has been arranged. The tour includes St. Nicholas Church with its churchyard, which was the focus of events in fall 1989. We go on to the **Augustusplatz** with the Opera and Gewandhaus Concert Hall and the freshly arising university complex. Opposite the **Naschmarkt** with the Old Stock Exchange you will see Leipzig's most famous arcade – **Mädlerpassage**.

Next to the entrances to **Auerbach's Keller**, the word-famous restaurant, are two groups of figures connected with Goethe's drama "Faust". The location has been a restaurant since the beginning of the 16th century. The Old Town Hall, one of the most beautiful Renaissance buildings in Germany, is situated the eastern side of the Market Square. We then pass **Barthel's Hof**, a passage courtyard leading to our most famous pub mile – **Barfußgässchen**. The last highlight of our tour will be **St. Thomas Church**, where Johann Sebastian Bach was Cantor and found his final resting place. It is also the main church of the **Thomanerchor**, Leipzig's famous boys choir, who are appreciated all over the world.

The walking tour leaves at **approximately 15:15** from the conference venue and is expected to finish **about 17:30** or thereabouts. Tickets are **10 euro** per person, and are available from the conference desk, cash only please.

Laptops and WiFi

WIFI is available at the conference venue. In addition to Eduroam being suitable for many, participants will be able to use the HTWK Leipzig guest network.

You are encouraged to bring your own laptop or tablet for your presentation and appropriate adaptors and chargers for your equipment as EvoStar does not provide these. All LCD projectors have a VGA input. Some may provide HDMI, but this is not granted.

Online access to Proceedings

Springer has made online access available for EvoStar participants for the conference proceedings for the week before, and several weeks after, the conference via links at `http://www.evostar.org`

The EvoStar volume numbers are as listed below:

EuroGP 2019: LNCS 11451   EvoCOP 2019: LNCS 11452
EvoMUSART 2019: LNCS 11453   EvoAPPS 2019: LNCS 11454

Instructions to session chairs

You must bear in mind that

- *long* talks take 20 minutes + 5 minutes questions

- *short* talks take 10 minutes, no questions

Please ensure your speakers stick to the allocated times, in order to allow attendants to move between parallel sessions.

Invited speakers

Opening talk on Wednesday, 24 April at 09:45

Risto Miikkulainen

Creative AI through Evolutionary Computation

Abstract: Last decade has seen tremendous progress in Artificial Intelligence (AI). AI is now in the real world, powering applications that have a large practical impact. Most of it is based on modeling what is already known, e.g. predicting what the right classification of an image or a language sequence might be. The next step for AI is machine creativity, e.g. designing engineering solutions are more complex, perform better, or at a lower cost than existing solutions. Evolutionary computation is likely to play a central role in future such AI. I will review several recent techniques and applications where evolutionary creativity improves upon best human solutions, including designing neural network architectures, web interfaces, and growth recipes for agriculture.

Risto Miikkulainen is a Professor of Computer Science at the University of Texas at Austin and Associate VP of Evolutionary AI at Cognizant. He received an M.S. in Engineering from Helsinki University of Technology (now Aalto University) in 1986, and a Ph.D. in Computer Science from UCLA in 1990. His current research focuses on methods and applications of neuroevolution, as well as neural network models of natural language processing and vision; he is an author of over 400 articles in these research areas. Risto is an IEEE Fellow, and his work on neuroevolution has recently been recognized with the Gabor Award of the International Neural Network Society and Outstanding Paper of the Decade Award of the International Society for Artificial Life.

Invited speakers

Closing talk on Friday, 26 April at 11:30

Manja Marz

The discovery of RNA evolution with long read sequencing methods
Abstract: Since more than a decade it is known that RNAs play a major role in basically all molecular processes o any cell. However the evolution of RNAs is not so easy to trace back due to their selection pressure on secondary structures instead of the nucleic acid sequence itself. In this talk we will understand the evolution of well known examples of conserved RNAs. But there have been a lot of mysterious RNA molecules of unknown shape and origin, which we will investigate during the talk by using newest sequencing methods, such as ONT Minion. This direct RNA sequencing technique reveals very long reads, which make it also possible to discover the evolution of whole genomes from RNA viruses.

Manja Marz is Full Professor for High Throughput Sequencing Analysis at the Faculty of Mathematics and Computer Science of the Friedrich Schiller University Jena, Germany and managing director of European Virus Bioinformatics Center. She studied Biology and Computer Science at the Universities in Edinburgh, Darmstadt and Leipzig, and received a PhD in Bioinformatics from the University of Leipzig. Dr. Marz is deputy editor of PLoS Computational Biology and Biology direct. Her main research interest are bioinformatic analysis and system biology of viruses, comparative genomics, as well as algorithmic bioinformatics and phylogenetic analysis. Apart from her scientific achievements, she is also a strong master of the board game Go and won the European Female Go Championship in 2017.

16

What is the killer application of Genetic Programming?

Wednesday, 24 April at 15:00
Room W11

Description: While the Internet existed as far back as the 1960s, it was not until the advent of the World Wide Web in the early 90s, that this technology began impacting our everyday lives as an information dissemination tool. This application is so dominant that many would treat the Web as the synonym of the Internet. A technique only takes off when it finds a vehicle to communicate with the wide audience, i.e., through a killer application.

What is the killer application that may make GP become a part of our everyday lives? What are the problems that GP is particularly suitable for? What can let GP outshine the other learning algorithms for the next waves of AI research?

Moderator: Ting Hu, Memorial University of Newfoundland (Canada)

Panelists:

- Gusz Eiben, Vrije Universiteit Amsterdam (NL)

- James Foster, University of Idaho (USA)

- Risto Miikkulainen, University of Texas (USA)

- Gabriela Ochoa, University of Stirling (UK)

Best paper nominations

EuroGP nominees

- **Can Genetic Programming Do Manifold Learning Too?** Andrew Lensen, Bing Xue, Mengjie Zhang

- **Why is Auto-Encoding Difficult for Genetic Programming?** James McDermott

- **Towards a Scalable EA-based Optimization of Digital Circuits** Jitka Kocnova, Zdenek Vasicek

EvoAPPLICATIONS nominees

- **Particle Swarm Optimization: Understanding Order-2 Stability Guarantees** Christopher Cleghorn

- **Supporting Medical Decisions for Treating Rare Diseases through Genetic Programming** Illya Bakurov, Leonardo Vanneschi, Mauro Castelli, Maria João Freitas

- **Evolutionary Algorithms for the Design of Quantum Protocols** Walter Krawec, Stjepan Picek, Domagoj Jakobovic

EvoCOP nominees

- **Clarifying the Differences in Local Optima Network Sampling Algorithms**, Sarah L. Thomson, Gabriela Ochoa, Sébastien Verel

- **An Iterated Local Search Algorithm for the Two-Machine Flow Shop Problem with Buffers and Constant Processing Times on One Machine**, Hoang Thanh Le, Philine Geser, Martin Middendorf

- **Quasi-Optimal Recombination Operator**, Francisco Chicano, Gabriela Ochoa, Darrell Whitley, Renato Tinós

EvoMUSART nominees

- **Swarm-based identification of animation key points from 2D-medialness maps** Prashant Aparajeya, Frederic Fol Leymarie, Mohammad Majid al-Rifaie

- **Paintings, Polygons and Plant Propagation** Misha Paauw, Daan van den Berg

EvoStar Outstanding Contribution to EC in Europe Award

Each year EvoStar recognises those who have made an outstanding contribution to evolutionary computation in Europe. The award is presented during the conference dinner, this year on **Thursday, 25 April**.

Previous recipients of the award are:

- **2018 - Parma:** Sara Silva
- **2017 - Amsterdam:** Gusz Eiben & James Foster
- **2016 - Porto:** Penousal Machado
- **2015 - Copenhagen:** Anna I Esparcia-Alcázar & Leonardo Vanneschi
- **2014 - Granada:** Terry Fogarty
- **2013 - Vienna:** Una-May O'Reilly & Elena Marchiori
- **2012 - Málaga:** Günter Raidl
- **2011 - Torino:** Julian Miller
- **2010 - Istanbul:** Marco Tomassini
- **2009 - Tübingen:** Stefano Cagnoni & Ernesto Costa
- **2008 - Napoli:** Marc Schoenauer & Bill Langdon
- **2007 - Valencia:** Wolfgang Banzhaf & Riccardo Poli
- **2006 - Budapest:** Jennifer Willies

Students Activities

Welcome Students Reception

We will be holding a reception for student attendees on Tuesday the evening of the 23rd of April, just before the conference commences. Based on our successful event last year, this will provide an opportunity to tell others about your research and meet other students working in areas similar to yours.

We will also form up the teams for the 2019 Evostar scavenger hunt, which will take place during the conference.

The reception will be held at the MoritzBastei, Kurt-Masur-Platz 1, 04109 Leipzig, from 18:30 until 19:30.

Scavenger Hunt

The organisers are also inviting all students to participate in the EvoStar 2019 Student Scavenger Hunt. Students have been placed in small teams to undertake these challenges below.

- Post a picture of your team outdoors in Leipzig

- Submit the title of a paper that solves a real-world problem

- Post a picture of your team in the world's largest train station by floor area

- Submit the title of a paper that was written by someone from Spain.

- Submit the title of a paper that has an application in games.

- Picture yourself with an attendee who has attended more than 10 EvoStar events.

- Post a picture of a member of your team presenting a paper.

- Post a picture of your team near Bach's tombstone

- Post a picture of your team with a robot

- Post a picture of your team with a winner of the EvoCrocs Award

- Upload a picture of each team member asking a question at the poster session

- Picture your team with a member of the SPECIES board who comes from Portugal

To be eligible for prizes, be sure to provide your answers to n.urquhart@napier.ac.uk no later than 10am on Friday the 26th. Winners will be announced and prizes given out at the closing session.

A series of mentoring activities has also been organised, which will be developed further in future years; please send your suggestions to **Neil Urquhart**, `n.urquhart@napier.ac.uk`.

EvoStar is grateful to **Edinburgh Napier University** for their support of these student activities.

Recognition to
Outstanding Students

In EvoStar 2018 we wanted to recognise the good work of our students, who represent the future of our community.

We selected papers that had obtained an overall review score greater than or equal to 5 or that had been nominated for a Best Paper Award, and whose first author was a student registered to attend EvoStar.

Following these rules we came up with a list of 14 Outstanding Students:

- Benedikte Wallace, University of Oslo, Norway

- Hoang Thanh Le, University of Leipzig, Germany

- Illya Bakurov, NOVA IMS, Lisbon, Portugal

- Jitka Kocnova, Brno University of Technology, Czech Republic

- Jonathan Kelly, Massachusetts Institute of Technology, Cambridge, United States

- Jörg Stork, TH Köln Gummersbach, Germany

- Muhammad Sheraz Anjum, University of Limerick, Ireland

- Nam Le, University College Dublin, Ireland

- Riccardo Gervasi, Politecnico di Torino, Italy

- Robert J. Smith, Dalhousie University, Halifax, Canada

- Samaneh Azari, Victoria University of Wellington, New Zealand

- Sarah Louise Thomson, University of Stirling, United Kingdom

- Shima Afzali, Victoria University of Wellington, New Zealand

- Timon van de Velde, University of Amsterdam, The Netherlands

- Timothy Atkinson, University of York, York, United Kingdom

Please come to the Poster Reception on Wednesday 24th and vote for your favorite for the **Evo* 2019 Best Student Paper award**.

<div align="center">

Introduction session to

Future and Emerging Technologies

</div>

Thursday, 25 April at 9:30
Room W11

In this session European Commission representatives will present the 2019 FET-related funding opportunities, both from FET-Open and FET-Proactive and within the new European Innovation Council (EIC) pilot.

FET researchers Gusz Eiben and Giovanni Iacca will also contribute their experience and advise on the FET programme.

EuroGP Programme

April 24, 2019

09:00-09:30 : *Registrations*

09:30-09:45 : *Conference opening by SPECIES Society President Marc Schoenauer*

09:45-10:45 : *Plenary invited talk: Risto Miikkulainen*

10:45-11:10 : *Coffee break*

11:10-13:20 : *EuroGP 1, room W11*
    Applications of GP
    Chair: Ryan Urbanowicz

Quantum Program Synthesis: Swarm Algorithms and Benchmarks,
    Timothy Atkinson, John Drake, Athena Karsa, Jerry Swan   **37**

A genetic programming approach to predict mosquito abundance,
    Riccardo Gervasi, Irene Azzali, Donal Bisanzio, Andrea Mosca, Luigi Bertolotti, Mario Giacobini **38**

A Model of External Memory for Navigation in Partially Observable Visual Reinforcement Learning Tasks (Regular Paper),
    Robert Smith, Malcolm Heywood   **39**

Fault Detection and Classification for Induction Motors using Genetic Programming,
    Yu Zhang, Ting Hu, Xiaodong Liang, Mohammad Zawad Ali, Md Nasmus Sakib Khan Shabbir **40**

Fast DENSER: Efficient Deep NeuroEvolution,
    Filipe Assunção, Nuno Lourenço, Penousal Machado, Bernardete Ribeiro   **41**

A vectorial approach to genetic programming (Regular Paper),
    Irene Azzali, Leonardo Vanneschi, Sara Silva, Illya Bakurov, Mario Giacobini   **41**

Learning Class Disjointness Axioms Using Grammatical Evolution ,
    Thu Huong Nguyen, Andrea G.B. Tettamanzi   **42**

13:20-14:30 : *Lunch at Mensa Petersteinweg*

14:30-**16:20** : *EuroGP 2, room W11*
   Short papers 1, 15:00 Panel debate
   Chair: James McDermott

Comparison of Genetic Programming Methods on Design of Cryptographic Boolean Functions,
   Jakub Husa   *42*

Evolving AVX512 Parallel C Code using GP,
   William B Langdon, Ronny Lorenz   *43*

Hyper-bent Boolean Functions and Evolutionary Algorithms,
   Luca Mariot, Domagoj Jakobovic, Alberto Leporati, Stjepan Picek   *43*

