

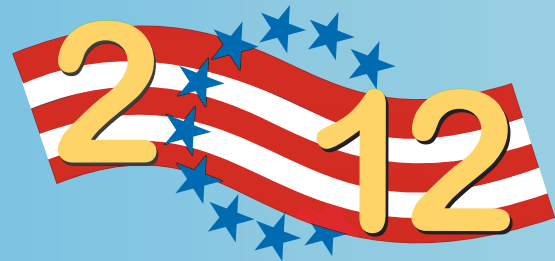
Conference Program

GECCO = RWA + GA + GP + EMO + ACO + AL + EDA + GBML + GDS + ES + ...

Largest Conference in the Field of Genetic and Evolutionary Computation



**Genetic and Evolutionary
Computation Conference**



**July 07-11, 2012
Philadelphia, USA**



Association for
Computing Machinery

Advancing Computing as a Science & Profession

Sponsored by the Association for Computing Machinery
Special Interest Group for Genetic and Evolutionary Computation

**A recombination of the 21st International Conference on Genetic Algorithms (ICGA)
and the 17th Annual Genetic Programming Conference (GP)**
www.sigevo.org/gecco-2012

Genetic and Evolutionary Computation Conference 2012

Conference Program



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We gratefully acknowledge and thank our supporters



ACM SIGEVO

Association for Computing Machinery

Special Interest Group on Genetic and Evolutionary Computation



Green Pocket

Welcome from General Chair

It is my pleasure to welcome you to Philadelphia for the 2012 Genetic and Evolutionary Computation Conference (GECCO-2012). This is the first time GECCO has been held in Philly. We very much hope you enjoy this historic American city and all it has to offer.

This will be my 14th year attending GECCO. I have contributed a number of papers and have enjoyed many thought-provoking presentations over the years. GECCO has played a very important role in my research program and in the training of many of my students and postdocs. I agreed to serve as General Chair of GECCO-2012 because it was time to give back to the community I have enjoyed being a part of since 1999.

Terence Soule served as the editor-in-chief this year and did a very skillful job maintaining the high quality of the conference. GECCO-2012 accepted 172 full papers for oral presentation out of a total of 467 submitted. This is an acceptance rate of less than 37%. I am very thankful to Terry, Anne Auger, our Proceedings Chair, and all the track chairs for their hard work managing the review, selection and scheduling process for the scientific papers. Thanks to Mark Montague from Linklings and Lisa Tolles from Sheridan Printing for their assistance with the publication of the proceedings.

One of the highlights of every GECCO is the free tutorials and the free workshops held during the first two days of the conference. I found these to be incredibly helpful when I was still learning about the field. Thanks to Gabriela Ochoa for chairing the tutorials and Bill Rand for chairing the workshops.

In addition to the main program, there are many other parts that make GECCO a special and meaningful experience. Marylyn Ritchie served as Local Chair and was very helpful with planning our visit to Philly. Xavier Llorà did a superb job of publicity with the help of our webmaster and design consultant, Gerardo Valencia. Daniele Loiacono did a great job as Competitions Chair and, as Student Chair, Josh Bongard masterfully oversaw the process of awarding student travel grants. I would also like to thank Thomas Bartz-Beielstein, David Davis and Joern Mehnert for their role as Evolutionary Computation in Practice Chairs.

I couldn't have planned GECCO-2012 without the generous time commitment of all the chairs mentioned above. I would also like to thank Wolfgang Banzhaf and Marc Schoenauer from the ACM SIGEVO Business Committee and Franz Rothlauf, the ACM SIGEVO Treasurer, for their encouragement and assistance navigating the enormous number of details from budgets to planning and execution. Additionally, I would like to thank Roxane Rose and Jill Skuba from Executive Events for their expert handling of the many logistical and registration-related details that are needed to make the conference a success.

Finally, I would like to thank you, the authors, presenters, reviewers, and all the other attendees. It is your participation that makes GECCO what it is, one of the premier conferences on evolutionary computation and a source of great discussions, ideas, and inspirations. Thank you all for your involvement.

Jason H. Moore, Ph.D.
Dartmouth College, USA

Instruction for Session Chairs and Presenters

Instructions for Session Chairs

Thank you for agreeing to chair a session! Session chairs are essential to keep sessions on schedule and moderate the question period.

- ✓ Arrive a few minutes early to check on room and equipment setup. Let the conference organizers at the Registration Desk know if problems arise or adjustments are needed.
- ✓ Please follow the scheduled order of talks, as well as presentation times.
- ✓ If a speaker is absent, we ask you to announce a short break until the next presentation is due to start.
- ✓ Do not start before, as participants may be moving between sessions/presentations.
- ✓ Introduce each speaker.
- ✓ Speakers presenting **accepted full papers** during the technical sessions are allocated **25 minutes** for each presentation, 20 minutes for set up and presentation and 5 minutes for questions.
- ✓ Moderate questions.
- ✓ If you chair a **best paper session**, please remind the audience that this is a best paper session, distribute the voting material that you will find in the room in the beginning of the session, and collect the votes at the end of the session. After the session, please bring the voting material to the registration desk.

If a session is without a chair, we ask the last scheduled speaker to perform those duties.

Instructions for Paper Presenters

Projectors and screens will be available for all presentations and larger rooms will have microphones. Presenters must bring their own laptop (or arrange to use a laptop for their presentation) and will need to bring any specialty equipment needed to enhance their presentations (computer speakers, laser pointers, etc.).

To keep the session on schedule:

- ✓ Please adhere to the scheduled slot of your presentation.
- ✓ Please try whether your laptop works with the video projector before the beginning of your session.
- ✓ Speakers presenting **accepted full papers** during the technical sessions are allocated **25 minutes** for each presentation, 20 minutes for set up and presentation and 5 minutes for questions.

Instructions for Poster Presenters

The poster session will be held Symphony/Overture room (Third Floor) 19:00 - 22:00 on Tuesday July 10th.

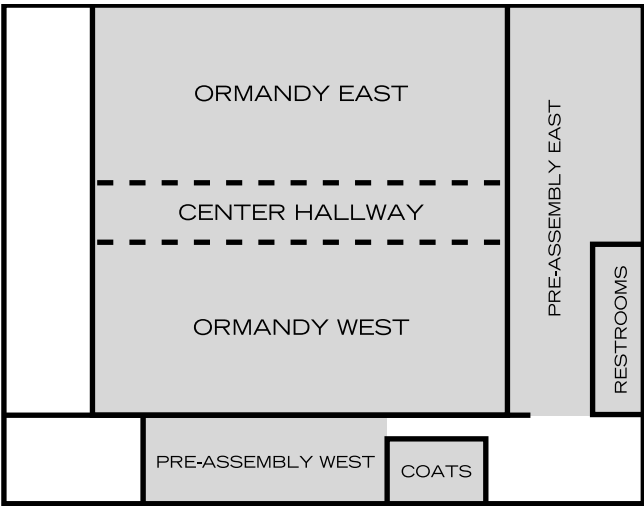
- ✓ Poster set-up will be 17:30-18:30.
- ✓ Poster boards and thumbtacks will be available.
- ✓ Posters should be no more than 36" wide and up to 44" high.

Program Schedule and Floor Plans

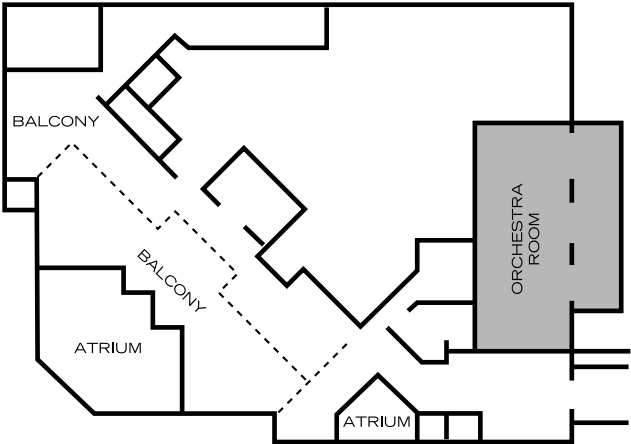
Track List and Abbreviations

ACO-SI	Ant Colony Optimization and Swarm Intelligence	BIO	Biological and Biomedical Applications
DETA	Digital Entertainment Technologies and Arts	EDA	Estimation of Distribution Algorithms
ECOM	Evolutionary Combinatorial Optimization and Metaheuristics	ESEP	Evolution Strategies and Evolutionary Programming
EMO	Evolutionary Multiobjective Optimization	GDS	Generative and Developmental Systems
GP	Genetic Programming	RWA	Real World Applications
GBML	Genetics Based Machine Learning	SBSE	Search-Based Software Engineering
PES	Parallel Evolutionary Systems	SS	Self-* Search
THEORY	Theory	GA	Genetic Algorithms
ALIFE	Artificial Life/Robotics/Evolvable Hardware	IGEC	Integrative Genetic and Evolutionary Computation
ECP	Evolutionary Computation in Practice		

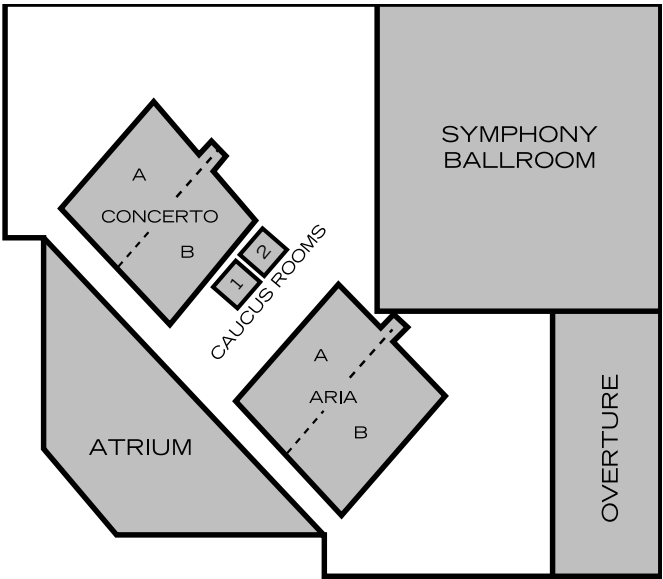
Floor Plans



BROAD STREET
LOBBY LEVEL

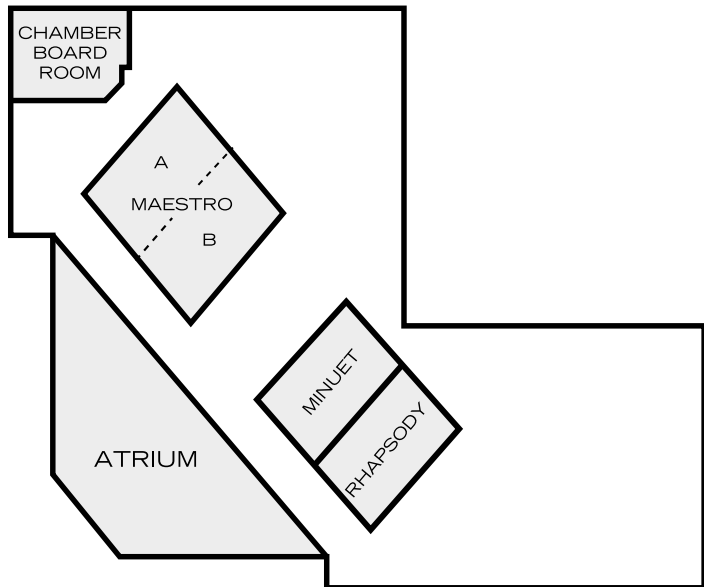


BROAD STREET
MEZZANINE LEVEL



BROAD STREET
THIRD FLOOR

Floor Plans



BROAD STREET

FOURTH FLOOR

Registration desk: Pre-Assembly

Open hours:

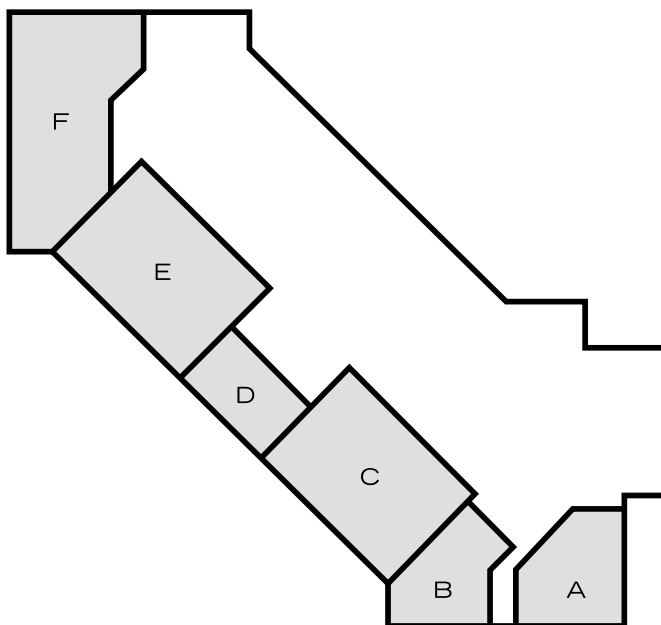
Saturday 8:00 - 15:30

Sunday 8:00 - 16:00

Monday 8:00 - 17:00

Tuesday 8:00 - 17:00

Wednesday 8:00 - 14:00



BROAD STREET

FIFTH FLOOR ASSEMBLY ON FIVE

Coffee breaks: Atrium/Pre-Assembly

Welcome reception: Sunday, July 8th 18:30
Symphony/Overture

Reception and posters: Tuesday, July 10th
19:00 - 22:00
Symphony/Overture

Room	8:30 - 10:20	10:40 - 12:30	14:00 - 15:50	16:10 - 18:00
Ormandy East	Intro Genetic Algorithms Erik Goodman	Intro Genetic Programming Una-May O'Reilly	Intro Evolutionary Multiobjective Optimization Dimo Brockhoff Kalyanmoy Deb	Special Large Scale Data Mining using Genetics-Based Machine Learning Jaume Bacardit Xavier Llorà
Ormandy West	Intro Evolutionary Neural Networks Risto Miikkulainen Ken Stanley	Intro Evolution Strategies: Basic Introduction Thomas Bäck	Advanced Evolution Strategies and CMA-ES (Covariance Matrix Adaptation) Anne Auger Nikolaus Hansen	Special Evolutionary Algorithms and Genetic Programming on Graphic Processing Units (GPU) Pierre Collet Simon Harding
Orchestra	Graduate Students Workshop A. Motsinger-Reif p. 52			
Aria AB	Black-Box-Optimization-Benchmarking 2012 (BBOB 2012) A. Auger, A. Chotard, N. Hansen, V. Heidrich-Meisner, O. Mersmann, P. Pošík, M. Preuss p. 45			
Concerto AB	Advanced Statistical Analysis for Evolutionary Computation: Introduction Mark Wineberger	Special Statistical Analysis of Optimization Algorithms with R Thomas Bartz-Beielstein Mike Preuss	Special Introduction to Bioinformatics and Computational Biology William S. Bush	Special Evolutionary Software Repair Stephanie Forrest
Maestro AB	Advanced Genetic Algorithms Theory Jon Rowe	Special Drift Analysis Per Kristian Lehre	Special Black-Box Complexity: From Complexity Theory to Playing Mastermind Benjamin Doerr	Advanced Bioinspired Computation in Combinatorial Optimization - Algorithms and Their Computational Complexity Frank Neumann Carsten Witt
Assembly C	Green and Efficient Energy Applications of Genetic and Evolutionary Computation Workshop (GreenGEC) A.-A. Tantar, E. Tantar, P. A.N. Bosman p. 43		Real World Applications of Evolutionary Computing N. Padhye, A. Baughman, S. Van Der Stock, M. Perlitz, O. S. M. Gustafson, J. Jesneck p. 44	
Assembly E	2nd Workshop on Evolutionary Computation for the Automated Design of Algorithms G. L. Pappa, J. Woodward, M. R. Hyde, J. Swan p. 44		1st workshop on Understanding Problems (GECCO-UP) K. McClymont, E. Keedwell p. 48	
Assembly F	Late-Breaking Abstracts Workshop Christian Blum, Katya Rodriguez p. 55			

- ☐ Tutorials
☒ Workshops

Intro: Introductory Tutorials
Advanced: Advanced Tutorials
Special: Specialized Techniques and Applications

Room	8:30 - 10:20	10:40 - 12:30	14:00 - 15:50	16:10 - 18:00	18:30-
Ormandy East	Intro Evolutionary Computation: A unified view Kenneth De Jong	Intro Probabilistic Model-building Genetic Algorithms Martin Pelikan	Special Artificial Immune Systems for Optimization Thomas Jansen Christine Zarges	Advanced Generative and Developmental Systems Kenneth O. Stanley	
Ormandy West	Advanced Elementary Landscapes: Theory and Applications Darrell Whitley Andrew Sutton	Advanced Fitness Landscapes and Graphs: Multimodularity Ruggedness and Neutrality Sébastien Verel	Special The Geometry of Evolutionary Algorithms Alberto Moraglio	Special Theory of Swarm Intelligence Dirk Sudholt	
Orchestra	Tenth GECCO Undergraduate Student Workshop S. Goings p. 51		Medical Applications of Genetic and Evolutionary Computation (MedGEC) S. L. Smith, S. Cagnoni, R. M. Patton p. 50		
Aria AB	Fifteenth International Workshop on Learning Classifier Systems D. Loiacono, A. Orriols-Puig, R. Urbanowicz p. 47				
Concerto AB	Special Cartesian Genetic Programming Julian Miller Simon Harding	Advanced Expressive Genetic Programming Lee Spector	Advanced Representations for evolutionary algorithms Franz Rothlauf	Special Industrial Data Modeling Mark Kotanchek	
Maestro AB	Advanced Constraint-Handling Techniques used with Evolutionary Algorithms Carlos Coello-Coello	Special Algorithm and Experiment Design with HeuristicLab - An Open Source Optimization Environment for Research and Education Stefan Wagner	Special Hyper-heuristics and Cross-domain Optimization Gabriela Ochoa	Special Computational Intelligence in Games Daniele Loiacono Mike Preuss	
Assembly C	Symbolic Regression and Modeling Workshop S. M. Gustafson, E. Vladislavleva p. 50		Evolutionary Music F. Fernández de Vega, C. Cotta p. 49		
Assembly E	Visualisation Methods for Genetic and Evolutionary Computation (VizGEC) R. Everson, J. Fieldsend, D. Walker p. 49		Evolutionary computation and multi-agent systems and simulation (EcoMass) F. Stonedahl, R. Riolo p. 47		
Assembly F	Evolutionary Developmental Robotics S. Doncieux, Y. Jin, J.-B. Mouret p. 53		Evolutionary Computation Software Systems (EvoSoft) S. Wagner, M. Affenzeller p. 54		
Symphony Overture					Welcome Reception

Room	8:30-10:10	10:40-12:00	12:40-13:40	13:40 - 15:00	15:40-17:00
Ormandy East	Conference Opening & Keynote Talk: Chris Adami p. 30	GDS 1: Biological Evolution & Development Stuart Kauffman's GDS Introduction p. 30, 63		GDS 2: Morphogenetic Robotics p. 70	GDS / EDA: Best papers p. 79
Ormandy West		RWA 1 p. 64	GECCO Competitions p. 33-37	RWA 2 p. 72	RWA 3 p. 80
Orchestra		ECP-1: Ask the Experts: EC questions from the audience Open panel discussion p. 38		Human-Competitive Competition (HUMIES) p. 32	
Aria AB		DETA 1 p. 64		PES 1 p. 71	DETA / PES / Bio: Best papers p. 79
Concerto AB		THEORY 1 p. 60		THEORY / ESEP: Best papers p. 67	THEORY 2 p. 75
Maestro AB		BIO 1 p. 60		BIO 2 p. 67	GP 1: Algorithm analysis and evaluation p. 76
Assembly C		EDA 1: Test Problems, Model Accuracy, Transfer Learning p. 62		EDA 2: Linkage Learning, Multiobjective EDAs p. 69	ESEP 1 p. 78
Assembly E		EMO 1 p. 61		EMO 2: Best papers p. 68	EMO 3 p. 77
Assembly F		GBML 1: Best papers p. 65		GBML 2: LCS Fundamentals p. 73	GBML 3: Optimisation and Feature Detection p. 81

Room	9:00-10:10	10:40-12:00	12:40-13:40	13:40-15:00	15:40-17:00	19:00-22:00
Ormandy East	Keynote Talk: Carl Schoonover How to look inside the brain p. 31	GDS 4: Architectural, Chemical & Behavioral Diversity p. 86		IGEC 1: Multi-agent systems p. 95	IGEC 2: Differential Evolution and Coevolution p. 102	
Ormandy West		RWA 4 p. 88	GECCO Competitions p. 33-37	RWA 5: Best papers p. 97	RWA 6 p. 104	
Orchestra		ECP-2: Managing an EC project for success, Emerging Technologies p. 38		ECP-3: EC in Design and Optimization p. 38	ECP-4: EC in Statistics and EA consultancy p. 38	
Aria AB		GA 1: Linkage Learning p. 87		GA 2: Dynamic Optimization & Exploration Techniques p. 95	GA 3: Best papers p. 103	
Concerto AB		THEORY / ESEP p. 83		ALIFE 1 p. 91	ALIFE 2: Best papers p. 99	
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Assembly C		IGEC / SS / SBSE: Best papers p. 85		SS 1 p. 94	SS 2 p. 101	
Assembly E		ECOM 1 p. 84		ECOM 2 p. 93	ECOM 3: Best papers p. 100	
Assembly F		GBML 4: Reinforcement Learning p. 89		ACO 1: Best papers p. 98	ACO 2 p. 105	
Symphony Overture						Reception and Posters p. 120-125

Room	9:00-10:10	10:40 - 12:00	13:40 - 15:00
Ormandy East	SIGEVO Meeting and awards. All are welcome.		
Ormandy West		RWA 7 p. 111	RWA 8 p. 118
Orchestra		ECP-5: Getting a Job: What to do and what not to do p. 38	
Aria AB		GA 4: Distance Measures & Recombination p. 110	GA 5: Applications p. 117
Concerto AB		ALIFE 3 p. 106	ALIFE 4 p. 114
Maestro AB		GP 5: Empirical Studies p. 107	GP 6: Theory and Representations p. 114
Assembly C		SBSE 1 p. 109	
Assembly E		ECOM 4 p. 108	ECOM 5 p. 115
Assembly F		ACO 3 p. 113	ACO 4 p. 119

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Digital Entertainment Technologies and Arts (DETA): Mike Preuss
Alan Dorin

Evolutionary Combinatorial Optimization and Metaheuristics (ECOM): Yew-Soon Ong
Christian Blum

Evolutionary Multiobjective Optimization (EMO): Dario Landa Silva
Frank Neumann

Genetic Programming (GP): Tina Yu
Aniko Ekart

Genetics Based Machine Learning (GBML): Wil Browne
Tim Kovacs

Parallel Evolutionary Systems (PES): Man-Leung Wong
Clara Pizzuti

Theory (THEORY): Jon Rowe
Tobias Friedrich

Artificial Life/Robotics/Evolvable Hardware (ALIFE): Giovanni Squillero
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Biological and Biomedical Applications (BIO): Stephen Smith
Alison Motsinger-Reif

Estimation of Distribution Algorithms (EDA): José Lozano
Martin Pelikan

Evolution Strategies and Evolutionary Programming (ESEP): Silja Meyer-Nienberg
Christian Igel

Generative and Developmental Systems (GDS): Greg Hornby
René Doursat

Real World Applications (RWA): Steve Gustafson
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John Clark

Self-* Search (SS): Gabriela Ochoa
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Ke Tang, *University of Science and Technology of China*
Ernesto Tarantino, *ICAR - CNR*
Daniel Tauritz, *Missouri University of Science and Technology*
Jorge Tavares, *University of Coimbra*
Tim Taylor, *Goldsmiths, University of London*
Jürgen Teich, *University of Erlangen-Nuremberg*
Hugo Terashima Marin, *ITESM - CSI*
German Terrazas Angulo, *University of Nottingham*
Andrea G. B. Tettamanzi, *Università degli Studi di Milano*
Christof Teuscher, *Portland State University*
Fabien Teytaud, *University of Paris-Dauphine / HEC Paris, CNRS*
Olivier Teytaud, *Inria*
Lothar Thiele, *ETH Zurich*
Dirk Thierens, *Universiteit Utrecht*
Adrian Thompson, *University of Sussex*
Tricia Thornton-Wells, *Vanderbilt Medical Center*
Jonathan Timmis, *University of York*
Chuan-Kang Ting, *Department of Computer Science and Information Engineering, National Chung Cheng University*
Ashutosh Tiwari, *Cranfield University*
Santosh Tiwari, *Vanderplaats Research & Development Inc.*
Peter M. Todd, *Indiana University*
Julian Togelius, *IT University of Copenhagen*
Michael Tolley
marco tomassini, *university of lausanne*
Alberto Paolo Tonda, *Politecnico di Torino*
Alexander Topchy, *Nielsen Media Research*
Jim Torresen, *University of Oslo*
Gregorio Toscano-Pulido, *Cinvestav-Tamaulipas*
Heike Trautmann, *TU Dortmund, Germany*
Martin Trefzer
Vito Trianni, *ISTC-CNR*
Leonardo Trujillo, *Instituto Tecnológico de Tijuana*
Elio Tuci, *Aberystwyth University*
Gunnar Tufte, *NTNU*
Cem Celal Tutum, *Technical University of Denmark*
Jamie Twycross, *University of Nottingham*

Man Chon U, *The University of Georgia*
Shmuel Ur, *Ur Innovation*
Ryan Urbanowicz
Neil Urquhart, *Edinburgh Napier University*
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Carola Winzen, *Max-Planck-Institut fuer Informatik*
Carsten Witt, *Technical University of Denmark*
M. L. Dennis Wong, *Xi'an Jiaotong-Liverpool University*
John Woodward, *Nottingham University*
Jonathan Wright, *Loughborough University*

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Rolf Wurtz, *Ruhr-Universitaet Bochum*
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Ming-Jie Zhao, *University of Manchester*
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Albert Zomaya

Best Paper Nominations

In 2002, ISGEC created a best paper award for GECCO. As part of the double blind peer review, the reviewers were asked to nominate papers for best paper awards. We continue the tradition this year. The Track Chairs, Editor in Chief, and the Conference Chair nominated the papers that received the most nominations and/or the highest evaluation scores for consideration by the conference. The winners are chosen by secret ballot of the GECCO attendees after the papers have been orally presented at the conference. Instead of one best paper award per track as in the previous years, this year we have grouped the smallest tracks to receive only one across-tracks best paper award while keeping one best paper for the largest tracks. Best paper winners are posted on the conference website. The titles and authors of all papers nominated are given below:

Genetics Based Machine Learning

Guided Evolution in XCSF

Patrick Stalph, Martin Butz

Filtering Sensory Information with XCSF: Improving Learning Robustness and Control Performance

*Jan Kneissler, Patrick Stalph, Jan Drugowitsch,
Martin Butz*

Evolutionary Multiobjective Optimization

Equitable Equilibrium: Evolutionary Detection

Réka Nagy, Mihai Alexanru Suciu, D. Dumitrescu

On the Properties of the R2 Indicator

Dimo Brockhoff, Heike Trautmann, Tobias Wagner

Genetic Programming

Spatial Co-Evolution - quicker, fitter and less bloated

Robin Harper Harper

Symbolic Regression of Multiple-Time-Scale Dynamical Systems

Theodore Cornforth, Hod Lipson

Theory / Evolution Strategies and Evolutionary Programming

Reducing the Arity in Unbiased Black-Box Complexity

Benjamin Doerr, Carola Winzen

The Choice of the Offspring Population Size in the $(1, \lambda)$ EA

Jonathan Rowe, Dirk Sudholt

A (1+1)-CMA-ES for Constrained Optimisation

Dirk Arnold, Nikolaus Hansen

Evolutionary Combinatorial Optimization and Metaheuristics

A Hybridization between Memetic Algorithm and Semidefinite Relaxation for the Max-Cut Problem

Bo Song, Victor O. K. Li

An Evolutionary Algorithm with Solution Archives and Bounding Extension for the Generalized Minimum Spanning Tree Problem

Bin Hu, Günther Raidl

Digital Entertainment Technologies and Arts / Parallel Evolutionary Systems / Biological and Biomedical Applications

An Improved CUDA-Based Implementation of Differential Evolution on GPU

Kai Qin, Federico Raimondo, Florence Forbes, Yew Soon Ong

Accelerating Interactive Evolutionary Algorithms through Comparative and Predictive User Models

Gregory Hornby, Josh Bongard

Artificial Life/Robotics/Evolvable Hardware

Hierarchical task decomposition through Symbiosis in reinforcement learning

John Doucette, Peter Lichodziejewski, Malcolm Heywood

A Comparison of a Communication Strategies in Cooperative Learning

Michael Solomon, Terence Soule, Robert Heckendorn

Generative and Developmental Systems / Estimation of Distribution Algorithms

Complex and Diverse Morphologies Can Develop from a Minimal Genome

Jose David Fernandez, Francisco Vico, Rene Doursat

A Memory Efficient and Continuous-valued Compact EDA for Large Scale Noisy Problems

Sergio Rojas-Galeano, Nestor Rodriguez

Integrative Genetic and Evolutionary Computation/Self-* Search/Search-Based Software Engineering

A Hyper-Heuristic Evolutionary Algorithm for Automatically Designing Decision-Tree Algorithms

Rodrigo Barros, Márcio Basgalupp, André de Carvalho, Alex Freitas

Evolutionary Algorithm for Prioritized Pairwise Test Data Generation

Javier Ferrer, Peter Kruse, Francisco Chicano, Enrique Alba

Representations and Operators for Improving Evolutionary Software Repair

Claire Le Goues, Westley Wemer, Stephanie Forrest

Ant Colony Optimization and Swarm Intelligence

Gaussian mixture modeling for dynamic particle swarm optimization of recurrent problems

Eduardo Vellasques, Robert Sabourin, Eric Granger

Learning Fuzzy Cognitive Maps from Data by Ant Colony Optimization

Ye Chen, Lawrence Mazlack, Long Lu

Best Paper Nominations

Genetic Algorithms

Crossover Speeds Up Building-Block Assembly

Dirk Sudholt

Runtime Analysis of Convex Evolutionary Search

Alberto Moraglio, Dirk Sudholt

Real World Applications

Evolving Large Scale UAV Communication System

Adrian Agogino, Chris HolmesParker, Kagan Tumer

The Unconstrained Automated Generation of Cell Image Features for Medical Diagnosis

Taras Kowaliw, Wolfgang Banzhaf

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Keynotes

Keynotes

Keynote with Chris Adami

Monday, July 9th, 2012, 9:00 - 10:10 am Ormandy East / West

About the speaker:

“Chris Adami is a professor of Microbiology and Molecular Genetics, as well as professor of Physics and Astronomy, at Michigan State University. Adami was born August 30, 1962 in Brussels, Belgium, and graduated from the European School of Brussels I. He obtained a Diplom in Physics from the University of Bonn and an MA and a Ph.D in Theoretical Nuclear Physics from Stony Brook University in 1991. He is best known for his work on Avida, an artificial life simulator used to study evolutionary biology, and for applying the theory of information to physical and biological systems. He is also an adviser to the Microbes Mind Forum.”¹

Keynote for the GDS track with Stuart Kauffman

Monday, July 9th, 2012, 10:40 - 11:30 am Ormandy East

No Entailing Laws, but Enablement in the Evolution of the Biosphere

see **No Entailing Laws, but Enablement in the Evolution of the Biosphere**
Giuseppe Longo, Maël Montévil, Stuart Kauffman
in Companion proceedings

About the speaker:

Dr. Kauffman is a renowned theoretical biologist and complex systems researcher especially interested in the question of the origins of life on Earth. He is best known for arguing that the complexity of biological systems and organisms might result as much from self-organization and far-from-equilibrium dynamics as from Darwinian natural selection, as well as for applying models of Boolean networks to simplified genetic circuits. Stuart Kauffman joined in 2010 the University of Vermont where he continues his work with UVM's Complex Systems Center.

¹ From wikipedia

Keynotes

Keynote with Carl Schoonover

Tuesday, July 10th, 2012, 9:00 - 10:10 am Ormandy East / West

How to look inside the brain

In the brain, less is more. Many of the most successful methods in neuroscience research draw their power from stripping away all but the structures or phenomena relevant to a particular experimental question--focusing on the problem at hand, and cutting out the distractions. The birth of the modern field one century ago is due to the discovery of a tissue staining protocol, the 'Golgi Stain', that marks only a small percentage of neurons in nervous tissue, but leaves the vast majority of them invisible, permitting visualization under the microscope of individual trees in what would otherwise have been an impenetrable forest.

Today, with the advent of modern genetics and molecular biology, this same principle has been applied across countless brain areas and a broad set of questions about the anatomical configuration, function, development, and plasticity of the nervous system. Many of the most powerful and commonly employed tools--like Green Fluorescence Protein, Channelrhodopsin, and virus-mediated tracing of neuronal projections--are actually biological solutions to completely unrelated problems, such as how to get a jellyfish to glow green, how to convey photosensitivity to a unicellular organism, or how to spread the Rabies virus across an entire nervous system. These research tools, the product of millions of years of evolution (and a few years of human tinkering) yield datasets whose explanatory power draws from the fact that they, like the Golgi Stain, allow researchers to focus on the question at hand and filter out the surrounding noise.

About the speaker:

Carl Schoonover is a neuroscience PhD candidate at Columbia University, the author of *Portraits of the Mind: Visualizing the Brain from Antiquity to the 21st Century* (Abrams, 2010), and has written for *The New York Times*, *Le Figaro*, and *Scientific American*. He is a cofounder of NeuWrite, a collaborative working group for scientists, writers, and those in between, and hosts a radio show on WKCR 89.9FM, which focuses on opera, classical music, and their relationship to the brain.