16:20-**16:40** : *Coffee break*

16:40-**18:00** : *LBA Session, room W11*

18:30-**20:00** : *EvoStar poster session and conference reception*

April 25, 2019

EvoAPPS Programme

April 24, 2019

11:10-13:20 : *EvoApplications 1* Room W8 Short talks
   Chair: Pedro A. Castillo Valdivieso

14:30-16:20 : *EvoApplications 2* Room W8 Short talks
  Chair: Francisco Fernández de Vega

16:40-18:00 : *EvoApplications 3 - Robots and Engineering Applications* Room W8
  Chair: Kyrre Glette

Influence of Local Selection and Robot Swarm Density on the Distributed Evolution of GRNs,
  Iñaki Fernández Pérez, Stéphane Sanchez   **60**

Body Symmetry in Morphologically Evolving Modular Robots,
  Timon van de Velde, C. Rossi, A.E. (Gusz) Eiben   **60**

Trophallaxis, Low-power Vision Sensors andMulti-objective Heuristics for 3D Scene Reconstruction using Swarm Robotics,
  María Carrillo, Javier Sánchez-Cubillo, Eneko Osaba, Miren Nekane Bilbao, Javier Del Ser   **56**

Evolving Robots on Easy Mode: Towards a Variable Complexity Controller for Quadrupeds,
  Tønnes F. Nygaard, Charles P. Martin, Jim Torresen, Kyrre Glette   **57**

Introducing Weighted Intermediate Recombination in On-line Collective Robotics,
  Amine Boumaza   **57**

09:30-11:10 : *EvoApplications 4 - Engineering and Real World Applications* Room W8
  Chair: Sara Silva

Solving the Multi-Objective Flexible Job-Shop Scheduling Problem with Alternative Recipes for a Chemical Production Process,
  Piotr Dziurzanski, Shuai Zhao, Jerry Swan, Leandro Indrusiak, Sebastian Scholze, Karl Krone **62**

GA-Novo: De Novo Peptide Sequencing via Tandem Mass Spectrometry using Genetic Algorithm,
  Samaneh Azari, Bing Xue, Mengjie Zhang, Lifeng Peng **62**

Ant Colony Optimization for Optimized Operation Scheduling of Combined Heat and Power Plants,
  Johannes Mast, Stefan Rädle, Joachim Gerlach, Oliver Bringmann **63**

A Comparison of Different Many-Objective Optimization Algorithms for Energy System Optimization,
  Tobias Rodemann **63**

11:30-13:15 : *EvoApplications 5 - Engineering and Real World Applications* Room W8
  Chair: Giovanni Iacca

Design of Powered Floor Systems for Mobile Robots with Differential Evolution,
  Eric Medvet, Stefano Seriani, Alberto Bartoli, Paolo Gallina **64**

Quantifying the effects of increasing user choice in MAP-Elites applied to a Workforce Scheduling and Routing Problem,
  Neil Urquhart, Emma Hart, William Hutcheson **64**

A Biased Random Key Genetic Algorithm with Local Search Chains for Molecular Docking,
  Pablo Felipe Leonhart, Marcio Dorn **65**

A Cultural Algorithm for Determining Similarity Values Between Users in Recommender Systems,
  Kalyani Selvarajah, Ziad Kobti, Mehdi Kargar **65**

EvoCOP Programme

April 25, 2019

11:30-13:15 : *EvoCOP 1* Room W4
    Chair: Arnaud Liefooghe

Insights into the Feature Selection Problem using Local Optima Networks,
    Werner Mostert, Katherine Malan, Gabriela Ochoa, Andries Engelbrecht   **72**

A Unifying View on Recombination Spaces and Abstract Convex Evolutionary Search,
    Marcos Diez Garcia, Alberto Moraglio   **72**

Program Trace Optimization with Constructive Heuristics for Combinatorial Problems,
    James McDermott, Alberto Moraglio   **73**

Runtime Analysis of Discrete Particle Swarm Optimization Applied to Shortest Paths Computation,
    Alexander Rass, Jonas Schreiner, Rolf Wanka   **73**

14:15-16:00 : *EvoCOP 2* Room W4
    Chair: Gabriela Ochoa

A Binary Algebraic Differential Evolution for the MultiDimensional Two-Way Number Partitioning Problem,
    Valentino Santucci, Marco Baioletti, Gabriele Di Bari, Alfredo Milani   **74**

A Cooperative Optimization Approach for Distributing Service Points in Mobility Applications,
    Thomas Jatschka, Tobias Rodemann, Günther Raidl   **74**

A New Representation in Genetic Programming for Evolving Dispatching Rules for Dynamic Flexible Job Shop Scheduling,
    Fangfang Zhang, Yi Mei, Mengjie Zhang   **85**

16:20-18:00 : *EvoCOP 3* Room W4
   Chair: Francisco Chicano

April 26, 2019

10:00-11:30 : *EvoCOP 4* Room W4 Best paper nominations
   Chair: Luís Paquete

EvoMUSART Programme

April 24, 2019

11:10-13:20 : *EvoMusArt 1* Room W4 Visuals
  Chair: Aniko Ekart

14:30-16:20 : *EvoMusArt 2* Room W4 Audio
  Chair: Luz Castro

April 25, 2019

EvoStar Late Breaking Abstracts Programme

April 24, 2019

List of Abstracts - EuroGP

Quantum Program Synthesis: Swarm Algorithms and Benchmarks
Timothy Atkinson, John Drake, Athena Karsa, Jerry Swan
EuroGP 1, Room W11

In the two decades since Shor's celebrated quantum algorithm for integer factorisation, manual design has failed to produce the anticipated growth in the number of quantum algorithms. Hence, there is a great deal of interest in the the automatic synthesis of quantum circuits and algorithms. Here we present a set of experiments which use Ant Programming to automatically synthesise quantum circuits. In the proposed approach, ants choosing paths in high-dimensional Cartesian space are analogous to transformation of qubits in Hilbert space. In addition to the proposed algorithm, we introduce new evaluation criteria for searching the space of quantum circuits, both for classical simulation and simulation on a quantum computer. We demonstrate that the proposed approach significantly outperforms random search on a suite of benchmark problems based on these new measures.

A genetic programming approach to predict mosquito abundance

Riccardo Gervasi, Irene Azzali, Donal Bisanzio, Andrea Mosca, Luigi Bertolotti, Mario Giacobini
EuroGP 1, Room W11

In ecology, one of the main interests is to understand species population dynamics and to describe its link with various environmental factors, such as habitat characteristics and climate. It is especially important to study the behaviour of animal species that can hosts pathogens, as they can be potential disease reservoir and/or vectors. Pathogens of vector borne diseases can only be transmitted from an infected to a susceptible individual by a vector. Thus, vector ecology is a crucial factor influencing the transmission dynamics of vector borne diseases and their complexity. The formulation of models able to predict vector abundance are essential tools to implement intervention plans aiming to reduce the spread of vector-borne diseases (e.g. West Nile Virus). The goal of this paper is to explore the possible advantages in using Genetic Programming (GP) in the field of vector ecology. In this study, we present the application of GP to predict the distribution of Culex pipiens, a mosquito species vector of West Nile virus (WNV), in Piedmont, Italy. Our modelling approach took in consideration the ecological factors which affect mosquitoes abundance. Our results showed that GP was able to outperform a statistical model that was used to address the same problem in a previous work. Furthermore, GP performed an implicit feature selection, discovered automatically relationships among variables and produced fully explorable models.

A Model of External Memory for Navigation in Partially Observable Visual Reinforcement Learning Tasks

Robert Smith, Malcom Heywood
EuroGP 1, Room W11

Visual reinforcement learning implies that, decision making policies are identified under delayed rewards from an environment. Moreover, state information takes the form of high-dimensional data, such as video. In addition, although the video might characterize a 3D world in high resolution, partial observability will place significant limits on what the agent can actually perceive of the world. This means that the agent also has to: 1) provide efficient encodings of state, 2) store the encodings of state efficiently in some form of memory, 3) recall such memories after arbitrary delays for decision making. In this work, we demonstrate how an external memory model facilitates decision making in the complex world of multi-agent 'deathmatches' in the ViZDoom first person shooter environment. The ViZDoom environment provides a complex environment of multiple rooms and resources in which agents are spawned from multiple different locations. A unique approach is adopted to defining external memory for genetic programming agents in which: 1) the state of memory is shared across all programs. 2) Writing is formulated as a probabilistic process, resulting in different regions of memory having short- versus long-term memory. 3) Read operations are indexed, enabling programs to identify regions of external memory with specific temporal properties. We demonstrate that agents purposefully navigate the world when external memory is provided, whereas those without external memory are limited to merely 'flight or fight' behaviour.

Fault Detection and Classification for Induction Motors using Genetic Programming

Yu Zhang, Ting Hu, Xiaodong Liang, Mohammad Zawad Ali, Md Nasmus Sakib Khan Shabbir
EuroGP 1, Room W11

Induction motors are the workhorse in various industry sectors, and their accurate fault detection is essential to ensure reliable operation of critical industrial processes. Since various types of mechanical and electrical faults could occur, induction motor fault diagnosis can be interpreted as a multi-label classification problem. The current and vibration input data collected by monitoring a motor often require signal processing to extract features that can better characterize these waveforms. However, some extracted features may not be relevant to the classification, feature selection is thus necessary. Given such challenges, in recent years, machine learning methods, including decision trees and support vector machines, are increasingly applied to detect and classify induction motor faults. Genetic programming (GP), as a powerful automatic learning algorithm with its abilities of embedded feature selection and multi-label classification, has not been explored to solve this problem. In this paper, we propose a linear GP (LGP) algorithm to search predictive models for motor fault detection and classification. Our method is able to evolve multi-label classifiers with high accuracies using experimentally collected data in the lab by monitoring two induction motors. We also compare the results of the LGP algorithm to other commonly used machine learning algorithms, and are able to show its superior performance on both feature selection and classification.

Fast DENSER: Efficient Deep NeuroEvolution

Filipe Assunção, Nuno Lourenço, Penousal Machado, Bernardete Ribeiro
EuroGP 1, Room W11

The search for Artificial Neural Networks (ANNs) that are effective in solving a particular task is a long and time consuming trial-and-error process where we have to make decisions about the topology of the network, learning algorithm, and numerical parameters. To ease this process, we can resort to methods that seek to automatically optimise either the topology or simultaneously the topology and learning parameters of ANNs. The main issue of such approaches is that they require large amounts of computational resources, and take a long time to generate a solution that is considered acceptable for the problem at hand. The current paper extends Deep Evolutionary Network Structured Representation (DENSER): a general-purpose NeuroEvolution (NE) approach that combines the principles of Genetic Algorithms with Grammatical Evolution; to adapt DENSER to optimise networks of different structures, or to solve various problems the user only needs to change the grammar that is specified in a text human-readable format. The new method, Fast DENSER (F-DENSER), speeds up DENSER, and adds another representation-level that allows the connectivity of the layers to be evolved. The results demonstrate that F-DENSER has a speedup of 20 times when compared to the time DENSER takes to find the best solutions. Concerning the effectiveness of the approach, the results are highly competitive with the state-of-the-art, with the best performing network reporting an average test accuracy of 91.46

A vectorial approach to genetic programming

Irene Azzali, Leonardo Vanneschi, Sara Silva, Illya Bakurov, Mario Giacobini
EuroGP 1, Room W11

Among the various typologies of problems to which Genetic Programming (GP) has been applied since its origins, symbolic regression is one of the most popular. A common situation consists in the prediction of a target time series based on scalar features and other time series variables collected from multiple subjects. To manage this problem with GP data needs a panel representation where each observation corresponds to a collection on a subject at a precise time instant. However, representing data in this form may imply a loss of information: for instance, the algorithm may not be able to recognize observations belonging to the same subject and their recording order. To maintain the source of knowledge supplied by ordered sequences as time series, we propose a new approach to GP that keeps instances of the same observation together in a vector, introducing vectorial variables as terminals. This new representation allows aggregate functions in the primitive GP set, included with the purpose of describing the behaviour of vectorial variables. In this work, we perform a comparative analysis of vectorial GP (VE-GP) against standard GP (ST-GP). Experiments are conducted on different benchmark problems to highlight the advantages of this new approach.

Learning Class Disjointness Axioms Using Grammatical Evolution
Thu Huong Nguyen, Andrea G.B. Tettamanzi
EuroGP 1, Room W11

Today, with the development of the Semantic Web, Linked Open Data (LOD),expressed using the Resource Description Framework (RDF),has reached the status of "big data" and can be considered as a giant data resource from which knowledge can be discovered. The process of learning knowledge defined in terms of OWL2 axioms from the RDF datasets can be viewed as a special case of knowledge discovery from data or "data mining", which can be called "RDF mining". The approaches to automated generation of the axioms from recorded RDF facts on the Web may be regarded as a case of inductive reasoning and ontology learning. The instances, represented by RDF triples, play the role of specific observations, from which axioms can be extracted by generalization. Based on the insight that discovering new knowledge is essentially an evolutionary process, whereby hypotheses are generated by some heuristic mechanism and then tested against the available evidence, so that only the best hypotheses survive, we propose the use of Grammatical Evolution, one type of evolutionary algorithm, for mining disjointness OWL2 axioms from an RDF data repository such as DBPedia. For the evaluation of candidate axioms against the DBPedia dataset, we adopt an approach based on possibility theory.

Comparison of Genetic Programming Methods on Design of Cryptographic Boolean Functions
Jakub Husa
EuroGP 2, Room W11

The ever-increasing need for information security requires a constant refinement of contemporary ciphers. One of these are stream ciphers which secure data by utilizing a pseudo-randomly generated binary sequence. Generating a cryptographically secure sequence is not an easy task and requires a Boolean function possessing multiple cryptographic properties. One of the most successful ways of designing these functions is genetic programming. In this paper, we present a comparative study of three genetic programming methods, tree-based, Cartesian and linear, on the task of generating Boolean functions with an even number of inputs possessing good values of nonlinearity, balancedness, correlation immunity, and algebraic degree. Our results provide a comprehensive overview of how genetic programming methods compare when designing functions of different sizes, and we show that linear genetic programming, which has not been used for design of some of these functions before, is the best at dealing with increasing number of inputs, and creates desired functions with better reliability than the commonly used methods.