He currently lives in New York City and works on microanatomy and electrophysiology of rodent somatosensory cortex in the Bruno laboratory at Columbia University Medical Center. He is a former NSF Graduate Research Fellow and a 2012 TED Fellow.

Human-Competitive Results: 9th annual (2012) HUMIES AWARDS

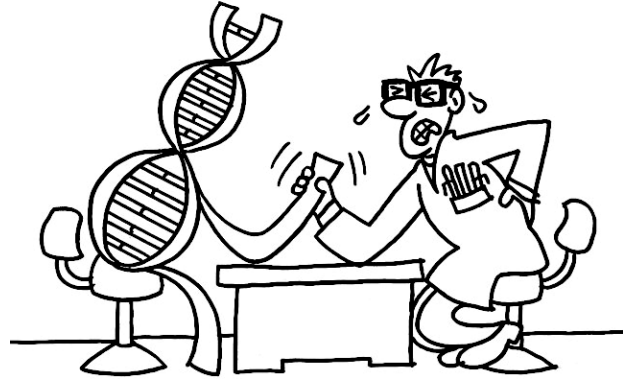
Presentations: Monday July 9th 13:40 - 17:00 Orchestra

Announcement of awards: Wednesday, July 11th

9:00 - 10:10 Ormandy East/West

Prizes Totaling \$10,000 to be Awarded

**Award prizes are sponsored by Third Millennium
On-Line Products Inc.**



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

This prize competition is based on published results. The publication may be a paper at the GECCO conference (i.e., regular paper, poster paper, or any other full-length paper), a paper published anywhere in the open literature (e.g., another conference, journal, technical report, thesis, book chapter, book), or a paper in final form that has been unconditionally accepted by a publication and is "in press" (that is, the entry must be identical to something that will be published imminently. The publication may not be an intermediate or draft version that is still subject to change or revision by the authors or editors. The publication must meet the usual standards of a scientific publication in that it must clearly describe a problem, the methods used to address the problem, the results obtained, and sufficient information to enable the work described to be replicated by an independent person.

Cash prizes of \$5,000 (gold), \$3,000 (silver), and bronze (either one prize of \$2,000 or two prizes of \$1,000) will be awarded for the best entries that satisfy the criteria for human-competitiveness. The awards will be divided equally among co-authors unless the authors specify a different division at the time of submission. Prizes are paid by check in U.S. dollars.

The judging committee:

Wolfgang Banzhaf

Erik Goodman

Darrell Whitley

Lee Spector

Una-May O'Reilly

Detailed information is at www.human-competitive.org

Room: Ormandy West

The Evolutionary Art, Design, and Creativity Competition

Organizers: Christian Gagné, Amy K. Hoover, Jon McCormack

Goal

The Evolutionary Art, Design, and Creativity Competition at the Genetic and Evolutionary Computation Conference showcases the power of evolutionary computation through human-quality artistic works or creativity enhancing experiences generated by or with the assistance of evolution. Entries can be music, images, sculptures, videos, or interactive online experiences, but are not limited to these forms of expression; the goal is that the submissions exhibit some form of independent creativity through genetic and evolutionary computation.

Evaluation

The submissions will be evaluated by a jury of researchers from the evolutionary computation and the technological arts communities. Each submission will be judged on the following criteria: artistic or design merit, innovation, creativity, technical quality, and relevance.

Demolition Derby

Organizer: Martin V. Butz

Goal

The **Demolition Derby 2012 competition** challenges you to design a racing car controller that manages to effectively crash into other cars while avoiding being crashed itself. Thus, the goal is simple: Wreck all opponent cars by crashing into them without getting wrecked yourself.

Demolition Derby takes place on a large circular track (surface: asphalt, length: 640m, width: 90m, number of laps: 1000). The sensor information is egocentric fostering the design and optimization of local interaction routines. The last car standing is declared winner of the match.

Rules and Scoring

The most important sensors and actuators of the competition are:

36 noiseless opponent sensors with a range of 300m indicate the presence of opponents around the own car.

19 noiseless track edge distance sensors (200m range) indicate the local track outline.

Other track information sensors indicate the orientation on the track as well as the locality with respect to the track edges.

Car state sensors indicate the current speed, gear, rpm of the engine, as well as the wheel speeds.

Damage sensors indicate the current own damage as well as the damage induced to other cars.

Actuators include all usual car control options (using the clutch, changing gears, accelerating, breaking, steering).

The damage model is such that the goal is to crash into other cars coming from the side or behind. Front crashes as well as crashes into walls do not result in damage. This is done to foster strategic driving and to decrease randomness in the results.

All racing controllers participating in Demolition Derby have to qualify for the final showdown match by competing with each other in preliminary 1-vs-1-matches. The best eight controllers then fight each other at the same time in ten final matches. The car that wins most often in these final matches will be the Winner of the Demolition Derby Competition.

Participation is open to anybody. You do not need to participate in the conference to send an entry. However, the price will be received by the best competitor that also participates in the conference.

GPUs for Genetic and Evolutionary Computation

Organizer: Simon Harding

Goal

This competition focuses on the applications of genetic and evolutionary computation that can maximally exploit the parallelism provided by low-cost consumer graphical cards. The competition will award the best applications both in terms of degree of parallelism obtained, in terms of overall speed-up, and in terms of programming style.

Rules and Regulations

Entrants must submit (1) the application sources with the instructions to compile it and (2) a two page description of the application. Submissions will be reviewed by a committee of researchers from the

evolutionary computation community and from industry. Each reviewer will score the submission according to 12 criteria concerning the submitted algorithm, the speed-up it achieves, and its impact on the evolutionary computation community. The total score will be obtained as the weighted sum of the 12 separate scores.

Visualizing Evolution Competition

Organizers: Nicholas Sinnott-Armstrong, Daniele Loiacono

Goal

This competition aims to enable participants to exhibit their cutting edge visualizations of evolutionary processes. The competition is a general set of guidelines and a framework within which a variety of visualization and interaction technologies can be used to portray current work in evolutionary computing in a compelling and elucidating manner. Hopefully, by visualizing these processes and applying techniques from scientific visualization and visual analytics, new insights and a broader understanding will be achieved.

Rules

The Visualizing Evolution Competition submission guidelines require the submission of a program and relevant data that can be used to elucidate some aspect of the EC community. The data must be collected from running an evolutionary computing algorithm, or can be input to such a program running as part of the visualization system. The materials required for submission are as follows:

1. The application program and any instructions necessary to install and run it.
2. Test data for the application.
3. A two page writeup describing the application, the evolutionary process being modeled, and any insights gained through use of the program.

EvoRobocode Competition

Organizers: Daniele Loiacono, Moshe Sipper

Goal

EvoRobocode challenges you to apply Evolutionary Computation to design a competitive robot tank for the **Robocode** game!

Robocode is a programming game, where the goal is developing in Java a robot tank to fight against other tanks. Battles can be either run in real-time and displayed on the screen or run in a batch mode without visualization.

Robocode also features an on-line tournament system to rank developed tanks.

To make the competition among robots more fair, each tank belongs to different categories based on its code size. Accordingly, only robots with a similar degree of complexity are allowed to battle together.

Scoring

Entries will be evaluated by a panel of judges based on different criteria including the performance, the relevance of EC in the development process, the quality of the documentation, and the degree of innovation of the proposed approach.

Simulated Car Racing Championship

Organizers: Daniele Loiacono, Luigi Cardamone, Pier Luca Lanzi

Goal

The goal of the championship is to design a controller for a racing car that will compete on a set of unknown tracks first alone (against the clock) and then against other drivers.

The controllers perceive the racing environment through a number of sensors that describe the relevant features of the car surroundings (e.g., the track limits, the position of near-by obstacles), of the car state (the fuel level, the engine RPMs, the current gear, etc.), and the current game state (lap time, number of lap, etc.). The controller can perform the typical driving actions (clutch, changing gear, accelerate, break, steering the wheel, etc.)

Rules and Regulations

The championship consists of several races on different tracks divided into legs.

Teams will be allowed to submit a different driver to each leg.

Each Grand Prix consists of three stages:

- the warm-up
- the qualifying
- the race

During **warm-up**, each driver races alone.

Drivers can collect useful information about the tracks and can tune their behaviors for the next stages.

Accordingly, the performance of drivers in this stage is not taken into account for their scores.

During the **qualifying stage** each driver races alone on each track of the leg.

The eight controllers that bridge the longest distances qualify for the actual Grand Prix races.

During the **final races**, these best eight drivers race together.

The races consist of eight runs on each of the three tracks. At the end of each race, the drivers are scored using the F1 system: 10 points to the first controller that completes the race, 8 points to the second one, 6 to the third one, 5 to the fourth, 4 to the fifth one, 3 to the sixth, 2 to the seventh, and 1 to the eighth. The driver performing the fastest lap in the race will get two additional points. The driver completing the race with the smallest amount of damage will also get two extra points. The starting grid of the first race will be based on the performance obtained in the qualifying stage. Each subsequent race, the starting grid will be shifted by one so that each driver starts from every position of the starting grid exactly once.

Industrial Challenge

Organizers: Oliver Flasch, Martina Frieze, Thomas Bartz-Beielstein, Wolfgang Konen, Jens Neuhalfen, Pier Luca Lanzi, Joern Mehnert

Goal

Goal of the GECCO 2012 Industrial Challenge is to develop accurate forecasting methods for electrical energy consumption profiles. Based on real-world energy consumption time series data, as recorded by modern smart metering equipment, these methods should provide accurate predictions of electrical energy consumption. As smart metering involves large volumes of streamed time series data to be processed in reasonable time, acceptable forecasting methods must be accurate and computationally efficient.

Rules and Regulations

The challenge is organized in a single round. In order to participate in the competition, appropriate predictions for the four training data sets provided have to be supplied. Submissions have to be accompanied by a two page report describing the algorithm that has been applied to generate the predicted time series. Submissions will be evaluated by the root mean square error (RMSE) of the predicted time series and the respective true energy consumption time series.

Evolutionary Computation in Practice

Organizers: Joern Mehnen, Thomas Bartz-Beielstein, David Davis

Ask the Experts

Session chairs: Jörn Mehnen, Thomas Bartz-Beielstein

This lively session consists of a panel of experts with decades of real-world application experience answering questions posed by attendees of the sessions. In the past, we have always had two or three discussions on industrial problems that lie on the cutting edge of EA development. This session gives you the opportunity to get free consulting from the experts!

Open panel discussion

Managing an EC project for success

Session chairs: Jörn Mehnen, Thomas Bartz-Beielstein

Experts in real-world optimization with decades of experience share their approaches to creating successful projects for real-world clients. Some of what they do is based on sound project management principles, and some is specific to our type of optimization projects. In this session a panel of experts describes a range of techniques you can use to identify, design, manage, and successfully complete an EA project for a client.

EC in Design and Optimization

Session chairs: Jörn Mehnen

In this session *industry speakers* will be presenting. They actually run companies in the field of optimization and applied statistics. If you attend, you will learn multiple ways to extend EC practice beyond the approaches found in textbooks.

EC in Statistics and EA Consultancy

Session chairs: Thomas Bartz-Beielstein

Statistics play a prominent role in today's industrial and business processes. New buzzwords like Data Mining or Big Data come up regularly. This session presents background and insider information about the true meaning a modern statistical approaches.

Speakers: Thomas Bäck, Guido Smits, Mark Kotanchek, Mike Preuß

Getting a Job

Session chairs: Jörn Mehnen, Thomas Bartz-Beielstein

Getting a job with training in evolutionary computation can be much easier if you know the things to do and the things not to do in your last year or two of study. In this session you will hear from a panel of experts who have trained students and who have hired students to carry out real-world optimization. Highly recommended if you will be looking for a job in the next few years — or if you are thinking of changing jobs.

Open panel discussion

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Workshop Presentations

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Green and Efficient Energy Applications of Genetic and Evolutionary Computation (GreenGEC)

Organizers: Alexandru-Adrian Tantar, Emilia Tantar, Peter Bosman

Time and room: Saturday, July 7th 2012 8:30-12:30 in Assembly C

Evolutionary Optimization of Multi-Agent Control Strategies for Electric Vehicle Charging

Stephan Hutterer, Michael Affenzeller, Franz Auinger

Green OLSR in VANETs with Differential Evolution

Jamal Toutouh, Enrique Alba

Evolutionary Multiobjective Optimization for Green Clouds

Dung H. Phan, Junichi Suzuki, Raymond Carroll, Sasitharan Balasubramaniam, William Donnelly, Dmitri Botvich

Roadside Unit Deployment for Information Dissemination in a VANET: An Evolutionary Approach

Evellyn S. Cavalcante, André L. L. Aquino, Gisele L. Pappa, Antonio A. F. Loureiro

Evolutionary Prediction of Photovoltaic Power Plant Energy Production

Pavel Kromer, Lukas Prokop, Vaclav Snasel, Stanislav Misak, Jan Platos, Ajith Abraham

Real World Applications of EC

Organizers: Nikhil Padhye, Aaron Baughman, Stefan Van Der Stock, Michael Perlitz, Steven M. Gustafson, Jonathan Jesneck

Time and room: Saturday, July 7th 2012 14:00-18:00 in Assembly C

Evolutionary Approaches for Real World Applications in 21st Century

Nikhil Padhye

2nd Workshop on Evolutionary Computation for the Automated Design of Algorithms

Organizers: Gisele L. Pappa, John Woodward, Matthew R. Hyde, Jerry Swan

Time and room: Saturday, July 7th 2012 8:30-12:30 in Assembly E

Evolving Evolutionary Algorithms

Nuno Lourenço, Francisco Pereira, Ernesto Costa

Supportive Coevolution

Brian W Goldman, Daniel R Tauritz

The Automatic Generation of Mutation Operators for Genetic Algorithms

John R Woodward, Jerry Swan

Autoconstructive Evolution for Structural Problems

Kyle I Harrington, Lee Spector, Jordan B Pollack, Una-May O'Reilly

Black Box Optimization Benchmarking 2012 (BBOB 2012)

Organizers: Anne Auger, Alexandre Chotard, Nikolaus Hansen, Verena Heidrich-Meisner, Olaf Mersmann, Petr Pošík, Mike Preuss

Time and room: Saturday, July 7th 2012 8:30-18:00 in Aria AB

An ACO Algorithm Benchmarked on the BBOB Noiseless Function Testbed

Tianjun Liao, Daniel Molina, Thomas Stutzle, Marco A. Montes de Oca, Marco Dorigo

Black-Box Optimization Benchmarking for Noiseless Function Testbed Using A Direction-Based RCGA

Yao-Chen Chuang, Chyi-Tsong Chen

Black-box Optimization Benchmarking of IPOP-saACM-ES and BIPOP-saACM-ES on the BBOB-2012 Noiseless Testbed

Ilya Loshchilov, Marc Schoenauer, Michele Sebag

Benchmarking the Multi-View Differential Evolution on the Noiseless BBOB-2012 Function Testbed

Vinícius Veloso de Melo

Benchmarking the Differential Evolution with Adaptive Encoding on Noiseless Functions

Petr Pošík, Václav Klema

JADE, an Adaptive Differential Evolution Algorithm, Benchmarked on the BBOB Noiseless Testbed

Petr Pošík, Václav Klema

Benchmarking Separable Natural Evolution Strategies on the Noiseless and Noisy Black-box Optimization Testbeds

Tom Schaul

Benchmarking Exponential Natural Evolution Strategies on the Noiseless and Noisy Black-box Optimization Testbeds

Tom Schaul

Investigating the Impact of Adaptation Sampling in Natural Evolution Strategies on Black-box Optimization Testbeds

Tom Schaul

Benchmarking Natural Evolution Strategies with Adaptation Sampling on the Noiseless and Noisy Black-box Optimization Testbeds*Tom Schaul***Comparing Natural Evolution Strategies to BIPOP-CMA-ES on Noiseless and Noisy Black-box Optimization Testbeds***Tom Schaul***MEMPSODE: An Empirical Assessment of Local Search Algorithm Impact on a Memetic Algorithm Using Noiseless Testbed***Costas Voglis, Grigoris S Piperagkas, Konstantinos E Parsopoulos, Dimitris G Papageorgiou, Isaac E Lagaris***MEMPSODE: Comparing Particle Swarm Optimization and Differential Evolution Within a Hybrid Memetic Global Optimization Framework***Costas Voglis, Grigoris S Piperagkas, Konstantinos E Parsopoulos, Dimitris G Papageorgiou, Isaac E Lagaris***Black-box Optimization Benchmarking of IPOP-saACM-ES on the BBOB-2012 Noisy Testbed***Ilya Loshchilov, Marc Schoenauer, Michele Sebag***Black-box Optimization Benchmarking of NIPOP-aCMA-ES and NBIPOP-aCMA-ES on the BBOB-2012 Noiseless Testbed***Ilya Loshchilov, Marc Schoenauer, Michele Sebag***On the Effect of Mirroring in the IPOP Active CMA-ES on the Noiseless BBOB Testbed***Dimo Brockhoff, Anne Auger, Nikolaus Hansen***On the Impact of a Small Initial Population Size in the IPOP Active CMA-ES with Mirrored Mutations on the Noiseless BBOB Testbed***Dimo Brockhoff, Anne Auger, Nikolaus Hansen***On the Impact of Active Covariance Matrix Adaptation in the CMA-ES With Mirrored Mutations and Small Initial Population Size on the Noiseless BBOB Testbed***Dimo Brockhoff, Anne Auger, Nikolaus Hansen***Comparing Mirrored Mutations and Active Covariance Matrix Adaptation in the IPOP-CMA-ES on the Noiseless BBOB Testbed***Dimo Brockhoff, Anne Auger, Nikolaus Hansen*

Evolutionary Computation and Multi-Agent Systems and Simulation (ECoMASS)

Organizers: Forrest Stonedahl, Rick Riolo

Time and room: Sunday, July 8th 2012 14:00-18:00 in Assembly E

Hybrid Particle Swarm Optimization and Convergence Analysis for Scheduling Problems

Xue-Feng Zhang, Miyuki Koshimura, Hiroshi Fujita

Integrating Evolutionary Computation and Sociotechnical Simulation for Flushing Contaminated Water Distribution Systems

Ehsan Shafiee, Emily Zechman

Modeling Technology Evolution Using Generalized Genotype-Phenotype Maps C.

Jason Woodard, Eric K. Clemons

Evolutionary Synthesis of Multi-Agent Systems for Dynamic Dial-a-Ride Problems

Rinde RS van Lon, Tom Holvoet, Greet Vanden Berghe, Tom Wenseleers, Juergen Branke

Automatic Discovery of Algorithms for Multi-Agent Systems

Sjors van Berkel, Daniel Turi, Andrei Pruteanu, Stefan Dulman

The Effects of Tags on the Evolution of Honest Signaling

A. Pinar Ozisik, Kyle I. Harrington

15th International Workshop on Learning Classifier Systems (ICWLS)

Organizers: Daniele Loiacono, Albert Orriols-Puig, Ryan Urbanowicz

Time and room: Sunday, July 8th 2012 8:30-18:00 in Aria AB

XCSF for Prediction on Emotion Induced by Image Based on Dimensional Theory of Emotion

Poming Lee, Yun Teng, Tzu-Chien Hsiao

1st workshop on Understanding Problems (GECCO-UP)

Organizers: Kent McClymont, Ed Keedwell

Time and room: Saturday, July 7th 2012 14:00-18:00 in Assembly E

Analysing Fitness Landscape Changes in Evolutionary Robots

Renato Tinós

Generic Hardness Estimation using Fitness and Parameter Landscapes applied to Robust Taboo Search and the Quadratic Assignment Problem

Erik Pitzer, Andreas Beham, Michael Affenzeller

Assessment of Problem Modality by Differential Performance of Lexicase Selection in Genetic Programming: A Preliminary Report

Lee Spector

A Call for Collaborative Landscape Analysis

Deon Garrett

Achieving COSMOS

Emma Tosch, Lee Spector

The Lay of the Land: a Brief Survey of Problem Understanding

Kent McClymont, David Walker, Max Dupenois

Visualisation Methods for Genetic and Evolutionary Computation (VizGEC)

Organizers: Richard Everson, Jonathan Fieldsend, David Walker

Time and room: Sunday, July 8th 2012 8:30-12:30 in Assembly E

Generating Colored 2-Dimensional Representations of Sleep EEG with the KANTS Clustering Algorithm

Carlos Miguel Fernandes, Antonio Mora Juan, Julian Merelo, Francisco Fernández, Agostinho Rosa

Biaxial Box Plots and Ordered Trial Ranks for Visualizing Large Sets of Experimental Results

Kent McClymont

Visualising Many-objective Populations

David Walker, Jonathan Fieldsend, Richard Everson

Evolutionary Music

Organizers: F. Fernández de Vega, Carlos Cotta

Time and room: Sunday, July 8th 2012 14:00-18:00 in Assembly C

Genetic Evolution of L and FL-systems for the Production of Rhythmic Sequences

Maximos A. Kaliakatsos-Papakostas, Andreas Floros, Nikolaos Kanellopoulos, Michael N. Vrahatis

An Adaption of the Schema Theorem to Various Crossover and Mutation Operators for a Music Segmentation Problem

Brigitte Rafael, Michael Affenzeller, Stefan Wagner

Evolutionary Algorithms and Automatic Transcription of Music

Gustavo Reis, Francisco Fernández, Aníbal Ferreira

Symbolic Regression and Modeling Workshop

Organizers: Steven Gustafson, Ekaterina Vladislavleva

Time and room: Sunday, July 8th 2012 8:30-12:30 in Assembly C

A New Framework for Scalable Genetic Programming

Nassima Aleb, Samir Kechid

Graphical Models and What they Reveal about GP When it solves a Symbolic Regression Problem

Erik Hemberg, Kalyan Veeramachaneni, Una-May O'Reilly

Sequential Parameter Optimization for Symbolic Regression

Thomas Bartz-Beielstein, Oliver Flasch, Martin Zaefferer

Robust Function Discovery and Feature Selection for Life Sciences and Engineering

Mark Kotanchek

Medical Applications of Genetic and Evolutionary Computation (MedGEC)

Organizers: Stephen L. Smith, Stefano Cagnoni, Robert M. Patton

Time and room: Sunday, July 8th 2012 14:00-18:00 in Orchestra

Interactive Differential Evolution for Prostate Ultrasound Image Thresholding

Arman Darvish, Shahryar Rahnamayan, Zaid S. Mohamad

First Results and Future Developments of the MIBISOC Project in the IBISlab of the University of Parma

Stefano Cagnoni, Oscar Cerdón, Pablo Mesejo, Youssef S. G. Nashed, Roberto Ugolotti

An Optimal Reconstruction of the Human Arterial Tree from Doppler Echotracking Measurements