Evolving AVX512 Parallel C Code using GP
William B Langdon, Ronny Lorenz
EuroGP 2, Room W11

Using 512 bit Advanced Vector Extensions (AVX), previous development history and Intel documentation, BNF grammar based genetic programming automatically ports RNAfold to AVX, giving up to a 1.77 fold speed up.

Hyper-bent Boolean Functions and Evolutionary Algorithms
Luca Mariot, Domagoj Jakobovic, Alberto Leporati, Stjepan Picek
EuroGP 2, Room W11

Bent Boolean functions play an important role in the design of secure symmetric ciphers, since they achieve the maximum distance from affine functions allowed by Parseval's relation. Hyper-bent functions, in turn, are those bent functions which additionally reach maximum distance from all bijective monomial functions, and provide further security towards approximation attacks. Being characterized by a stricter definition, hyper-bent functions are rarer than bent functions, and much more difficult to construct. In this paper, we employ several evolutionary algorithms in order to evolve hyper-bent Boolean functions of various sizes. Our results show that hyper-bent functions are extremely difficult to evolve, since we manage to find such functions only for the smallest investigated size. Interestingly, we are able to identify this difficulty as not lying in the evolution of hyper-bent functions itself, but rather in evolving some of their components, i.e. bent functions. Finally, we present an additional parameter to evaluate the performance of evolutionary algorithms when evolving Boolean functions: the diversity of the obtained solutions.

Complex Network Analysis of a Genetic Programming Phenotype Network
Ting Hu, Marco Tomassini, Wolfgang Banzhaf
EuroGP 3, Room W11

The genotype-to-phenotype mapping plays an essential role in the design of an evolutionary algorithm. Since variation occurs at the genotypic level but fitness is evaluated at the phenotypic level, this mapping determines how variations are effectively translated into quality improvements. We numerically study the redundant genotype-to-phenotype mapping of a simple Boolean linear genetic programming system. In particular, we investigate the resulting phenotypic network using tools of complex network analysis. The analysis yields a number of interesting statistics of this network, considered both as a directed as well as an undirected graph. We show by numerical simulation that less redundant phenotypes are more difficult to find as targets of a search than others that have much more genotypic abundance. We connect this observation with the fact that hard to find phenotypes tend to belong to small and almost isolated clusters in the phenotypic network.

Improving Genetic Programming with Novel Exploration - Exploitation Control
Jonathan Kelly, Erik Hemberg, Una-May O'Reilly
EuroGP 3, Room W11

Low population diversity is recognized as a factor in premature convergence of evolutionary algorithms. We investigate program synthesis performance via grammatical evolution. We focus on novelty search – substituting the conventional search objective – based on synthesis quality, with a novelty objective. This prompts us to introduce a new selection method named knobelty. It parametrically balances exploration and exploitation by creating a mixed population of parents. One subset is chosen based on performance quality and the other subset is chosen based on diversity. Three versions of this method, two that adaptively tune balance during evolution solve program synthesis problems more accurately, faster and with less duplication than grammatical evolution with lexicase selection.

Cartesian Genetic Programming as an Optimizer of Programs Evolved with Geometric Semantic Genetic Programming

Ondrej Koncal, Lukas Sekanina
EuroGP 3, Room W11

In Geometric Semantic Genetic Programming (GSGP), genetic operators directly work at the level of semantics rather than syntax. It provides many advantages, including much higher quality of resulting individuals (in terms of error) in comparison with a common genetic programming. However, GSGP produces extremely huge solutions that could be difficult to apply in systems with limited resources such as embedded systems. We propose Subtree Cartesian Genetic Programming (SCGP) – a method capable of reducing the number of nodes in the trees generated by GSGP. SCGP executes a common Cartesian Genetic Programming (CGP) on all elementary subtrees created by GSGP and on various compositions of these optimized subtrees in order to create one compact representation of the original program. SCGP does not guarantee the (exact) semantic equivalence between the CGP individuals and the GSGP subtrees, but the user can define conditions when a particular CGP individual is acceptable. We evaluated SCGP on four common symbolic regression benchmark problems and the obtained node reduction is from 92.4% to 99.9%.

Ariadne: Evolving test data using Grammatical Evolution

Muhammad Sheraz Anjum, Conor Ryan
EuroGP 3, Room W11

Software testing is a key component in software quality assurance; it typically involves generating test data that exercises all instructions and tested conditions in a program and, due to its complexity, can consume as much as 50% of overall software development budget. Some evolutionary computing techniques have been successfully applied to automate the process of test data generation but no existing techniques exploit variable interdependencies in the process of test data generation, even though several studies from the software testing literature suggest that the variables examined in the branching conditions of real life programs are often interdependent on each other, for example, if (x==y), etc.

We propose the Ariadne system which uses Grammatical Evolution (GE) and a simple Attribute Grammar to exploit the variable interdependencies in the process of test data generation. Our results show that Ariadne dramatically improves both effectiveness and efficiency when compared with existing techniques based upon well-established criteria, attaining coverage (the standard software testing success metric for these sorts of problems) of 100% on all benchmarks with far fewer program evaluations (often between a third and a tenth of other systems).

Solution and Fitness Evolution (SAFE): Coevolving Solutions and Their Objective Functions

Moshe Sipper, Jason Moore, Ryan Urbanowicz

EuroGP 4, Room W11

We recently highlighted a fundamental problem recognized to confound algorithmic optimization, namely, conflating the objective with the objective function. Even when the former is well defined, the latter may not be obvious, e.g., in learning a strategy to navigate a maze to find a goal (objective), an effective objective function to evaluate strategies may not be a simple function of the distance to the objective. We proposed to automate the means by which a good objective function may be discovered—a proposal reified herein. We present Solution And Fitness Evolution (SAFE), a commensalistic coevolutionary algorithm that maintains two coevolving populations: a population of candidate solutions and a population of candidate objective functions. As proof of principle of this concept, we show that SAFE successfully evolves not only solutions within a robotic maze domain, but also the objective functions needed to measure solution quality during evolution.

Towards a Scalable EA-based Optimization of Digital Circuits

Jitka Kocnova, Zdenek Vasicek

EuroGP 4, Room W11

Scalability of fitness evaluation was the main bottleneck preventing adopting the evolution in the task of logic circuits synthesis since early nineties. Recently, various formal approaches have been introduced to this field to overcome this issue. This made it possible to optimise complex circuits consisting of hundreds of inputs and thousands of gates. Unfortunately, we are facing to the another problem - scalability of representation. The efficiency of the evolutionary optimization applied at the global level deteriorates with the increasing complexity. In this paper, we propose to apply the concept of local resynthesis. Resynthesis is an iterative process based on extraction of smaller sub-circuits from a complex circuit that are optimized locally and implanted back to the original circuit. When applied appropriately, this approach can mitigate the problem of scalability of representation. Our evaluation on a set of nontrivial real-world benchmark problems shows that the proposed method provides better results compared to global evolutionary optimization. In more than 60% cases, substantially higher number of redundant gates was removed while keeping the computational effort at the same level.

Can Genetic Programming Do Manifold Learning Too?
Andrew Lensen, Bing Xue, Mengjie Zhang
EuroGP 4, Room W11

Exploratory data analysis is a fundamental aspect of knowledge discovery that aims to find the main characteristics of a dataset. Dimensionality reduction, such as manifold learning, is often used to reduce the number of features in a dataset to a manageable level for human interpretation. Despite this, most manifold learning techniques do not explain anything about the original features nor the true characteristics of a dataset. In this paper, we propose a genetic programming approach to manifold learning called GP-MaL which evolves functional mappings from a high-dimensional space to a lower dimensional space through the use of interpretable trees. We show that GP-MaL is competitive with existing manifold learning algorithms, while producing models that can be interpreted and re-used on unseen data. A number of promising future directions of research are found in the process.

Why is Auto-Encoding Difficult for Genetic Programming?
James McDermott
EuroGP 4, Room W11

Unsupervised learning is an important component in many recent successes in machine learning. The autoencoder neural network is one of the most prominent approaches to unsupervised learning. Here, we use the genetic programming paradigm to create autoencoders and find that the task is difficult for genetic programming, even on small datasets which are easy for neural networks. We investigate which aspects of the autoencoding task are difficult for genetic programming.

List of Abstracts - EvoApplications

Efficient Online Hyperparameter Adaptation for Deep Reinforcement Learning
Yinda Zhou, Weiming Liu, Bin Li
EvoApplications 1

Deep Reinforcement Learning (DRL) has shown its extraordinary performance on a variety of challenging learning tasks, especially those in games. It has been recognized that DRL process is a high-dynamic and non-stationary optimization process even in the static environments, their performance is notoriously sensitive to the hyperparameter configuration which includes learning rate, discount coefficient, and step size, etc. The situation will be more serious when DRL is conducting in a changing environment. The most ideal state of hyperparameter configuration in DRL is that the hyperparameter can self-adapt to the best values promptly for their current learning state, rather than using a fixed set of hyperparameters for the whole course of training like most previous works did. In this paper, an efficient online hyperparameter adaptation method is presented, which is an improved version of Population-based Training (PBT) method on the promptness of adaptation. A recombination operation inspired by GA is introduced into the population adaptation to accelerating the convergence of the population towards the better hyperparameter configurations. Experiment results have shown that in four test environments, the presented method has achieved 92%, 70%, 2% and 15% performance improvement over PBT.

Free Form Evolution for Angry Birds Level Generation
Laura Calle, JJ Merelo, Mario Garcia-Valdez, Antonio Mora-García
EvoApplications 1

This paper presents an original approach for building structures that are stable under gravity for the physics-based puzzle game Angry Birds, with the ultimate objective of creating fun and aesthetically pleasing Angry Birds levels with the minimum number of constraints. This approach consists of a search-based procedural level generation method that uses evolutionary algorithms. In order to evaluate the stability of the levels, they are executed in an adaptation of an open source version of the game called *Science Birds*. In the same way, an open source evolutionary computation framework has been implemented to fit the requirements of the problem. The main challenge has been to design a fitness function that, first, avoids if possible the actual execution of the simulator, which is time consuming, and, then, to take

GAMER: A Genetic Algorithm with Motion Encoding Reuse for action-adventure video games
Tasos Papagiannis, Georgios Alexandridis, Andreas Stafylopatis
EvoApplications 1

Genetic Algorithms (GAs) have been predominantly used in video games for finding the best possible sequence of actions that leads to a win condition. This work sets out to investigate an alternative application of GAs on action-adventure type video games. The main intuition is to encode actions depending on the state of the world of the game instead of the sequence of actions, like most of the other GA approaches do. Additionally, a methodology is being introduced which modifies a part of the agent's logic and reuses it in another game. The proposed algorithm has been implemented in the GVG-AI competition's framework and more specifically for the Zelda and Portals games. The obtained results, in terms of average score and win percentage, seem quite satisfactory and highlight the advantages of the suggested technique, especially when compared to a rolling horizon GA implementation of the aforementioned framework; firstly, the agent is efficient at various levels (different world topologies) after being trained in only one of them and secondly, the agent may be generalized to play more games of the same category.

Memetic Evolution of Classification Ensembles
Szymon Piechaczek, Michal Kawulok, Jakub Nalepa
EvoApplications 1

Creating classification ensembles may be perceived as a regularization technique which aims at improving the generalization capabilities of a classifier. In this paper, we introduce a multi-level memetic algorithm for evolving classification ensembles (they can be either homo- or heterogeneous). First, we evolve the content of such ensembles, and then we optimize the weights (both for the classifiers and for different classes) exploited while voting. The experimental study showed that our memetic algorithm retrieves high-quality heterogeneous ensembles, and can effectively deal with small training sets in multi-class classification.

Variable length representation for EC-based feature selection in high-dimensional data

Nicole Dalia Cilia, Claudio De Stefano, Francesco Fontanella, Alessandra Scotto di Freca
EvoApplications 1

Feature selection is a challenging problem, especially when hundreds or thousands of features are involved. Evolutionary Computation based techniques and in particular genetic algorithms, because of their ability to explore large and complex search spaces, have proven to be effective in solving such kind of problems. Though genetic algorithms binary strings provide a natural way to represent feature subsets, several different representation schemes have been proposed to improve the performance, with most of them needing to a priori set the number of features. In this paper, we propose a novel variable length representation, in which feature subsets are represented by lists of integers. We also devised a crossover operator to cope with the variable length representation. The proposed approach has been tested on several datasets and the results compared with those achieved by a standard genetic algorithm. Results of comparisons demonstrated the effectiveness of the proposed approach in improving the performance obtainable with a standard genetic algorithm when thousand of features are involved.

Optimizing the C Index Using a Canonical Genetic Algorithm

Thomas Runkler, James Bezdek
EvoApplications 1

Clustering is an important family of unsupervised machine learning methods. Cluster validity indices are widely used to assess the quality of obtained clustering results. The C index is one of the most popular cluster validity indices. This paper shows that the C index can be used not only to validate but also to actually find clusters. This leads to difficult discrete optimization problems which can be approximately solved by a canonical genetic algorithm. Numerical experiments compare this novel approach to the well-known c-means and single linkage clustering algorithms. For all five considered popular real-world benchmark data sets the proposed method yields a better C index than any of the other (pure) clustering methods.