Laurent Dumas, Pierre Boutouyrie, Erwan Bozec

Bézier Control Parameterization for Evolutionary Optimization in Disease Models

Tim Rogalsky

Early Diagnosis of Lung Tumors by Genetically Optimized 3D-Metaball Malignancy Metric

Vitoantonio Bevilacqua, Giuseppe Filograno, Michele Fiorentino, Antonio E. Uva

Analysis of a Feature-Deselective Neuroevolution Classifier (FD-NEAT) in a Computer-Aided Lung Nodule Detection System for CT Images

Maxine Tan, Rudi Deklerck, Bart Jansen, Jan Cornelis

Tenth GECCO Undergraduate Student Workshop

Organizer: Sherri Goings

Time and room: Sunday, July 8th 2012 8:30-12:30 in Orchestra

Flea Market Simulator: A Market Simulator for Experiments on the Computational Evolution of Trading Strategies for Economic Agents

Omri Bernstein

GAMIV: A Genetic Algorithm for Identifying Variable-length Motifs in Noncoding DNA

David J Gagne

Grammatical Evolution Decision Trees for Trio Designs

Holly Petruso, Chong Wang

Trade-offs Using GAMID for the Inference of DNA Motifs That Are Represented in Only a Subset of Sequences of Interest

Jeffrey Thompson

Evolving Software Applications using Genetic Programming

Kwaku Yeboah-Antwi

Principal Coordinate Strategy: A Novel Adaptive Control Strategy for Differential Evolution

Yifeng Gao, Dan Lv

Evolutionary Fabrication

Timothy J Kuehn

Graduate Students Workshop

Organizer: Alison Motsinger-Reif

Time and room: Saturday, July 7th 2012 8:30-18:00 in Orchestra

Discrete vs. Continuous Multiobjective Optimization of Continuous Casting of Steel

Miha Mlakar, Tea Taaar, Bogdan Filipi

Evolving EFSMs Solving a Path-Planning Problem by Genetic Programming

Maxim Buzdalov, Andrey Sokolov

Grammatical Evolution Support Vector Machines for Predicting Human Genetic Disease Association

Skylar Marvel, Alison Motsinger-Reif

Batting Order Optimization by Genetic Algorithm

Sen Han

Test-Based Extended Finite-State Machines Induction with Evolutionary Algorithms and Ant Colony Optimization

Daniil Chivilikhin, Vladimir Ulyantsev, Fedor Tsarev

Robotic Swarm Cooperation by Co-adaptation

François-Michel De Rainville

A Comparison of GE Optimized Neural Networks and Decision Trees

Kristopher Hoover, Rachel Marceau, Tyndall Harris, David Reif, Alison Motsinger-Reif

Evolutionary Developmental Robotics

Organizers: Stephane Doncieux, Yaochu Jin, Jean-Baptiste Mouret

Time and room: Sunday, July 8th 2012 8:30-12:30 in Assembly F

Evo-Devo-Robo Workshop Program

Stephane Doncieux, Yaochu Jin, Jean-Baptiste Mouret

Evolving Morphologies and Controllers for Soft-bodied Multicellular Animats Using Gene Regulatory Networks and Artificial Embryogenesis

Michal Joachimczak, Taras Kowaliw, Rene Doursat, Borys Wróbel

An Artificial Visual Cortex Drives Behavioral Evolution in Co-evolved Predator and Prey Robots

Michael E Palmer, Andrew K Chou

Empirical Mode Decomposition for Saliency Detection

Maja Rudinac, Boris Lenseigne, Pieter P. Jonker

Emergence of Memory in Neuroevolution: Impact of Selection Pressures

Charles Ollion, Tony Pinville, Stéphane Doncieux

Evolutionary Computation Software Systems (EvoSoft)

Organizers: Stefan Wagner, Michael Affenzeller

Time and room: Sunday, July 8th 2012 14:00-18:00 in Assembly F

DEAP: A Python Framework for Evolutionary Algorithms

François-Michel De Rainville, Félix-Antoine Fortin, Marc-André Gardner, Marc Parizeau, Christian Gagné

EpochX: Genetic Programming in Java with Statistics and Event Monitoring

Fernando Otero, Tom Castle, Colin Johnson

On the Architecture and Implementation of Tree-based Genetic Programming in HeuristicLab

Michael Kommenda, Gabriel Kronberger, Stefan Wagner, Stephan Winkler, Michael Affenzeller

SofEA, a Pool-Based Framework for Evolutionary Algorithms using CouchDB

Juan J. Merelo, Carlos M Fernandes, Antonio M. Mora, Anna I. Esparcia

libCudaOptimize: an Open Source Library of GPU-based Metaheuristics

Youssef S. G. Nashed, Roberto Ugolotti, Pablo Mesejo, Stefano Cagnoni

Integration of Flexible Interfaces in Optimization Software Frameworks for Simulation-Based Optimization

Andreas Beham, Erik Pitzer, Stefan Wagner, Michael Affenzeller, Klaus Altendorfer, Thomas Felberbauer, Martin Bäck

The SEEDS Platform for Evolutionary and Ecological Simulations

Brian D Connelly, Luis Zaman, Philip K McKinley

Optimization Knowledge Base: An Open Database for Algorithm and Problem Characteristics and Optimization Results

Andreas Scheibenpflug, Stefan Wagner, Erik Pitzer, Michael Affenzeller

InPUT: The Intelligent Parameter Utilization Tool

Felix Dobsław

Late Breaking Abstracts Workshop

Chairs: Christian Blum, Katya Rodríguez

Time and room: Saturday, July 7th 2012 8:30-18:00 in Assembly F

Comparison of Scoring Methods for Interactive Evolutionary Computation based Image Retouching System

Du-Mim Yoon, Kyung-Joong Kim

GeDEA-II: A Simplex-Crossover Based Multi Objective Evolutionary Algorithm Including The Genetic Diversity As Objective

Claudio Comis Da Ronco, Ernesto Benini

Application of Evolutionary Algorithms for Model Calibration

Mikhail A. Semenov, Pierre Stratonowitch

Experiences on Memetic Computation for Locating Transition States in Biochemical Applications

Mostafa Mostafa Hashim Ellabaan, Yew Soon Ong

Differential Evolution of Constants in Genetic Programming Improves Efficacy and Bloat

Shreya Mukherjee, Margaret J Eppstein

Interactive Simulated Robot Construction and Controller Evolution

Paul Beliveau, Greg Hornby, Josh Bongard

On the Effect of Using Multiple GPUs in Solving QAPs with CUDA

Shigeyoshi Tsutsui, Noriyuki Fujimoto

Evolving Players that Use Selective Game-Tree Search with Genetic Programming

Amit Benbassat, Moshe Sipper

A Surrogate Multiobjective Evolutionary Strategy with Local Search and Pre-Selection

Martin Pilat, Roman Neruda

The Evolutionary Algorithm SAMOA with Use of Dynamic Constraints

Susanne Zaglauer

The Evolutionary Algorithm SAMOA with Use of Design of Experiments

Susanne Zaglauer

Evolving Instances of Unconstrained Binary Quadratic Programming that Challenge a Tabu Search Heuristic

Michael Porta, Bryant A. Julstrom

Automatic Python Programming using Stack-based Genetic Programming

Hyun Soo Park, Kyung Joong Kim

Combining Programs to Counter Code Disruption

Cyril Fonlupt, Denis Robilliard

SPOT Applied to Non-Stochastic Optimization Problems - An Experimental Study

Thomas Bartz-Beielstein, Martina Frieze, Boris Naujoks, Martin Zaefferer

Generalized Compressed Network Search

Rupesh Kumar Srivastava, Juergen Schmidhuber, Faustino Gomez

A Linkage-Learning Niching in Estimation of Distribution Algorithm

Tsung-Yu Ho, Tian-Li Yu

Density-Based Evolutionary Outlier Detection

Amit Banerjee

3-D Modeling Using Collaborative Evolution

Juan C Quiroz, Amit Banerjee, Sushil J Louis

Evolving Mixed Nash Equilibria for Bimatrix Games

David Iclanzan, Noémi Gaskó, D. Dumitrescu

Evolving Data Sets to Highlight the Performance Differences between Machine Learning Classifiers

Thomas Raway, David J Schaffer, Kenneth J Kurtz, Hiroki Sayama

Not All Physics Simulators Can Be Wrong in the Same Way

Shane Eric Celis, Josh Bongard

A New Interactive Evolutionary Algorithm for the Vehicle Routing Problem

Sahbi Ben Ismail, François Legras, Gilles Coppin

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Paper Presentations

Theory 1

Session Chair: Jonathan Rowe

Room: Concerto AB

10:40-11:06 On the Analysis of the Simple Genetic Algorithm

Pietro Oliveto, Carsten Witt

For many years it has been a challenge to analyze the time complexity of Genetic Algorithms (GAs) using stochastic selection together with crossover and mutation. This paper presents a rigorous runtime analysis of the well-known Simple Genetic Algorithm (SGA) for OneMax . It is proved that the SGA has exponential runtime with overwhelming probability for population sizes up to $\mu \leq n^{1/8 - \epsilon}$ for some arbitrarily small constant ϵ and problem size n . To the best of our knowledge, this is the first time non-trivial lower bounds are obtained on the runtime of a standard crossover-based GA for a standard benchmark function. The presented techniques might serve as a first basis towards systematic runtime analyses of GAs.

11:06-11:32 Exact Computation of the Expectation Curves for Uniform Crossover

Francisco Chicano, Darrell Whitley, Enrique Alba

Uniform crossover is a popular operator used in genetic algorithms to combine two tentative solutions of a problem represented as binary strings. We use the Walsh decomposition of pseudo-Boolean functions and properties of Krawtchouk matrices to exactly compute the expected value for the fitness of a child generated by uniform crossover from two parent solutions. We prove that this expectation is a polynomial in ρ , the probability of selecting the best-parent bit. We provide efficient algorithms to compute this polynomial for ONEMAX and MAX-kSAT problems, but the results also hold for domains such as NK-Landscapes.

11:32-11:58 The Max Problem Revisited: The Importance of Mutation in Genetic Programming

Timo Kötzing, Andrew Sutton, Frank Neumann, Una-May O'Reilly

This paper contributes to the rigorous understanding of genetic programming algorithms by providing runtime complexity analyses of the well-studied Max problem. Several experimental studies have indicated that it is hard to solve the Max problem with crossover-based algorithms. Our analyses show that different variants of the Max problem can provably be solved using simple mutation-based genetic programming algorithms. Our results advance the body of computational complexity analyses of genetic programming, indicate the importance of mutation in genetic programming, and reveal new insights into the behavior of mutation-based genetic programming algorithms.

BIO 1

Session Chair: Stephen Leslie Smith

Room: Maestro AB

10:40-11:06 Experimental Evaluation of Topological-based Fitness Functions to Detect Complexes in PPI Networks

Clara Pizzuti, Simona Rombo

The detection of groups of proteins sharing common biological features is an important research issue, intensively investigated in the last few years, because of the insights it can give in understanding cell behavior. In this paper we

present an extensive experimental evaluation campaign aiming at exploring the capability of Genetic Algorithms (GAs) to find clusters in PPI networks, when different topological-based fitness functions are employed. A complete experimentation on the yeast PPI network, along with a comparative evaluation of the effectiveness in detecting true complexes on the yeast and human networks, reveals GAs as a feasible and competitive computational technique to cope with this problem.