A Knowledge Based Differential Evolution Algorithm for Protein Structure Prediction

Pedro Henrique Narloch, Marcio Dorn, Pedro Henrique Narloch; Marcio Dorn

EvoApplications 1

Three-dimensional protein structure prediction is an open-challenging problem in Structural Bioinformatics and classified as an NP-complete problem in computational complexity theory. As exact algorithms cannot solve this type of problem, metaheuristics became useful strategies to find solutions in viable computational time. In this way, we analyze four standard mutation mechanisms present in Differential Evolution algorithms using the Angle Probability List as a source of information to predict tertiary protein structures, something not explored yet with Differential Evolution. As the balance between diversification and intensification is an essential fact during the optimization process, we also analyzed how the Angle Probability List might influence the algorithm behavior, something not investigated in other algorithms. Our tests reinforce that the use of structural data is a crucial factor to reach better results. Furthermore, combining experimental data in the optimization process can help the algorithm to avoid premature convergence, maintaining population diversity during the whole process and, consequently, reaching better conformational results.

Early Detection of Botnet Activities using Grammatical Evolution

Selim Yilmaz, Sevil Sen, Selim Yilmaz, Sevil Sen

EvoApplications 1

There have been numerous studies proposed for detecting botnets in the literature. However, it is still a challenging issue as most of the proposed systems are unable to detect botnets in their early stage and they cannot perform satisfying performance on new forms of botnets. In this study, we propose an evolutionary computation-based approach that relies on grammatical evolution to generate a botnet detection algorithm automatically. The performance of the proposed flow-based detection system reveals that it detects botnets accurately in their very early stage and performs better than most of the existing methods.

Exploring concurrent and stateless evolutionary algorithms
JJ Merelo, JLJ Laredo, Pedro Castillo, Mario Garcia Valdez, Sergio Rojas
EvoApplications 1

Creating a concurrent and stateless version of an evolutionary algorithm implies changes in its behavior. From the performance point of view, the main challenge is to balance computation with communication, but from the algorithmic point of view we have to keep diversity high so that the algorithm is not stuck in local minima. In a concurrent setting, we will have to find the right balance so that improvements in both fields do not cancel out. This is what we will be doing in this paper, where we explore the space of parameters of a population based concurrent evolutionary algorithm to find out the best combination for a particular problem.

Evolving Trust Formula to Evaluate Data Trustworthiness in VANETs Using Genetic Programming
Mehmet Aslan, Sevil Sen
EvoApplications 1

Vehicular Ad Hoc Networks (VANETs) provide traffic safety, improve traffic efficiency and present infotainment by sending messages about events on the road. Trust is widely used to distinguish genuine messages from fake ones. However, trust management in VANETs is a challenging area due to their dynamically changing and decentralized topology. In this study, a genetic programming based trust management model for VANETs is proposed to properly evaluate trustworthiness of data about events. A large number of features is introduced in order to take into account VANETs' complex characteristics. Simulations with bogus information attack scenarios show that the proposed trust model considerably increase the security of the network.

Prolong the network lifetime of Wireless Underground Sensor Networks by optimal relay node placement

Tam Nguyen Thi, Binh Huynh Thi Thanh, Hung Tran Huy, Dung Dinh Anh, Vinh Le Trong
EvoApplications 1

Wireless Underground Sensor Networks (WUSNs) have received attention in the past years because of their popularity and cost-effectiveness when they are used in many practical fields such as military applications, environmental applications, and home applications. In WUSNs, sensors are deployed with limited power, once their power is out of, the sensors are ineffectual. The extension of the networks lifetime is a critical issue in WUSNs, making it a topic of much interest in research. Several approaches have been proposed to keep the sensor nodes active, one of which is deploying relay nodes above ground to transfer data from sensor nodes to the base station. However, this method has faced issues, such as balancing the load of relay nodes and the increased transmission loss between relay nodes and sensor nodes. This paper addresses this concern and proposes two heuristics named Beam Genitor Search and Connection Swap for the relay node placement problem to guarantee load balance among relay nodes and maximize network lifetime. Our experiments show that the proposed methods result in significantly better quality solutions (longer network lifetime) for the problem when compared to the existing methods.

Coevolution of Generative Adversarial Networks

Victor Costa, Nuno Lourenço, Penousal Machado
EvoApplications 2

Generative adversarial networks (GAN) became a hot topic, presenting impressive results in the field of computer vision. However, there are still open problems with the GAN model, such as the training stability and the hand-design of architectures. Neuroevolution is a technique that can be used to provide the automatic design of network architectures even in large search spaces as in deep neural networks. Therefore, this project proposes COEGAN, a model that combines neuroevolution and coevolution in the coordination of the GAN training algorithm. The proposal uses the adversarial characteristic between the generator and discriminator components to design an algorithm using coevolution techniques. Our proposal was evaluated in the MNIST dataset. The results suggest the improvement of the training stability and the automatic discovery of efficient network architectures for GANs. Our model also partially solves the mode collapse problem.

Compact Optimization Algorithms with Re-sampled Inheritance

Giovanni Iacca, Fabio Caraffini

EvoApplications 2

Compact optimization algorithms are a class of Estimation of Distribution Algorithms (EDAs) characterized by extremely limited memory requirements (hence they are called "compact"). As all EDAs, compact algorithms build and update a probabilistic model of the distribution of solutions within the search space, as opposed to population-based algorithms that instead make use of an explicit population of solutions. In addition to that, to keep their memory consumption low, compact algorithms purposely employ simple probabilistic models that can be described with a small number of parameters. Despite their simplicity, compact algorithms have shown good performances on a broad range of benchmark functions and real-world problems. However, compact algorithms also come with some drawbacks, i.e. they tend to premature convergence and show poorer performance on non-separable problems. To overcome these limitations, here we investigate a possible algorithmic scheme obtained by combining compact algorithms with a non-disruptive restart mechanism taken from the literature, named Re-Sampled Inheritance (RI). The resulting compact algorithms with RI are tested on the CEC 2014 benchmark functions. The numerical results show on the one hand that the use of RI consistently enhances the performances of compact algorithms, still keeping a limited usage of memory. On the other hand, our experiments show that among the tested algorithms, the best performance is obtained by compact Differential Evolution with RI.

Fundamental Flowers: Evolutionary Discovery of Coresets for Classification

Pietro Barbiero, Alberto Tonda

EvoApplications 2

In an optimization problem, a coreset can be defined as a subset of the input points, such that a good approximation to the optimization problem can be obtained by solving it directly on the coreset, instead of using the whole original input. In machine learning, coresets are exploited for applications ranging from speeding up training time, to helping humans understand the fundamental properties of a class, by considering only a few meaningful samples. The problem of discovering coresets, starting from a dataset and an application, can be defined as identifying the minimal amount of samples that do not significangly lower performance with respect to the performance on the whole dataset. Specialized literature offers several approaches to finding coresets, but such algorithms often disregard the application, or explicitly ask the user for the desired number of points. Starting from the consideration that finding coresets is an intuitively multi-objective problem, as minimizing the number of points goes against maintaining the original performance, in this paper we propose a multi-objective evolutionary approach to identifying coresets for classification. The proposed approach is tested on classical machine learning classification benchmarks, using 6 state-of-the-art classifiers, comparing against 7 algorithms for coreset discovery. Results show that not only the proposed approach is able to find coresets representing different compromises between compactness and performance, but that different coresets are identified for different classifiers, reinforcing the assumption that coresets might be closely linked to the specific application.

Trophallaxis, Low-power Vision Sensors andMulti-objective Heuristics for 3D Scene Reconstruction using Swarm Robotics

María Carrillo, Javier Sánchez-Cubillo, Eneko Osaba, Miren Nekane Bilbao, Javier Del Ser
EvoApplications 2

A profitable strand of literature has lately capitalized on the exploitation of the collaborative capabilities of robotic swarms for efficiently undertaking diverse tasks without any human intervention, ranging from the blind exploration of devastated areas after massive disasters to mechanical repairs of industrial machinery in hostile environments, among others. However, most contributions reported to date deal only with robotic missions driven by a single task-related metric to be optimized by the robotic swarm, even though other objectives such as energy consumption may conflict with the imposed goal. In this paper four multi-objective heuristic solvers, namely NSGA-II, NSGA-III, MOEA/D and SMPSO, are used to command and route a set of robots towards efficiently reconstructing a scene using simple camera sensors and stereo vision in two phases: explore the area and then achieve validated map points. The need for resorting to multi-objective heuristics stems, from the consideration of energy efficiency as a second target of the mission plan. In this regard, by incorporating energy trophallaxis within the swarm, overall autonomy is increased. An environment is arranged in V-REP to shed light on the performance over a realistically emulated physical environment. SMPSO shows better exploration capabilities during the first phase of the mission. However, in the second phase the performance of SMPSO degrades in contrast to NSGA-II and NSGA-III. Moreover, the entire robotic swarm is able to return to the original departure position in all the simulations. The obtained results stimulate further research lines aimed at considering decentralized heuristics for the considered problem.

Evolving Robots on Easy Mode: Towards a Variable Complexity Controller for Quadrupeds

Tønnes F. Nygaard, Charles P. Martin, Jim Torresen, Kyrre Glette

EvoApplications 2

The complexity of a legged robot's environment or task can inform how specialised its gait must be to ensure success. Evolving specialised robotic gaits demands many evaluations - acceptable for computer simulations, but not for physical robots. For some tasks, a more general gait, with lower optimization costs, could be satisfactory. In this paper, we introduce a new type of gait controller where complexity can be set by a single parameter, using a dynamic genotype-phenotype mapping. Low controller complexity leads to conservative gaits, while higher complexity allows more sophistication and high performance for demanding tasks, at the cost of optimization effort. We investigate the new controller on a virtual robot in simulations and do preliminary testing on a real-world robot. We show that having variable complexity allows us to adapt to different optimization budgets. With a high evaluation budget in simulation, a complex controller performs best. Moreover, real-world evolution with a limited evaluation budget indicates that a lower gait complexity is preferable for a relatively simple environment.

Introducing Weighted Intermediate Recombination in On-line Collective Robotics

Amine Boumaza

EvoApplications 2

Weighted intermediate recombination has been proven very useful in evolution strategies. We propose here to use it in the case of on-line embodied evolutionary algorithms. With this recombination scheme, solutions at the local populations are recombined using a weighted average that favors fitter solutions to produce a new solution. We describe the newly proposed algorithm which we dubbed (mu/mu W, 1)-On-line EEA, and assess it performance on two swarm robotics benchmarks while comparing the results to other existing algorithms. The experiments show that the recombination scheme is very beneficial on these problems.

Evolutionary successful strategies in a transparent iterated Prisoner's Dilemma

Anton M. Unakafov, Thomas Schultze, Igor Kagan, Sebastian Moeller, Alexander Gail, Stefan Treue, Stephan Eule, Fred Wolf
EvoApplications 2

A Transparent game is a game-theoretic setting that takes action visibility into account. In each round, depending on the relative timing of their actions, players have a certain probability to see their partner's choice before making their own decision. This probability is determined by the level of transparency. At the two extremes a game with zero transparency is equivalent to the classical simultaneous game, and a game with maximal transparency corresponds to a sequential game. Despite the prevalence of intermediate transparency in many everyday interactions such scenarios have not been sufficiently studied. Here we consider a transparent iterated Prisoner's dilemma (iPD) and use evolutionary simulations to investigate how and why the success of various strategies changes with the level of transparency. We demonstrate that non-zero transparency greatly reduces the set of successful memory-one strategies compared to the simultaneous iPD. For low and moderate transparency the classical "Win - Stay, Lose - Shift" (WSLS) strategy is the only evolutionary successful strategy. For high transparency all strategies are evolutionary unstable in the sense that they can be easily counteracted, and, finally, for maximal transparency a novel "Leader-Follower" strategy outperforms WSLS. Our results provide a partial explanation for the fact that the strategies proposed for the simultaneous iPD are rarely observed in nature, where high levels of transparency are common.

Evolutionary Computation Techniques for Constructing SAT-based Attacks in Algebraic Cryptanalysis

Artyom Pavlenko, Alexander Semenov, Vladimir Ulyantsev
EvoApplications 2

In this paper we present the results on applying evolutionary computation techniques to construction of several cryptographic attacks. In particular, SAT-based guess-and-determine attacks studied in the context of algebraic cryptanalysis. Each of these attacks is built upon some set of Boolean variables, thus it can be specified by a Boolean vector. We use two general evolutionary strategies to find an optimal vector: (1+1)-EA and GA. Based on these strategies parallel algorithms (based on modern SAT-solvers) for solving the problem of minimization of a special pseudo-Boolean function are implemented. This function is a fitness function used to evaluate the runtime of a guess-and-determine attack. We compare the efficiency of (1+1)-EA and GA with the algorithm from the Tabu search class, that was earlier used to solve related problems. Our GA-based solution showed the best results on a number of test instances, namely, cryptanalysis problems of several stream ciphers (cryptographic keystream generators).

On the Use of Evolutionary Computation for In-Silico Medicine: Modelling Sepsis via Evolving Continuous Petri Nets

Ahmed Hallawa, Elisabeth Zechendorf, Yi Song, Anke Schmeink, Arne Peine, Lukas Martin, Gerd Ascheid, Guido Dartmann

EvoApplications 2

Sepsis is one of the leading causes of death in Intensive Care Units (ICU) world-wide. Continuous Petri Nets (CPNs) offer a promising solution in modelling its underlying, complex pathophysiological processes. In this work, we propose a framework to evolve CPNs, i.e. evolve its places, transitions, arc weights, topology, and kinetics. This facilitates modeling complex biological systems, including activated signalling pathway in sepsis using limited experimental data. Inspired by Neuroevolution of Augmenting Toplogies (NEAT), which is adopted in Artificial Neural Networks (ANNs), our framework includes a genotype to phenotype mapping based on the CPN incidence matrix, and a fitness function, which considers both the behaviour of the evolving CPN and its emerging structural complexity. We tested our framework on ten different cases with different complexity structures. In the worst case, results show the NMSE less than 2

Influence of Local Selection and Robot Swarm Density on the Distributed Evolution of GRNs

Iñaki Fernández Pérez, Stéphane Sanchez
EvoApplications 3 - Robots and Engineering Applications

Distributed Embodied Evolution (dEE) is a powerful approach to learn behaviors in robot swarms by exploiting their intrinsic parallelism: each robot runs an evolutionary algorithm, and locally shares its learning experience with other nearby robots. Given the distributed nature of this approach, dEE entails different evolutionary dynamics when compared to standard centralized Evolutionary Robotics. In this paper, we investigate the distributed evolution of Gene Regulatory Networks (GRNs) as controller representation to learn swarm robot behavior, which have been extensively used for the evolution of single- robot behavior with remarkable success. Concretely, we use dEE to evolve fixed-topology GRN swarm robot controllers for an item collection task; this constitutes the first work to evolve GRNs in distributed swarm robot settings. To improve our understanding of such distributed GRN evolution, we analyze the fitness and the behavioral diversity of the swarm over generations when using 5 levels of increasing local selection pressure and 4 different swarm sizes, from 25 to 200 robots. Our experiments reveal that there exist different regimes, depending on the swarm size, in the relationship between local selection pressure, and both behavioral diversity and overall swarm performance, providing several insights on distributed evolution. We further use a metric to quantify selection pressure in evolutionary systems, which is based on the correlation between number of offspring and fitness of the behaviors. This reveals a complex relationship on the overall selection pressure between the ability or ease to spread genomes (or environmental pressure), and the fitness of the behavior (or task-oriented (local) pressure), opening new research questions. We conclude the paper by discussing the need for developing specialized statistical tools to facilitate the analysis of the large and diverse amount of data relevant to distributed Embodied Evolution.