11:06-11:32 ProtRank: A Method for Detecting Protein Complexes

Nazar Zaki

Detecting protein complexes from protein-protein interaction (PPI) network is becoming a difficult challenge in computational biology. Observations show that genes causing the same or similar diseases tend to lie close to one another in a network of protein-protein or functional interactions. This paper introduces a novel method for detecting protein-complexes from PPI by using a protein ranking algorithm (ProtRank) and incorporating evolutionarily relationships between proteins in the PPI network. The method successfully predicted 57 out of 81 benchmarked protein complexes created from MIPS. The level of the accuracy achieved using ProtRank in comparison to other recent methods for detecting protein complexes is a strong argument in favor of our proposed method.

11:32-11:58 Efficient algorithms for extracting biological key pathways with global constraints

Jan Baumbach, Tobias Friedrich, Timo Kötzing, Anton Krohmer, Joachim Müller, Josch Pauling

The integrated analysis of data of different types and with various interdependencies is one of the major challenges in computational biology. Recently, we developed KeyPathwayMiner, a method that combines biological networks modeled as graphs with disease-specific genetic expression data gained from a set of cases (patients, cell lines, tissues, etc.). We aimed to find all maximal connected sub-graphs where all nodes but $\$K\$$ are expressed in all cases but at most $\$L\$$, i.e. key pathways. To do so, we combined biological networks with OMICS data, instead of analyzing these data sets in isolation. Here we present an alternative approach: Now we aim to extract all maximal connected sub-networks where all but at most $\$K\$$ nodes are expressed in all cases but in total (!) at most $\$L\$$, i.e. accumulated over all cases and all nodes in a solution. We call this strategy GLONE (global node exceptions); the previous problem we call INES (individual node exceptions). Since finding GLONE-components is NP-hard, we developed an Ant Colony Optimization algorithm and implemented it with the KeyPathwayMiner Cytoscape framework as an alternative to the INES algorithms.

EMO 1

Session Chair: Hisao Ishibuchi

Room: Assembly E

10:40-11:06 Convergence of Hypervolume-Based Archiving Algorithms II: Competitiveness

Karl Bringmann, Tobias Friedrich

We study the convergence behavior of $(\mu + \lambda)$ -archiving algorithms. A $(\mu + \lambda)$ -archiving algorithm defines how to choose in each generation μ children from μ parents and λ offspring together. Archiving algorithms have to choose individuals online without knowing future offspring. Previous studies assumed the offspring generation to be best-case. We assume the initial population and the offspring generation to be worst-case and use the competitive ratio to measure how much smaller hypervolumes an archiving algorithm finds due to not knowing the future in advance. We prove that all archiving algorithms which increase the hyper-volume in each step (if they can) are only μ -competitive. We also present a new archiving algorithm which is $(4 + 2/\mu)$ -competitive. This algorithm not only achieves a constant competitive ratio, but is also efficiently computable. Both properties provably do not hold for the commonly used greedy archiving algorithms, for example those used in SIBEA or the generational MO-CMA-ES.

11:06-11:32 Effects of Discrete Objective Functions with Different Granularities on the Search Behavior of EMO Algorithms*Hisao Ishibuchi, Masakazu Yamane, Yusuke Nojima*

Objective functions in combinatorial optimization are discrete. The number of possible values of a discrete objective function is totally different from problem to problem. Optimization of a discrete objective function is often very difficult. In the case of multiobjective optimization, a different objective function has a different number of possible values. This means that each axis of the objective space has a different granularity. Some axes may have fine granularities while others are coarse. In this paper, we examine the effect of discrete objective functions with different granularities on the search behavior of EMO (evolutionary multiobjective optimization) algorithms through computational experiments. Experimental results show that a discrete objective function with a coarse granularity slows down the search of EMO algorithms along that objective. An interesting observation is that such a slow-down along one objective often leads to the speed-up of the search along other objectives. We also examine the effect of adding a small random noise to each discrete objective function in order to increase the number of possible objective values.

11:32-11:58 Leveraging Indicator-based Ensemble Selection in Evolutionary Multiobjective Optimization Algorithms*Dung Phan, Junichi Suzuki, Isao Hayashi*

Various evolutionary multiobjective optimization algorithms (EMOAs) have replaced or augmented the notion of dominance with quality indicators and leveraged them in selection operators. Recent studies show that indicator-based EMOAs outperform traditional dominance-based EMOAs. This paper proposes and evaluates an ensemble learning method that constructs an ensemble of existing indicators with a novel boosting algorithm called Pdi-Boosting. The proposed method is carried out with a training problem in which Pareto-optimal solutions are known. It can work with a simple training problem, and an ensemble of indicators can effectively aid parent selection and environmental selection in order to solve harder problems. Experimental results show that the proposed method is efficient thanks to its dynamic adjustment of training data. An ensemble of indicators outperforms existing individual indicators in optimality, diversity and robustness. The proposed ensemble-based evolutionary algorithm outperforms a well-known dominance-based EMOA and existing indicator-based EMOAs.

EDA 1: Test Problems, Model Accuracy, Transfer Learning**Session Chair: Martin Pelikan****Room: Assembly C**

10:40-11:06 A Test Problem with Adjustable Degrees of Overlap and Conflict among Subproblems*Wei-Ming Chen, Chung-Yu Shao, Po-Chun Hsu, Tian-Li Yu*

In the field of genetic algorithms (GAs), some researches on overlapping building blocks (BBs) have been proposed. To further study on overlapping BBs, we need to measure the performance of an algorithm to solve problems with overlap among subproblems. Several test problems have been proposed, but the controllability over the degree of overlapping is not yet fully satisfactory. Our new test problem is designed with full controllability of overlapping as well as conflict, a

specific type of overlap, among BBs. We present a framework for building the structure of this problem in this paper. Some model-building GAs are tested by the proposed problem. This test problem can be applied to further researches on overlapping and conflicting BBs.

11:06-11:32 Influence of Selection on Structure Learning in Markov Network EDAs: An Empirical Study

Alexander Brownlee, John McCall, Martin Pelikan

Learning a good model structure is important to the efficient solving of problems by estimation of distribution algorithms. In this paper we present the results of a series of experiments, applying a structure learning algorithm for undirected probabilistic graphical models based on statistical dependency tests to three fitness functions with different selection operators and pressures. The number of spurious interactions found by the algorithm are measured and reported. Truncation selection, and its complement (selecting only low fitness solutions) prove quite robust, resulting in a similar number of spurious dependencies regardless of selection pressure. In contrast, tournament and fitness proportionate selection are strongly affected by selection pressure.

11:32-11:58 Distance-Based Bias in Model-Directed Optimization of Additively Decomposable Problems

Martin Pelikan, Mark Hauschild

For many optimization problems it is possible to define a distance metric between problem variables that correlates with the likelihood and strength of interactions between the variables. For example, one may define a metric so that the dependencies between variables that are closer to each other with respect to the metric are expected to be stronger than the dependencies between variables that are further apart. The purpose of this paper is to describe a method that combines such a problem-specific distance metric with information mined from probabilistic models obtained in previous runs of estimation of distribution algorithms with the goal of solving future problem instances of similar type with increased speed, accuracy and reliability. While the focus of the paper is on additively decomposable problems and the hierarchical Bayesian optimization algorithm, it should be straightforward to generalize the approach to other model-directed optimization techniques and other problem classes. Compared to other techniques for learning from experience put forward in the past, the proposed technique is both more practical and more broadly applicable.

GDS 1: Biological Evolution & Development

Session Chair: Rene Doursat

Room: Ormandy East

11:32-11:58 Co-evolution of morphology and control of soft-bodied multicellular animats

Michał Joachimczak, Borys Wrobel

We present a platform that allows for co-evolution of development and motion control of soft-bodied, multicellular animats in a 2-dimensional fluid-like environment. Artificial gene regulatory networks (GRNs) with real-valued expression levels control cell division and differentiation in multicellular embryos. Embryos develop in a simulated physics environment and are converted into animat structures by connecting neighboring cells with elastic springs. The springs connecting outer cells form the external envelope which is subject to fluid drag. Both the developmental program and motion control are encoded indirectly in a single linear genome, which consists of regulatory regions and regions that code for transcription factors and morphogens. We applied a genetic algorithm to co-evolve morphology and control using a fitness measure whose value depends on distance traveled during the evaluation phase. We obtained various emergent morphologies and types of locomotion, some of them showing the use of appendages.

DETA 1**Session Chair: Mike Preuss****Room: Aria AB**

10:40-11:06 Photogrowth: Non-Photorealistic Renderings Through Ant Paintings*Penousal Machado, Luis Pereira*

We introduce photogrowth, an evolutionary approach to the production of non-photorealistic renderings of images. The painting algorithm -- inspired by ant colony approaches -- is described and explained, giving emphasis to its novel aspects: the evolution of the sensory parameters of the ants; the production of resolution independent images; the rendering lines of variable width. The experimental results highlight the range of imagery that can be evolved by the system and show the potential of the approach for the production of large-format artworks.

11:06-11:32 Adaptive Learning Evaluation Model For Evolutionary Art*Yang Li, Ming Chen, Changjun Hu*

The automation of aesthetic judgements in evolutionary art system is essential for lessening the burden placed on users in hundreds of loops. Although judging beauty is a highly subjective task, certain features are considered to be more important to aesthetic judgement. This paper introduces an adaptive learning evaluation model for guiding the evolutionary process. The model is built by selecting the learning approach with better accuracy. The training sets are composed of different aesthetic features we proposed, which are extracted from internal evolutionary images and external real world paintings, which could lead to more interesting paths. Our results show that these features play important roles in aesthetic judgements and the adaptive model is efficient at predicting user's preference.

11:32-11:58 HyperNEAT-GGP: A HyperNEAT-based Atari General Game Player*Matthew Hausknecht, Piyush Khandelwal, Risto Miikkulainen, Peter Stone*

This paper considers the challenge of enabling agents to learn with as little domain-specific knowledge as possible. The main contribution is HyperNEAT-GGP, a HyperNEAT based approach to playing general Atari games using a visual representation of the game screen. By leveraging the geometric regularities present in the Atari game screen, HyperNEAT effectively evolves policies for playing two different Atari games, Asterix and Freeway. Results show that HyperNEAT-GGP outperforms existing benchmarks on these games. HyperNEAT-GGP represents a step towards the ambitious goal of creating an agent capable of learning and seamlessly transitioning between many different tasks.

RWA 1**Session Chair: Roberto Santana****Room: Ormandy West**

10:40-11:06 Estimating Markov Switching Model Using Differential Evolution Algorithm in Prospective Infectious Disease Outbreak Detection*Rui-tian Xu, Jun Zhang*

Prospective infectious disease outbreak detection has long been a major concern in public health. Using time series analysis method for the outbreak detection, a nonlinear Markov switching model is more excellent than linear models in modelling time series, due to its ability to describe the switching process of time series variables in different states.

However the estimation difficulty of Markov switching model hinders the model's extensive application in practice. The paper proposes using Differential Evolution (termed DE) algorithm to obtain maximum likelihood estimator of Markov switching model in consideration of DE's good global optimization ability. In addition, to effectively reduce negative impact of label switching problem on disease outbreak detection validity of the estimated model by maximum likelihood estimation (termed MLE) method, the paper introduces identifiability constraint on estimation parameters constructed with the heuristic information about difference between durations of different states in MLE using DE. Encouraging experimental study has demonstrated the effectiveness and efficiency of DE in maximizing likelihood function of the studied Markov switching model as well as the effectiveness of the proposed identifiability constraint on improving disease outbreak detection validity of the estimated Markov switching model by MLE.