Body Symmetry in Morphologically Evolving Modular Robots

T. van de Velde, C. Rossi, A.E. Eiben
EvoApplications 3 - Robots and Engineering Applications

Almost all animals natural evolution has produced on Earth have a symmetrical body. In this paper we investigate the evolution of body symmetry in an artificial system where robots evolve. To this end, we define several measures to quantify symmetry in modular robots and see how these relate to fitness that corresponds to a locomotion task. We find that, although there is only a weak correlation between symmetry and fitness over the course of a single evolutionary run, there is a positive correlation between the level of symmetry and maximum fitness when a set of runs is taken into account.

A Hybrid Multiobjective Differential Evolution Approach to Stator Winding Optimization

André Silva, Fernando Ferreira, Carlos Antunes

EvoApplications 3 - Robots and Engineering Applications

This paper describes a multiobjective differential evolution approach to the optimization of the design of alternating current distributed stator windings of electric motors. The objective functions are minimizing both the machine airgap magnetomotive force distortion and the winding wire length. Constraints are related to the physical feasibility of solutions. Four distinct winding types are considered. Three mutation variations of the multiobjective differential evolution algorithm are developed and assessed using different performance metrics. These algorithmic approaches are able to generate well-distributed, uniformly spread solutions on the nondominated front. The characterization of the nondominated fronts conveys helpful information for aiding design engineers to choose the most suitable compromise solution for a specific machine, embodying a balanced trade-off between machine efficiency and manufacturing cost.

A flexible dissimilarity measure for active and passive 3D structures and its application in the fitness-distance analysis

Maciej Komosinski, Agnieszka Mensfelt

EvoApplications 3 - Robots and Engineering Applications

Evolutionary design of 3D structures - either static structures, or equipped with some sort of a control system - is one of the hardest optimization tasks. One of the reasons are rugged fitness landscapes resulting from complex and non-obvious genetic representations of such structures and their genetic operators. This paper investigates global convexity of fitness landscapes in optimization tasks of maximizing velocity and height of both active and passive structures. For this purpose, a new dissimilarity measure for 3D active and passive structures represented as undirected graphs is introduced. The proposed measure is general and flexible - any vertex properties can be easily incorporated as dissimilarity components. The new measure was compared against the previously introduced measure in terms of triangle inequality satisfiability, changes in raw measure values and the computational cost. The comparison revealed improvements for triangle inequality and raw values at the expense of increased computational complexity. The investigation of global convexity of the fitness landscape, involving the fitness-distance correlation analysis, revealed negative correlation between the dissimilarity of the structures and their fitness for most of the investigated cases.

Solving the Multi-Objective Flexible Job-Shop Scheduling Problem with Alternative Recipes for a Chemical Production Process

Piotr Dziurzanski, Shuai Zhao, Jerry Swan, Leandro Indrusiak, Sebastian Scholze, Karl Krone
EvoApplications 4 - Engineering and Real World Applications

This paper considers a new variant of a multi-objective flexible job-shop scheduling problem, featuring multisubset selection of manufactured recipes. We propose a novel associated chromosome encoding and customise the classic MOEA/D multi-objective genetic algorithm with new genetic operators. The applicability of the proposed approach is evaluated experimentally and showed to outperform typical multi-objective genetic algorithms. The problem variant is motivated by real-world manufacturing in a chemical plant and is applicable to other plants that manufacture goods using alternative recipes.

GA-Novo: De Novo Peptide Sequencing via Tandem Mass Spectrometry using Genetic Algorithm

Samaneh Azari, Bing Xue, Mengjie Zhang, Lifeng Peng
EvoApplications 4 - Engineering and Real World Applications

Proteomics is the large-scale analysis of the proteins. The common method for identifying proteins and characterising their amino acid sequences is to digest the proteins into peptides, analyse the peptides using mass spectrometry and assign the resulting tandem mass spectra (MS/MS) to peptides using database search tools. However, database search algorithms are highly dependent on a reference protein database and they cannot identify peptides and proteins not included in the database. Therefore, de novo sequencing algorithms are developed to overcome the problem by directly reconstructing the peptide sequence of an MS/MS spectrum without using any protein database. Current de novo sequencing algorithms often fail to construct the completely matched sequences, and produce partial matches. In this study, we propose a genetic algorithm based method, GA-Novo, to solve the complex optimisation task of de novo peptide sequencing, aiming at constructing full length sequences. Given an MS/MS spectrum, GA-Novo optimises the amino acid sequences to best fit the input spectrum. On the testing dataset, GA-Novo outperforms PEAKS, the most commonly used software for this task, by constructing 8

Ant Colony Optimization for Optimized Operation Scheduling of Combined Heat and Power Plants

Johannes Mast, Stefan Rädle, Joachim Gerlach, Oliver Bringmann
EvoApplications 4 - Engineering and Real World Applications

In the worldwide expansion of renewable energies, there is not only a need for weather-dependent plants, but also for plants with flexible power generation that have the potential to reduce storage requirements by working against fluctuations. A highly promising technology is provided by Combined heat and power (CHP) plants, which achieve high efficiencies through the simultaneous generation of electricity and heat. This is why they are also being promoted by the European Union. Also, the construction of biogas plants is usually linked to the construction of CHP plants in order to generate energy from the emission-free produced biogas. However, until now CHP plants have mostly been operated by heat demand (just like boilers), causing the generated electricity often to put additional stress on the power grid. The planning of a CHP plant, whose generated heat always finds a consumer and the generated electricity is simultaneously optimized with regard to an optimization objective, requires nonlinear optimization approaches due to the physical effects in the heat storage. This paper presents a methodology for optimized planning of CHP plants using Ant Colony Optimization. The selected optimization objectives are the power exchange, the tenant electricity and CO_2. It could be shown that all optimizations are at least 10

A Comparison of Different Many-Objective Optimization Algorithms for Energy System Optimization

Tobias Rodemann
EvoApplications 4 - Engineering and Real World Applications

The usage of renewable energy sources, storage devices, and flexible loads has the potential to greatly improve the overall efficiency of a building complex or factory. However, one needs to consider a multitude of upgrade options and several performance criteria. We therefore formulated this task as a many-objective optimization problem with 10 design parameters and 5 objectives (investment cost, yearly energy costs, CO_2 emissions, system resilience, and battery lifetime). We investigated if different optimization algorithms might produce different results, we therefore tested several different many-objective optimization algorithms in terms of their hypervolume performance and the practical relevance of their results. We found substantial performance differences between the algorithms, both regarding hypervolume and in the basic distribution of solutions in objective space. We have also used the concept of desirabilities to better visualize and assess the quality of solutions found.

Design of Powered Floor Systems for Mobile Robots with Differential Evolution
Eric Medvet, Stefano Seriani, Alberto Bartoli, Paolo Gallina
EvoApplications 5 - Engineering and Real World Applications

Mobile robots depend on power for performing their task. Powered floor systems, i.e., surfaces with conductive strips alternatively connected to the two poles of a power source, are a practical and effective way for supplying power to robots without interruptions, by means of sliding contacts. Deciding where to place the sliding contacts so as to guarantee that a robot is actually powered irrespective of its position and orientation is a difficult task. We here propose a solution based on Differential Evolution: we formally define problem-specific constraints and objectives and we use them for driving the evolutionary search. We validate experimentally our proposed solution by applying it to three real robots and by studying the impact of the main problem parameters on the effectiveness of the evolved designs for the sliding contacts. The experimental results suggest that our solution may be useful in practice for assisting the design of powered floor systems.

Quantifying the effects of increasing user choice in MAP-Elites applied to a Workforce Scheduling and Routing Problem
Neil Urquhart, Emma Hart, William Hutcheson
EvoApplications 5 - Engineering and Real World Applications

Quality-diversity algorithms such as MAP-Elites provide a means of supporting the users when finding and choosing solutions to a problem by returning a set of solutions which are diverse according to set of user-defined features. The number of solutions that can potentially be returned by MAP-Elites is controlled by a parameter that discretises the user-defined features into 'bins'. For a fixed evaluation budget, increasing the number of bins increases user-choice, but at the same time, can lead to a reduction in overall quality of solutions while vice-versa, decreasing the number of bins can lead to higher-quality solutions at the expense of reducing choice. The goal of this paper is to explicitly quantify this trade-off, through a study of the application of Map-Elites to a Workforce Scheduling and Routing problem, using large realistic instances based in London and Edinburgh. We note that for the problems under consideration 30 bins or above maximises coverage (and therefore the choice to the end user), whilst fewer bins maximise performance.

A Biased Random Key Genetic Algorithm with Local Search Chains for Molecular Docking

Pablo Felipe Leonhart, Marcio Dorn

EvoApplications 5 - Engineering and Real World Applications

Molecular Docking is an essential tool in drug discovery. The procedure for finding the best energy affinity between ligand-receptor molecules is a computationally expensive optimization process because of the roughness of the search space and the thousands of possible conformations of ligand. In this way, besides a realistic energy function to evaluate possible solutions, a robust search method must be applied to avoid local minimums. Recently, many algorithms have been proposed to solve the docking problem, mainly based on Evolutionary Strategies. However, the question remained unsolved and its needed the development of new and efficient techniques. In this paper, we developed a Biased Random Key Genetic Algorithm, as global search procedure, hybridized with three variations of Hill-climbing and a Simulated Annealing version, as local search strategies. To evaluate the receptor-ligand binding affinity we used the Rosetta scoring function. The proposed approaches have been tested on a benchmark of protein-ligand complexes and compared to ex- isting tools AUTODOCK VINA, DOCKTHOR, and jMETAL. A statistical test was performed on the results, and shown that the application of local search methods provides better solutions for the molecular docking problem.

A Cultural Algorithm for Determining Similarity Values Between Users in Recommender Systems

Kalyani Selvarajah, Ziad Kobti, Mehdi Kargar

EvoApplications 5 - Engineering and Real World Applications

Recommendation systems for online marketing often rely on users' ratings to evaluate the similarity between users in Collaborative Filtering (CF) recommender systems. This paper applies knowledge- based evolutionary optimization algorithms called Cultural Algorithms (CA) to evaluate the similarity between users. To deal with the sparsity of data, we combine CF with a trust network between users. The trust network is then clustered using Singular Value Decomposition (SVD) which helps to discover the top neighbors' trust value. By incorporating trust relationships with CF, we predict the rating by each user on a given item. This study uses the Epinions dataset in order to train and test the accuracy of the results of the approach. The results are then compared against those produced by Genetic Algorithms (GA), Cosine, and Pearson Correlation Coefficient (PCC) methods. The comparison of the results suggests that the proposed algorithm outperforms the other similarity functions.

Particle Swarm Optimization: Understanding Order-2 Stability Guarantees
Christopher Cleghorn
EvoApplications 6 - Best Paper Session

This paper's primary aim is to provide clarity on which guarantees about particle stability can actually be made. The particle swarm optimization algorithm has undergone a considerable amount of theoretical analysis. However, with this abundance of theory has come some terminological inconstancies, and as a result it is easy for a practitioner to be misguided by overloaded terminology. Specifically, the criteria for both order-1 and order-2 stability are well studied, but the exact definition of order-2 stability is not consistent amongst researchers. A consequence of this inconsistency in terminology is that the existing theory may in fact misguide practitioners instead of assisting them. In this paper it is theoretically and empirically demonstrated which practical guarantees can in fact be made about particle stability. Specifically, it is shown that the definition of order-2 stability which accurately reflects PSO behavior is that of convergence in second order moment to a constant, and not to zero.

Supporting Medical Decisions for Treating Rare Diseases through Genetic Programming
Illya Bakurov, Leonardo Vanneschi, Mauro Castelli, Maria João Freitas
EvoApplications 6 - Best Paper Session

Casa dos Marcos is the largest specialized medical and residential center for rare diseases in the Iberian Peninsula. The large number of patients and the uniqueness of their diseases demand a considerable amount of diverse and highly personalized therapies, that are nowadays largely managed manually. This paper aims at catering for the emergent need of efficient and effective artificial intelligence systems for the support of the everyday activities of centers like Casa dos Marcos. We present six predictive data models developed with a genetic programming based system which, integrated into a web-application, enabled data-driven support for the therapists in Casa dos Marcos. The presented results clearly indicate the usefulness of the system in assisting complex therapeutic procedures for children suffering from rare diseases.

Evolutionary Algorithms for the Design of Quantum Protocols
Walter Krawec, Stjepan Picek, Domagoj Jakobovic
EvoApplications 6 - Best Paper Session

In this paper, we use evolutionary algorithm to evolve customized quantum key distribution (QKD) protocols designed to counter attacks against the system in order to optimize the speed of the secure communication. This is in contrast to most work in QKD protocols, where a fixed protocol is designed and then its security is analyzed to determine how strong an attack it can withstand. We show that our system is able to find protocols that can operate securely against attacks where ordinary QKD protocols would fail. Our algorithm evolves protocols as quantum circuits, thus making the end result potentially easier to implement in practice.

A Matheuristic for Green and Robust 5G Virtual Network Function
Thomas Bauschert, Fabio D'Andreagiovanni, Andreas Kassler, Chenghao Wang
EvoApplications 7

We investigate the problem of optimally placing virtual network functions in 5G-based virtualized infrastructures according to a green paradigm that pursues energy-efficiency. This optimization problem can be modelled as an articulated 0-1 Linear Program based on a flow model. Since the problem can prove hard to be solved by a state-of-the-art optimization software, even for instances of moderate size, we propose a new fast matheuristic for its solution. Preliminary computational tests on a set of realistic instances return encouraging results, showing that our algorithm can find better solutions in considerably less time than a state-of-the-art solver.

Genetic Programming for Feature Selection and Feature Combination in Salient Object Detection
Shima Afzali, Harith Al-Sahaf, Bing Xue, Christopher Hollitt, Mengjie Zhang
EvoApplications 7

Salient Object Detection (SOD) aims to model human visual attention system to cope with the complex natural scene which contains various objects at different scales. Over the past two decades, a wide range of saliency features have been introduced in the SOD field, however feature selection has not been widely investigated regarding selecting informative, non-redundant, and complementary features from the exciting features. In SOD, multi-level feature extraction and feature combination are two fundamental stages to compute the final saliency map. However, designing a good feature combination framework is a challenging task and requires domain-expert intervention. In this paper, we propose a genetic programming (GP) based method that is able to automatically select the complementary saliency features and generate mathematical function to combine those features. The performance of the proposed method is evaluated using four benchmark datasets and compared to nine state-of-the-art methods. The qualitative and quantitative results show that the proposed method significantly outperformed, or achieved comparable performance to, the competitor methods.

Self-sustainability Challenges of Plants Colonization Strategies in Virtual 3D Environments
Kevin Godin-Dubois, Sylvain Cussat-Blanc, Yves Duthen
EvoApplications 7

The Biosphere is a bountiful source of inspiration for the biologically inclined scientist, though one may be seized by the twists and turns of its complexity. Artificial Life emerged from the conundrum of condensing this overwhelming intricacy into a tractable volume of data.

To tackle the challenge of studying the long-term dynamics of artificial ecosystems, we focused our efforts on plant-plant interactions in a 3D setting. Through an extension of K. Sims' directed graphs, we devised a polyvalent genotype for artificial plants development. These individuals compete and collaborate with one another in a shared plot of earth with the environment playing a crucial part in the phenotype's expression. We illustrate and analyze how the use of multi-objective fitnesses generated a panel of diverse morphologies and strategies. Furthermore we identify two driving forces of the emerge of self-reproduction and investigate their effect on self-sustainability.

Effects of Input Addition in Learning for Adaptive Games: Towards Learning with Structural Changes
Iago Bonnici, Abdelkader Gouaïch, Fabien Michel
EvoApplications 7

Adaptive Games (AG) involve a controller agent that continuously feeds from player actions and game state to tweak a set of game parameters in order to maintain or achieve an objective function such as the flow measure defined by Csíkszentmihályi. This can be considered a Reinforcement Learning (RL) situation, so that classical Machine Learning (ML) approaches can be used. On the other hand, many games naturally exhibit an incremental gameplay where new actions and elements are introduced or removed progressively to enhance player's learning curve or to introduce variety within the game. This makes the RL situation unusual because the controller agent input/output signature can change over the course of learning. In this paper, we get interested in this unusual "protean" learning situation (PL). In particular, we assess how the learner can rely on its past shapes and experience to keep improving among signature changes without needing to restart the learning from scratch on each change. We first develop a rigorous formalization of the PL problem. Then, we address the first elementary signature change: "input addition", with Recurrent Neural Networks (RNNs) in an idealized PL situation. As a first result, we find that it is possible to benefit from prior learning in RNNs even if the past controller agent signature has less inputs. The use of PL in AG thus remains encouraged. Investigating output addition, input/output removal and translating these results to generic PL will be part of future works.

Ensemble-based Evolutionary Algorithms for Detecting Known and Unknown Attacks
Hasanen Alyasiri, Daniel Kudenko, John Clark
EvoApplications 8 - Neuroevolution

The internet and computer networks have become an important asset in distributed computing organisations especially through enabling the collaboration between components of heterogeneous systems. As they have grown in popularity, so have the numbers of attacks on them. Threats are becoming more sophisticated, with attackers using new attacks or modifying existing ones. Thus, security teams must deal with numerous threats and the threat landscape is continuously evolving. We investigate the use of Evolutionary Computation (EC) algorithms for synthesising intrusion detection programs for such environments. EC algorithms extended with the ensemble-learning paradigm, indicating how EC can be used as a stacking technique to evolve detectors. The experiments were conducted on up-to-date datasets and compared with state-of-the-art algorithms. The potential application of these algorithms to detect unknown attacks is also examined and discussed.

The Evolution of Self-taught Neural Networks in a Multi-agent Environment

Nam Le, Michael O'Neill, Anthony Brabazon
EvoApplications 8 - Neuroevolution

Evolution and learning are two different forms of adaptation by which the organism can change their behaviour to cope with problems posed by the environment. The second form of adaptation occurs when individuals exhibit plasticity in response to environmental conditions that may strengthen their survival. Learning has been shown to be beneficial to the evolutionary process through the Baldwin Effect. This line of thought has also been employed in evolving adaptive neural networks, in which learning algorithms, such as Backpropagation, can be used to enhance the adaptivity of the population. Most work focuses on evolving learning agents in separate environments, this means each agent experiences its own environment (mostly similar), and has no interactive effect on others (e.g., the more one gains, the more another loses). The competition for survival in such settings is not that strong, if being compared to that of a multi-agent (or shared) environment . This paper investigates an evolving population of self-taught neural networks – networks that can teach themselves – in a shared environment. Experimental results show that learning presents an effect in increasing the performance of the evolving multi-agent system. Indications for future work on evolving neural networks are also presented.

Improving NeuroEvolution Efficiency by Surrogate Model-based Optimization with Phenotypic Distance Kernels

Jörg Stork, Martin Zaefferer, Thomas Bartz-Beielstein
EvoApplications 8 - Neuroevolution

In NeuroEvolution, the topologies of artificial neural networks are optimized with evolutionary algorithms to solve tasks in data regression, data classification, or reinforcement learning. One downside of NeuroEvolution is the large amount of necessary fitness evaluations, which might render it inefficient for tasks with expensive evaluations, such as real-time learning. For these expensive optimization tasks, surrogate model-based optimization is frequently applied as it features a good evaluation efficiency. While a combination of both procedures appears as a valuable solution, the definition of adequate distance measures for the surrogate modeling process is difficult. In this study, we will extend cartesian genetic programming of artificial neural networks by the use of surrogate model-based optimization. We propose different distance measures and test our algorithm on a replicable benchmark task. The results indicate that we can significantly increase the evaluation efficiency and that a phenotypic distance, which is based on the behavior of the associated neural networks, is most promising.

Evolving Recurrent Neural Networks for Time Series Data Prediction of Coal Plant Parameters

Abd-El-Rahman ElSaid, Steven Benson, Shuchita Patwardhan, David Stadem, Travis Desell

EvoApplications 8 - Neuroevolution

This paper presents the Evolutionary eXploration of Augmenting LSTM Topologies (EXALT) algorithm and its use in evolving recurrent neural networks (RNNs) for time series data prediction. It introduces a new open data set from a coal-fired power plant, consisting of 10 days of per minute sensor recordings from 12 different burners at the plant. This large scale real world data set involves complex depedencies between sensor parameters and makes for challening data to predict. EXALT provides interesting new techniques for evolving neural networks, including epigenetic weight initialization, where child neural networks re-use parental weights as a starting point to backpropagation, as well as node-level mutation operations which can improve evolutionary progress. EXALT has been designed with parallel computation in mind to further improve performance. Preliminary results were gathered predicting the Main Flame Intensity data parameter, with EXALT strongly outperforming five traditional neural network architectures on the best, average and worse cases across 10 repeated training runs per test case; and was only slightly behind the best trained Elman recurrent neural networks while being significantly more reliable (i.e., much better average and worst case results). Further, EXALT achived these results 2 to 10 times faster than the traditional methods, in part due to its scalability, showing strong potential to beat traditional architectures given additional runtime.

List of Abstracts - EvoCOP

Insights into the Feature Selection Problem using Local Optima Networks
Werner Mostert, Katherine Malan, Gabriela Ochoa, Andries Engelbrecht
EvoCOP 1

The binary feature selection problem is investigated in this paper. Feature selection fitness landscape analysis is done, which allows for a better understanding of the behaviour of feature selection algorithms. Local optima networks are employed as a tool to visualise and characterise the fitness landscapes of the feature selection problem in the context of classification. An analysis of the fitness landscape global structure is provided, based on seven real-world datasets with up to 17 features. Formation of neutral global optima plateaus are shown to indicate the existence of irrelevant features in the datasets. Removal of irrelevant features resulted in a reduction of neutrality and the ratio of local optima to the size of the search space, resulting in improved performance of genetic algorithm search in finding the global optimum.

A Unifying View on Recombination Spaces and Abstract Convex Evolutionary Search
Marcos Diez Garcia, Alberto Moraglio
EvoCOP 1

Previous work proposed to unify an algebraic theory of fitness landscapes and a geometric framework of evolutionary algorithms (EAs). The aim behind this unification is to develop an analytical method that verifies if a problem's landscape belongs to certain abstract convex landscape classes, where certain recombination-based EAs (without mutation) have polynomial runtime performance. This paper advances such unification by showing that: (a) crossovers can be formally classified according to geometric or algebraic axiomatic properties; and (b) a class of crossovers admits both a geometric and algebraic understanding of the population-behaviour induced by them in a recombination-based EA. These results make a significant contribution for the basis of an integrated geometric-algebraic framework with which analyse recombination spaces and recombination-based EAs.

Program Trace Optimization with Constructive Heuristics for Combinatorial Problems
James McDermott, Alberto Moraglio
EvoCOP 1

Program Trace Optimisation (PTO), a recent and highly general optimisation framework, is applied to a range of combinatorial optimisation (COP) problems. It effectively combines "smart" problem-specific constructive heuristics and problem-agnostic metaheuristic search, automatically and implicitly designing problem-appropriate search operators. A weakness is identified in PTO's operators when applied in conjunction with smart heuristics on COP problems, and an improved method is introduced to address this. To facilitate the comparison of this new method with the original, across problems, a common format for PTO generators is demonstrated, similar to that of GRASP. This also facilitates comparison of the degree of greediness (the GRASP alpha parameter) in the heuristics. Experiments across several problems show that the novel operators consistently outperform the original without any loss of generality or cost in CPU time; hill-climbing is a sufficient metaheuristic; and intermediate levels of greediness are usually best.

Runtime Analysis of Discrete Particle Swarm Optimization Applied to Shortest Paths Computation
Alexander Rass, Jonas Schreiner, Rolf Wanka
EvoCOP 1

We mathematically analyze a discrete particle swarm optimization (PSO) algorithm solving the single-source shortest path (SSSP) problem. Key features are an improved and extended study on Markov chains expanding the adaptability of this technique and its application on the well-known SSSP problem. The results are upper and lower bounds on the expected optimization time. For upper bounds, we combine return times within a Markov model with the well known fitness level method which is appropriate even for the non-elitist PSO algorithm. For lower bounds we prove that the recently introduced property of indistinguishability applies in this setting and we also combine it with a further Markov chain analysis. We prove a cubic upper and a quadratic lower bound and an exponential upper and lower bound on the expected runtime, respectively, depending on a PSO parameter.

A Binary Algebraic Differential Evolution for the MultiDimensional Two-Way Number Partitioning Problem

Valentino Santucci, Marco Baioletti, Gabriele Di Bari, Alfredo Milani
EvoCOP 2

This paper introduces MADEB, a Memetic Algebraic Differential Evolution algorithm for the Binary search space. MADEB has been applied to the Multidimensional Two-Way Number Partitioning Problem (MDTWNPP) and its main components are the binary differential mutation operator and a variable neighborhood descent procedure. The binary differential mutation is a concrete application of the abstract algebraic framework for the binary search space. The variable neighborhood descent is a local search procedure specifically designed for MDTWNPP. Experiments have been held on a widely accepted benchmark suite and MADEB is experimentally compared with respect to the current state-of-the-art algorithms for MDTWNPP. The experimental results clearly show that MADEB is the new state-of-the-art algorithm in the problem here investigated.

A Cooperative Optimization Approach for Distributing Service Points in Mobility Applications

Thomas Jatschka, Tobias Rodemann, Günther Raidl
EvoCOP 2

We investigate a variant of the facility location problem concerning the optimal distribution of service points with incomplete information within a certain geographical area. The application scenario is generic in principle, but we have the setup of charging stations for electric vehicles or rental stations for bicycles or cars in mind. When planning such systems, estimating under which conditions which customer demand can be fulfilled is fundamental in order to evaluate and optimize possible solutions. In this paper we present a cooperative optimization approach for distributing service points that incorporates potential customers not only in the data acquisition but also during the optimization process. A surrogate objective function is used to evaluate intermediate solutions during the optimization. The quality of this surrogate objective function is iteratively improved by learning from the feedback of potential users given to candidate solutions. For the actual optimization we consider a population based iterated greedy algorithm. Experiments on artificial benchmark scenarios with idealized simulated user behavior show the learning capabilities of the surrogate objective function and the effectiveness of the optimization.

A New Representation in Genetic Programming for Evolving Dispatching Rules for Dynamic Flexible Job Shop Scheduling
Fangfang Zhang, Yi Mei, Mengjie Zhang
EvoCOP 2

Dynamic flexible job shop scheduling (DFJSS) is a very important problem with a wide range of real-world applications such as cloud computing and manufacturing. In DFJSS, it is critical to make two kinds of real-time decisions (i.e. the routing decision that assigns machine to each job and the sequencing decision that prioritises the jobs in a machine's queue) effectively in the dynamic environment with unpredicted events such as new job arrivals and machine breakdowns. Dispatching rule is an ideal technique for this purpose. In DFJSS, one has to design a routing rule and a sequencing rule for making the two kinds of decisions. Manually designing these rules is time consuming and requires human expertise which is not always available. Genetic programming (GP) has been applied to automatically evolve more effective rules than the manually designed ones. In GP for DFJSS, different features in the terminal set have different contributions to the decision making. However, the current GP approaches cannot perfectly find proper combinations between the features in accordance with their contributions. In this paper, we propose a new representation for GP that better considers the different contributions of different features and combines them in a sophisticated way, thus to evolve more effective rules. The results show that the proposed GP approach can achieve significantly better performance than the baseline GP in a range of job shop scenarios.

Rigorous Performance Analysis of State-of-the-art TSP Heuristic Solvers
Paul McMenemy, Nadarajen Veerapen, Jason Adair, Gabriela Ochoa
EvoCOP 3

Understanding why some problems are better solved by one algorithm rather than another is still an open problem, and the symmetric Travelling Salesperson Problem (TSP) is no exception. We apply three state-of-the-art heuristic solvers to a large set of TSP instances of varying structure and size, identifying which heuristics solve specific instances to optimality faster than others. The first two solvers considered are variants of the multi-trial Helsgaun's Lin-Kernighan Heuristic (a form of iterated local search), with each utilising a different form of Partition Crossover; the third solver is a genetic algorithm (GA) using Edge Assembly Crossover. Our results show that the GA with Edge Assembly Crossover is the best solver, shown to significantly outperform the other algorithms in 73A comprehensive set of features for all instances is also extracted, and decision trees are used to identify main features which could best inform algorithm selection. The most prominent features identified a high proportion of instances where the GA with Edge Assembly Crossover performed significantly better when solving to optimality.

Multiple periods vehicle routing problems: a case study
Bilal Messaoudi, Ammar Oulamara, Nastaran Rahmani
EvoCOP 3

In this paper, we consider a challenging problem faced by a hygiene services company. The problem consists of planning and routing a set of customers over a 3-month horizon period where multiple frequencies of visits can be required simultaneously by each single customer. The objective is then threefold: (1) balancing workload between vehicles (agents) (2) minimizing number of visits to the same customer (3) minimizing total routing costs. In this context, a routing plan must be prepared for the whole horizon, taking into account all constraints of the problem. We model the problem using a decomposition approach of planning horizon, namely, weeks planning and days planning optimization. We propose an adaptive large neighborhood search with several operators for routing phase of solving approach. To evaluate the performance of the solving approach we solve an industrial instance with more than 6000 customers and 69951 requests of visits. The results show an excellent performance of the solving approach in terms of solution quality compared with the existing plan used by the hygiene services company.

Route Planning for a Fleet of Electric Vehicles with Waiting Times at Charging Stations
Baoxiang Li, Shashi Jha, Hoong Chuin Lau
EvoCOP 3

Electric Vehicles (EVs) are the next wave of technology in the transportation industry. EVs are increasingly becoming common for personal transport and pushing the boundaries to become the mainstream mode of transportation. Use of such EVs in logistic fleets for delivering customer goods is not far from becoming reality. However, managing such fleet of EVs bring new challenges in terms of battery capacities and charging infrastructure for efficient route planning. Researchers have addressed such issues considering different aspects of the EVs such as linear battery charging/discharging rate, fixed travel times, etc. In this paper, we address the issue of waiting times due to limited charging capacity at the charging stations while planning the routes of EVs for providing pickup/delivery services. We provide an exact mathematical model of the problem considering waiting times of vehicle based on their arrival at the charging stations. We further develop a genetic algorithm approach that embeds Constraint Programming to solve the problem. We test our approach on a set of benchmark Solomon instances.

Quasi-Optimal Recombination Operator
Francisco Chicano, Gabriela Ochoa, Darrell Whitley, Renato Tinós
EvoCOP 4

The output of an optimal recombination operator for two parent solutions is a solution with the best possible value for the objective function among all the solutions fulfilling the gene transmission property: the value of any variable in the offspring must be inherited from one of the parents. This set of solutions coincides with the largest dynastic potential for the two parent solutions of any recombination operator with the gene transmission property. In general, exploring the full dynastic potential is computationally costly, but if the variables of the objective function have a low number of non-linear interactions among them, the exploration can be done in $O(4^\beta(n+m)+n^2)$ time, for problems with n variables, m subfunctions and β a constant. In this paper, we propose a quasi-optimal recombination operator, called Dynastic Potential Crossover (DPX), that runs in $O(4^\beta(n+m)+n^2)$ time in any case and is able to explore the full dynastic potential for low-epistasis combinatorial problems. We compare this operator, both theoretically and experimentally, with two recently defined efficient recombination operators: Partition Crossover (PX) and Articulation Points Partition Crossover (APX). The empirical comparison uses NKQ Landscapes and MAX-SAT instances.

Clarifying the Differences in Local Optima Network Sampling Algorithms
Sarah L. Thomson, Gabriela Ochoa, Sébastien Verel
EvoCOP 4

We conduct the first ever statistical comparison between two Local Optima Network (LON) sampling algorithms. These methodologies attempt to capture the connectivity in the local optima space of a fitness landscape. One sampling algorithm is based on a random-walk snowballing procedure, while the other is centered around multiple traced runs of an Iterated Local Search. Both of these are proposed for the Quadratic Assignment Problem (QAP), making this the focus of our study. It is important to note the sampling algorithm frameworks could easily be modified for other domains. In our study descriptive statistics for the obtained search space samples are contrasted and commented on. The LON features are also used in linear mixed models and random forest regression for predicting heuristic optimisation performance of two prominent heuristics for the QAP on the underlying combinatorial problems. The model results are then used to make deductions about the sampling algorithms' utility. We also propose a specific set of LON metrics for use in future predictive models alongside previously-proposed network metrics, demonstrating the payoff in doing so.

An Iterated Local Search Algorithm for the Two-Machine Flow Shop Problem with Buffers and Constant Processing Times on One Machine

Hoang Thanh Le, Philine Geser, Martin Middendorf

EvoCOP 4

This paper considers a special case of two-machine flow shop scheduling problems with buffers, namely, the case that all processing times on one of the two machines are equal. This case is interesting because it occurs in various applications, e.g., when one machine is a packing machine. For the buffers we consider two types of buffers that have been studied in the literature for flow shops. It is shown that all considered buffered flow shop problems remain NP-hard for the makespan criterion and permutation schedules even with the restriction of equal processing times on one machine. Two specific heuristics for solving the problems are proposed: i) a modification of the commonly used NEH heuristic (mNEH) and ii) an Iterated Local Search heuristic (2BF-ILS) that uses the mNEH heuristic for computing its initial solution. It is shown experimentally that the proposed 2BF-ILS heuristic obtains better results than two state-of-the-art algorithms for buffered flow shop problems from the literature and an Ant Colony Optimization algorithm. In addition, it is shown experimentally that 2BF-ILS can obtain the same solution quality as the standard NEH heuristic with a smaller number of function evaluations.

List of Abstracts - EvoMUSART

Deep Learning Concepts for Evolutionary Art
Fazle Tanjil, Brian Ross
EvoMusArt 1

A deep convolutional neural network (CNN) trained on millions of images forms a very high-level abstract overview of an image. Our primary goal is to use this high-level content information a given target image to guide the automatic evolution of images using genetic programming. We investigate the use of a pre-trained deep CNN model as a fitness guide for evolution. Two different approaches are considered. Firstly, we developed a heuristic technique called Mean Minimum Matrix Strategy (MMMS) for determining the most suitable high-level CNN nodes to be used for fitness evaluation. This pre-evolution strategy determines the common high-level CNN nodes that show high activation values for a family of images that share an image feature of interest. Using MMMS, experiments show that GP can evolve procedural texture images that likewise have the same high-level feature. Secondly, we use the highest-level fully connected classifier layers of the deep CNN. Here, the user supplies a high-level classification label such as "peacock" or "banana", and GP tries to evolve an image that maximizes the classification score for that target label. Experiments evolved images that often achieved high confidence scores for the supplied labels. However, the images themselves usually display some key aspect of the target required for CNN classification, rather than the entire subject matter expected by humans. We conclude that deep learning concepts show much potential as a tool for evolutionary art, and future results will improve as deep CNN models are better understood.

Adversarial evolution and deep learning - how does an artist play with our visual system?
Alan Blair
EvoMusArt 1

We create artworks using adversarial coevolution between a genetic program (HERCL) generator and a deep convolutional neural network (LeNet) critic. The resulting artificially intelligent artist, whimsically named Hercule LeNet, aims to produce images of low algorithmic complexity which nevertheless resemble a set of real photographs well enough to fool an adversarially trained deep learning critic modeled on the human visual system. Although it is not exposed to any pre-existing art, or asked to mimic the style of any human artist, nevertheless it discovers for itself many of the stylistic features associated with influential art movements of the 19th and 20th Century. A detailed analysis of its work can help us to better understand the way an artist plays with the human visual system to produce aesthetically appealing images.

Camera Obscurer:Generative Art for Design Inspiration
Dilpreet Singh, Nina Rajcic, Simon Colton, Jon McCormack
EvoMusArt 1

We investigate using generated decorative art as a source of inspiration for design tasks. Using a visual similarity search for image retrieval, the *Camera Obscurer* app enables rapid searching of tens of thousands of generated abstract images of various types. The seed for a visual similarity search is a given image, and the retrieved generated images share some visual similarity with the seed. Implemented in a hand-held device, the app empowers users to use photos of their surroundings to search through the archive of generated images and other image archives. Being abstract in nature, the retrieved images supplement the seed image rather than replace it, providing different visual stimuli including shapes, colours, textures and juxtapositions, in addition to affording their own interpretations. This approach can therefore be used to provide inspiration for a design task, with the abstract images suggesting new ideas that might give direction to a graphic design project. We describe a crowdsourcing experiment with the app to estimate user confidence in retrieved images, and we describe a pilot study where Camera Obscurer provided inspiration for a design task. These experiments have enabled us to describe future improvements, and to begin to understand sources of visual inspiration for design tasks.

Emojinating: Evolving Emoji Blends

João M. Cunha, Nuno Lourenço, João Correia, Pedro Martins, Penousal Machado
EvoMusArt 1

Graphic designers visually represent concepts in several of their daily tasks, such as in icon design. Computational systems can be of help in such tasks by stimulating creativity. However, current computational approaches to concept visual representation lack in effectiveness in promoting the exploration of the space of possible solutions. In this paper, we present an evolutionary approach that combines a standard Evolutionary Algorithm with a method inspired by Estimation of Distribution Algorithms to evolve emoji blends to represent user-introduced concepts. The quality of the developed approach is assessed using two separate user-studies. In comparison to previous approaches, our evolutionary system is able to better explore the search space, obtaining solutions of higher quality in terms of concept representativeness.

Evolutionary Games for Audiovisual Works: exploring the Demographic Prisoner's Dilemma

Stefano Kalonaris
EvoMusArt 2

This paper presents AV DPD, a minimalist audiovisual display of an evolutionary game known as the Demographic Prisoner's Dilemma, which demonstrates the emergence of cooperation as an evolutionary stable behaviour. Abiding by a dialogical approach foregrounding the dynamical negotiation of the author's aesthetic aspirational levels, the system undergoes several variations and modi

cations. Questions regarding computational measures of beauty are raised and discussed.

Stochastic Synthesizer Patch Exploration in Edisyn
Sean Luke
EvoMusArt 2

Edisyn is a music synthesizer program (or "patch") editor library which enables musicians to easily edit and manipulate a variety of difficult-to-program synthesizers. Edisyn sports a first-in-class set of tools designed to help explore the parameterized space of synthesizer patches without needing to directly edit the parameters. This paper discusses the most sophisticated of these tools, Edisyn's Hill-Climber and Constrictor methods, which are based on interactive evolutionary computation techniques. The paper discusses the special difficulties encountered in programming synthesizers, the motivation behind these techniques, and their design. It then evaluates them in an experiment with novice synthesizer users, and concludes with additional observations regarding utility and efficacy.

Comparing Models for Harmony Prediction in an Interactive Audio Looper
Benedikte Wallace, Charles P. Martin
EvoMusArt 2

Musicians often use tools such as loop-pedals and multitrack recorders to assist in improvisation and songwriting, but these tools generally don't proactively contribute aspects of the musical performance. In this work, we introduce an interactive audio looper that predicts a loop's harmony and constructs an accompaniment automatically using concatenative synthesis. The system uses a machine learning (ML) model for harmony prediction, that is, it generates a sequence of chords symbols for a given melody. We analyse the performance of two potential ML models for this task: a hidden Markov model (HMM) and a recurrent neural network (RNN) with bidirectional long short-term memory (BLSTM) cells. Our findings show that the RNN approach provides more accurate predictions and is more robust with respect to changes in the training data. We consider the impact of each model's predictions in live performance and ask: "What is an accurate chord prediction anyway?"

Evolutionary Multi-Objective Training Set Selection of Data Instances and Augmentations for Vocal Detection

Igor Vatolkin, Daniel Stoller

EvoMusArt 2

The size of publicly available music data sets has grown significantly in recent years, which allows training better classification models. However, training on large data sets is time-intensive and cumbersome, and some training instances might be unrepresentative and thus hurt classification performance regardless of the used model. On the other hand, it is often beneficial to extend the original training data with augmentations, but only if they are carefully chosen. Therefore, identifying a "smart" selection of training instances should improve performance. In this paper, we introduce a novel, multi-objective framework for training set selection with the target to simultaneously minimise the number of training instances and the classification error. Experimentally, we apply our method to vocal activity detection on a multi-track database extended with various audio augmentations for accompaniment and vocals. Results show that our approach is very effective at reducing classification error on a separate validation set, and that the resulting training set selections either reduce classification error or require only a small fraction of training instances for comparable performance.

Automatically Generating Engaging Presentation Slide Decks

Thomas Winters, Kory W. Mathewson

EvoMusArt 3

Talented public speakers have thousands of hours of practice. One means of improving public speaking skills is practice through improvisation, e.g. presenting an improvised presentation using an unseen slide deck. We present TEDRIC, a novel system capable of generating coherent slide decks based on a single topic suggestion. It combines semantic word webs with text and image data sources to create an engaging slide deck with an overarching theme. We found that audience members perceived the quality of improvised presentations using these generated slide decks to be on par with presentations using human created slide decks for the "Improvised TED Talk" performance format. TEDRIC is thus a valuable new creative tool for improvisers to perform with, and for anyone looking to improve their presentation skills.

Tired of choosing? Just add structure and Virtual Reality

Edward Easton, Ulysses Bernardet, Aniko Ekart

EvoMusArt 3

Interactive Evolutionary Computation (IEC) systems often suffer from users only performing a small number of generations, a phenomenon known as user fatigue. This is one of the main hindrances to these systems generating complex and aesthetically pleasing pieces of art. This paper presents two novel approaches to addressing the issue by improving user engagement, firstly through using Virtual Environments and secondly improving the predictability of the generated images using a well-defined structure and giving the user more control.

To establish their efficacy, the concepts are applied to a series of prototype systems.

Our results show that the approaches are effective to some degree. We propose alterations to further improve their implementation in future systems.

Exploring Transfer Functions in Evolved CTRNNs for Music Generation

Steffan Ianigro, Oliver Bown

EvoMusArt 3

This paper expands on prior research into the generation of audio through the evolution of Continuous Time Recurrent Neural Networks (CTRNNs). CTRNNs are a type of recurrent neural network that can be used to model dynamical systems and can exhibit many different characteristics that can be used for music creation such as the generation of non-linear audio signals which unfold with a level of generative agency or unpredictability. Furthermore, their compact structure makes them ideal for use as an evolvable genotype for musical search as a finite set of CTRNN parameters can be manipulated to discover a vast audio search space. In prior research, we have successfully evolved CTRNNs to generate timbral and melodic content that can be used for electronic music composition. However, although the initial adopted CTRNN algorithm produced oscillations similar to some conventional synthesis algorithms and timbres reminiscent of acoustic instruments, it was hard to find configurations that produced the timbral and temporal richness we expected. Within this paper, we look into modifying the currently used tanh transfer function by modulating it with a sine function to further enhance the idiosyncratic characteristics of CTRNNs. We explore to what degree they can aid musicians in the search for unique sounds and performative dynamics in which some creative control is given to a CTRNN agent. We aim to measure the difference between the two transfer functions by discovering two populations of CTRNNs using a novelty search evolutionary algorithm, each utilising a different transfer function. The effect that each transfer function has on the respective novelty of each CTRNN population is compared using quantitative analysis as well as through a compositional study.

Automatic Jazz Melody Composition through a Learning-based Genetic Algorithm
Yong-Wook Nam, Yong-Hyuk Kim
EvoMusArt 3

In this study, we automate the production of good-quality jazz melodies through genetic algorithm and pattern learning by preserving the musically important properties. Unlike previous automatic composition studies that use fixed-length chromosomes to express a bar in a score, we use a variable-length chromosome and geometric crossover to accommodate the variable length. Pattern learning uses the musical instrument digital interface data containing the jazz melody; a user can additionally learn about the melody pattern by scoring the generated melody. The pattern of the music is stored in a chord table that contains the harmonic elements of the melody. In addition, a sequence table preserves the flow and rhythmic elements. In the evaluation function, the two tables are used to calculate the fitness of a given music. We use this estimated fitness and geometric crossover to improve the music until users are satisfied. Through this, we successfully create a jazz melody as per user preference and training data.

EvoChef: Show me What to Cook! The Artificial Evolution of Culinary Arts
Hajira Jabeen, Nargis Tahara, Jens Lehmann
EvoMusArt 3

Computational Intelligence(CI) has proven its artistry in the creation of music, graphics, and drawings. Taking the inspiration, this work demonstrates the creativity of CI in artificial evolution of culinary arts. We present EvoChef, that takes input from well-rated recipes of different cuisines and evolves new recipes by recombining the instructions, spices, and ingredients. We represent each recipe as a property graph containing ingredients, their status, spices, and cooking instructions. These recipes are evolved using recombination and mutation operators. We have used expert opinion(user ratings) as the fitness function for our evolved recipes. We observed that the overall fitness of the recipes improved with the number of generations and almost all the resulting recipes were found to be conceptually correct. We also conducted a blind-comparison of the original recipes with the EvoChef recipes and the EvoChef was rated to be more innovative. To the best of our knowledge, EvoChef is the first semi-automated, open source, and valid recipe generator that creates easily to follow, and novel recipes.

Autonomy, Authenticity, Authorship and Intention in computer generated art
Jon McCormack, Toby Gifford, Patrick Hutchings
EvoMusArt 4

This paper examines five key questions surrounding computer generated art. Driven by the recent public auction of a work of "AI Art" we selectively summarise many decades of research and commentary around topics of autonomy, authenticity, authorship and intention in computer generated art, and use this research to answer contemporary questions often asked about art made by computers that concern these topics. We additionally reflect on whether current techniques in deep learning and Generative Adversarial Networks significantly change the answers provided by many decades of prior research.

Swarm-based identification of animation key points from 2D-medialness maps
Prashant Aparajeya, Frederic Fol Leymarie, Mohammad Majid al-Rifaie
EvoMusArt 4

In this article we present the use of dispersive flies optimisation (DFO) for swarms of particles active on a medialness map – a 2D field representation of shape informed by perception studies. Optimising swarms activity permits to efficiently identify shape-based keypoints to automatically annotate movement and is capable of producing meaningful qualitative descriptions for animation applications. When taken together as a set, these keypoints represent the full body pose of a character in each processed frame. In addition, such keypoints can be used to embody the notion of the Line of Action (LoA), a well known classic technique from the Disney studios used to capture the overall pose of a character to be fleshed out. Keypoints along a medialness ridge are local peaks which are efficiently localised using DFO driven swarms. DFO is optimised in a way so that it does not need to scan every image pixel and always tend to converge at these peaks. A series of experimental trials on different animation characters in movement sequences confirms the promising performance of the optimiser over a simpler, currently-in-use brute-force approach.

Paintings, Polygons and Plant Propagation

Misha Paauw, Daan van den Berg

EvoMusArt 4

. It is possible to approximate artistic images from a limited number of stacked semi-transparent colored polygons. To match the target image as closely as possible, the locations of the vertices, the drawing order of the polygons and the RGBA color values must be optimized for the entire set at once. Because of the vast combinatorial space, the relatively simple constraints and the well-defined objective function, these optimization problems might be well suited for nature-inspired optimization algorithms. In this pioneering study, we start with sets of randomized polygons and try to find optimal arrangements for several well-known paintings using three iterative optimization algorithms: stochastic hillclimbing, simulated annealing and the plant propagation algorithm. We discuss the performance of the algorithms, relate the found objective values to the polygonal invariants and supply a challenge to the community.

List of Late Breaking Abstracts

Neural Darwinism as Discrete Combinatorial Optimization
Darrell Whitley
LBA 1

The current interest in deep learning had fueled new interest in using evolutionary computation to optimize artificial neural networks. This abstract forces on "Neural Darwinism" as a form of learning, and explores how neural selection can be posed as a k-bounded optimization problem.

Kinetic Market Model: An Evolutionary Algorithm
Evandro Luquini, Nizam Omar
LBA 1

This research proposes an identity between econophysics kinetic market models and evolutionary computing. The immediate results from this proposal is a new replacement rule for family competition evolutionary algorithms. It is also a starting point in adding evolvable entities to kinetic market models and discuss assumptions of social selection.

The Plant Propagation Algorithm on Timetables: First Results
Romi Geleijn, Marrit van der Meer, Quinten van der Post, Daan van den Berg
LBA 1

One Stochastic HillClimber and two implementations of the Plant Propagation Algorithm (PPA-1 and PPA-2) are applied to an instance of the University Course Timetabling Problem from the University of Amsterdam. After completing 10 runs of 200,000 objective function evaluations each, results show that PPA-1 outperforms the HillClimber, but PPA-2 makes the best timetables.

Constructing Class-Based Portfolios on Gulf Markets with Metaheuristics
Tahani Alotaibi, Panagiotis Tsiogkidis, Matthew Craven
LBA 1

None.

Caracolillo
Annika Sorenstam, Annika Settergren, Pipilotta Langstrumpf and Hermione Granger
EvoTales 1 - Little beasties stories

Caracolillo vivía en un jardín. Un día, se posó una libélula sobre una rama y dijo: "Conozco un campo de coles". La libélula dijo también "En una col se vive mucho mejor". Caracolillo dejó el jardín y se fue a vivir al huerto. Pero un día cortaron la col y Caracolillo se encontró de repente hirviendo dentro de una cacerola!

Con gran esfuerzo logró escapar de aquel lugar asfixiante y, alcanzando la ventana, salió al jardín de la casa. En un árbol cercano tenía Pajarón su nido. "¡Oh, que rica comida para mis pajarillos!", exclamó, y lo cogió con el pico.

Esta vez también logró escapar Caracolillo. Un burro pasaba por allí. Se subió por las patas y se instaló en el lomo. El burro le llevó a una granja. Los polluelos le recibieron con un alegre "pío, pío"...pero Caracolillo se dio cuenta de que sus intenciones no eran muy amistosas!

Por la valla salió a un jardín. ¡Oh, qué flores más lindas!", dijo subiendo por el tallo de un rosal. "¡Ay, una espina!", gritó. Y mientras seguía subiendo comentaba "La vida de un caracol está llena de sustos"

EvoStar Participants

Shima	Afzali V. Moghaddam	Victoria University of Wellington	Wellington	New Zealand
Prashant	Aparajeya	Goldsmiths, University of London	London	United Kingdom
Mehmet	Aslan	Hacettepe University	Ankara	Turkey
Filipe	Assunção	CISUC, University of Coimbra	Coimbra	Portugal
Timothy	Atkinson	University of York	York	United Kingdom
Samaneh	Azari	Victoria University of Wellington	Wellington	New Zealand
Irene	Azzali	University of Torino	Torino	Italy
Marco	Baioletti	University of Perugia	Perugia	Italy
Illya	Bakurov	NOVA IMS	Lisbon	Portugal
Wolfgang	Banzhaf	Michigan State University	East Lansing, MI	USA
Jonas	Berger	HTWK Leipzig	Leipzig	Germany
Alan	Blair	University of New South Wales	Sydney	Australia
Iago	Bonnici	LIRMM, Université de Montpellier, CNRS	Montpellier	France
Amine	Boumaza	Unversité de Lorraine / LORIA	Nancy	France
Stefano	Cagnoni	University of Parma	Parma	Italy
Mauro	Castelli	Nova Information Management School (NOVA IMS)	Lisbon	Portugal
Pedro A.	Castillo-Valdivieso	University of Granada	Granada	Spain
Mª Luz	Castro Pena	UDC	A Coruña	Spain
Francisco	Chicano	University of Malaga	Malaga	Spain
Vic	Ciesielski	RMIT University	Melbourne	Australia
Christopher	Cleghorn	University of Pretoria	Pretoria	South Africa
Ernesto	Costa	University of Coimbra	Coimbra	Portugal
Victor	Costa	University of Coimbra	Coimbra	Portugal
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Marcos	Diez Garcia	University of Exeter	Exeter	United Kingdom
Marcio	Dorn	Federal University of Rio Grande do Sul	Porto Alegre	Brazil
John	Drake	Queen Mary University of London	London	UK
Piotr	Dziurzanski	University of York	York	United Kingdom
Edward	Easton	Aston University	Birmingham	United Kingdom
Marc	Ebner	Ernst Moritz Arndt Universität Greifswald	Greifswald	Germany
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Francesco	Fontanella	Università di Cassino e del Lazio meridionale	Cassino	Italy
James	Foster	University of Idaho	Moscow, Idaho	USA
Zong Woo	Geem	Gachon University	Seongnam	Republic of Korea
Riccardo	Gervasi	Politecnico di Torino - DIGEP	Torino	Italy
Mario	Giacobini	University of Torino	Torino	Italy
Kyrre	Glette	University of Oslo	Oslo	Norway
Kevin	Godin-Dubois	IRIT	Toulouse	France
Bernard	Gress	Fannie Mae	Washington	USA

EvoStar Participants

Ahmed	Hallawa	RWTH Aachen University	Aachen	Germany
Ting	Hu	Memorial University	St. John's	Canada
Jakub	Husa	Brno University of Technology, Faculty of Information Technology	Brno	Czech Republic
Giovanni	Iacca	University of Trento	Trento	Italy
Steffan	Ianigro	University of New South Wales	Sydney	Australia
Hajira	Jabeen	University of Bonn	Bonn	Germany
Domagoj	Jakobovic	University of Zagreb, Faculty of electrical engineering and computing	Zagreb	Croatia
Thomas	Jatschka	Institute of Logic and Computation, TU Wien, Austria	Vienna	Austria
Juan Luis	Jiménez Laredo	Ri2C-LITIS, Université du Havre Normandie	Le Havre	France
Stefano	Kalonaris	RIKEN	Tokyo	Japan
Paul	Kaufmann	Mainz University	Mainz	Germany
Michal	Kawulok	Silesian University of Technology	Gliwice	Polska
Jonathan	Kelly	Massachusetts Institute of Technology	Cambridge	United States
Ziad	Kobti	University of Windsor	Windsor	Canada
Jitka	Kocnova	Faculty of Information Technology, Brno University of Technology	Brno	Czech Republic
Walter	Krawec	University of Connecticut	Storrs	USA
Natalie	Kruck	HTWK Leipzig	Leipzig	Germany
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