11:06-11:32 **Breast Cancer Detection Using Cartesian Genetic Programming evolved Artificial Neural Network**

Arbab Ahmad, Gul Khan, Sahibzada Mahmud, Julian Miller

A fast learning neuro-evolutionary algorithm called Cartesian Genetic Programming evolved Artificial Neural Network (CGPANN) is explored for the detection of breast cancer. Features from breast mass are extracted using fine needle aspiration (FNA) and are applied to the CGPANN for diagnosis of breast cancer. FNA data is obtained from the Wisconsin Diagnostic Breast Cancer website and is used for training and testing the network. The developed system produces fast and accurate results when compared to contemporary work done in the field. The error of the model comes out to be as low as 1% for Type-I (classifying benign sample falsely as malignant) and 0.5% for Type- II (classifying malignant sample falsely as benign).

11:32-11:58 **Introducing the use of model-based evolutionary algorithms for EEG-based motor imagery classification**

Roberto Santana, Laurent Bonnet, Jozef Legeny, Anatole Lécuyer

Brain computer interfaces (BCIs) allow the direct human-computer interaction without the need of motor intervention. To properly and efficiently decode brain signals into computer commands the application of machine-learning techniques is required. Evolutionary algorithms have been increasingly implied in different steps of BCI implementations. In this paper we propose the use of the covariance matrix adaptation evolution strategy (CMA-ES) for BCI based on motor imagery. The optimization algorithm is used to evolve linear classifiers able to outperform other traditional classifiers. We also analyze the role of modeling variables interactions for additional insight in the understanding of the BCI paradigms.

GBML 1 Best Papers

Session Chair: Tim Kovacs

Room: Assembly F

10:40-11:06 **★ Guided Evolution in XCSF**

Patrick Stalph, Martin Butz

High-dimensional problems impose multiple difficulties for Learning Classifier Systems. The most severe one is the complexity of the evolutionary search space, which is directly connected to the required learning time. In the worst case, evolution might be completely stuck because the fitness signal is weaker than fitness noise due to iterative sampling. The present work addresses this issue by guiding the evolutionary algorithm towards optimal classifier structures. We explore a guided mutation operator for XCSF based on local knowledge: Each classifier stores the last matched samples and mutation uses those to optimize the shape by means of a weighted covariance matrix. While this does not necessarily produce an optimal shape, it is sufficient to discriminate relevant from irrelevant dimensions. Regular evolutionary

operators handle the fine tuning. We show that this approach does not only drastically speed up learning, but it also allows to solve higher-dimensional problems, where regular XCSF fails to reach the target error at all. Experiments illustrate that guided XCSF quickly detects the intrinsic structure of non-linear, oblique, fully sampled, ten-dimensional approximation tasks. It outperforms regular XCSF as well as a statistics-based machine learning approach, the so called Locally Weighted Projection Regression algorithm.

11:06-11:32 **★ Filtering Sensory Information with XCSF: Improving Learning Robustness and Control Performance**

Jan Kneissler, Patrick Stalph, Jan Drugowitsch, Martin Butz

It has been shown previously that the control of a robot arm can be efficiently learned using the XCSF classifier systems. So far, however, the predictive knowledge about how actual motor activity changes the state of the arm system has not been exploited. In this paper, we exploit the forward velocity kinematics knowledge of XCSF to alleviate the negative effect of noisy sensors for successful learning and control. We incorporate Kalman filtering for estimating successive arm positions iteratively combining sensory readings with XCSF-based predictions of hand position changes over time. The filtered arm position is used to improve both trajectory planning and further learning of the forward velocity kinematics. We test the approach on a simulated, kinematic robot arm model. The results show that the combination can improve learning and control performance significantly. However, we also show that variance estimates of XCSF predictions may be underestimated, in which case self-delusional spiraling effects hinder effective learning. Thus, we introduce a heuristic parameter, which limits the influence of XCSF's predictions on its own further learning input. As a result, we obtain drastic improvements in noise tolerance coping with more than ten times higher noise levels.

11:32-11:58 **Post-processing Operators for Decision Lists**

Maria Franco, Natalio Krasnogor, Jaume Bacardit

This paper proposes three post-processing operators (rule cleaning, rule pruning and rule swapping) which combined together in different ways can help reduce the complexity of decision lists evolved by means of genetics-based machine learning. While the first two operators work on the independent rules to reduce the number of expressed attributes, the last one changes the order of the rules (based on the similarities between them) to identify and delete the unnecessary ones. These operators were tested using the BioHEL system over 35 different problems. Our results show that it is possible to reduce the number of specified attributes per rule and the number rules up to 30% each, without producing significant changes in the test accuracy. Moreover, the approaches presented in this paper can be easily extended to other learning paradigms and representations.

Theory/ESEP: Best Papers
Session Chair: Tobias Friedrich

Room: Concerto AB

13:40-14:06 ★ **Reducing the Arity in Unbiased Black-Box Complexity**

Benjamin Doerr, Carola Winzen

We show that for all $2 \leq k \leq \log n$ the k -ary unbiased black-box complexity of the n -dimensional ONEMAX function class is $\mathcal{O}(n/k)$. This indicates that the power of higher arity operators is much stronger than what the previous $\mathcal{O}(n/\log k)$ bound by Doerr et al. (Faster black-box algorithms through higher arity operators, Proc. of FOGA 2011, pp. 163--172, ACM, 2011) suggests. The main technique is an encoding strategy which allows to simulate a storage (memory) of $\mathcal{O}(2^k)$ bits. Only variation operators of arity at most k are needed to read from and write to this memory.

14:06-14:32 ★ **The Choice of the Offspring Population Size in the $(1, \lambda)$ EA**

Jonathan Rowe, Dirk Sudholt

We extend the theory of non-elitist evolutionary algorithms (EAs) by considering the offspring population size in the $(1, \lambda)$ EA. We establish a sharp threshold at $\lambda = \log_{\frac{e}{e-1}} n \approx 5 \log_{10} n$ between exponential and polynomial running times on the function ONEMAX. For any smaller value, the $(1, \lambda)$ EA needs exponential time on every function that has only one global optimum. We also consider arbitrary unimodal functions and show that the threshold can shift towards larger offspring population sizes. Finally, we investigate the relationship between the offspring population size and arbitrary mutation rates on ONEMAX. We get sharp thresholds for λ that decrease with the mutation rate. This illustrates the balance between selection and mutation.

14:32-14:58 ★ **A (1+1)-CMA-ES for Constrained Optimisation**

Dirk Arnold, Nikolaus Hansen

This paper introduces a novel constraint handling approach for covariance matrix adaptation evolution strategies (CMA-ES). The key idea is to approximate the directions of the local normal vectors of the constraint boundaries by accumulating steps that violate the respective constraints, and to then reduce variances of the mutation distribution in those directions. The resulting strategy is able to approach the boundary of the feasible region without being impeded in its ability to search in directions tangential to the constraint boundaries. The approach is implemented in the (1+1)-CMA-ES and evaluated numerically on several test problems. The results compare very favourably with data for other constraint handling approaches applied to unimodal test problems that can be found in the literature.

BIO 2

Session Chair: Alison Motsinger

Room: Maestro AB

13:40-14:06 **Bee Algorithms for Solving DNA Fragment Assembly Problem with Noisy and Noiseless data**

Tanay Saha, Jesun Firoz, M. Sohel Rahman

DNA fragment assembly problem is one of the crucial challenges faced by computational biologists where, given a set of DNA fragments, we have to construct a complete DNA sequence from them. As it is an NP-hard problem, accurate DNA sequence is hard to find. Moreover, due to experimental limitations, the fragments considered for assembly are exposed

to additional errors while reading the fragments. In such scenarios, meta-heuristic based algorithms can come in handy. We analyze the performance of two swarm intelligence based algorithms namely Artificial Bee Colony (ABC) algorithm and Queen Bee Evolution Based on Genetic Algorithm (QEGA) to solve the fragment assembly problem and report quite promising results. Our main focus is to design meta-heuristic based techniques to efficiently handle DNA fragment assembly problem for noisy and noiseless data.

14:06-14:32 Reverse engineering of GRNs: an evolutionary approach based on the Tsallis entropy
Mariana Mendoza, Fabrício Lopes, Ana Lúcia Bazzan

The discovery of regulatory interactions between genes is one of the main current goals in the field of bioinformatics due to their relevance, for instance, in the development of new drugs and medical treatments. The idea underneath this task is to recover gene interactions in a global and simple way, identifying the most significant connections and thereby generating a model to depict the mechanisms and dynamics of gene expression and regulation. In the present paper we tackle this challenge by applying a genetic algorithm to Boolean-based networks whose structures are inferred through the optimization of a Tsallis entropy function, which has been already successfully used in the inference of gene networks with other search schemes. Additionally, wisdom of crowds is applied to create a consensus network from the information contained within the last generation of the genetic algorithm. Results show that the proposed method is a promising approach and that the combination of a criterion function based on Tsallis entropy with an heuristic search such as genetic algorithms yields networks up to 50% more accurate when compared to other Boolean-based approaches.

14:32-14:58 Evolving Bio-PEPA Process Algebra Models Using Genetic Programming
David Marco, Carron Shankland, David Cairns

This paper presents initial results of applying a Genetic Programming (GP) approach to the evolution of process algebra models defined in Bio-PEPA. An incomplete model of a system is provided together with target behaviour. GP is then used to evolve new rules that complete the model while ensuring that they maintain a good fit to target data. Our results show that a set of effective models can be developed with this approach that can either be used directly or further refined using a modeller's domain knowledge. Such an approach can greatly reduce the time taken to develop new models, enabling a modeller to focus on the subtler modelling aspects of the problem domain. Although the focus of this work concerns the modelling of biological systems, the approach is generally applicable to systems for which appropriate target behaviour can be captured and that can be formalised as a set of communicating processes.

EMO Best Paper

Session Chair: Frank Neumann

Room: Assembly E

13:40-14:06 Local Preference-inspired Co-evolutionary Algorithms
RUI WANG, Robin Purshouse, Peter Fleming

Preference-inspired co-evolutionary algorithms (PICEAs) are a new class of approaches which have been demonstrated to perform well on multi-objective problems (MOPs). The good performance of PICEAs is largely due to its clever fitness calculation method which is in a competitive co-evolutionary way. However, this fitness calculation method has a potential limitation. In this work, we analyze this limitation and propose to implement PICEAs within a local structure (LPICEAs). By using the local structure, the benefits of local operations are incorporated into PICEAs. Meanwhile, the limitation of the original fitness calculation method is solved. In details, the candidate solutions are firstly partitioned into several clusters according to a clustering technique. Then the evolutionary operations, i.e. selection-for-survival and

genetic-variation are executed on each cluster, separately. To validate the performance of LPICEAs, LPICEAs are compared to PICEAs on some benchmarks functions. Experimental results indicate LPICEAs significantly outperform PICEAs on most of the benchmarks. Moreover, the influence of LPICEAs to the tuning of the parameter k , i.e. the number of clusters used in LPICEAs is studied. The results indicate that the performance of LPICEAs is sensitive to the parameter k .

14:06-14:32 ★Equitable Equilibrium: Evolutionary Detection

Réka Nagy, Mihai Alexanru Suciu, D. Dumitrescu

The most popular solution concept in game theory, Nash equilibrium, has some limitations when applied to real life problems. Nash equilibrium rarely assures maximal payoff. A possibility is to consider Pareto equilibrium, inspired from the standard solution concept in multi-criteria optimization, but the obtained equilibria often consists of a large set of solutions that is too hard to process. Our aim is to find an equilibrium concept that provides a small set of efficient solutions, equitable for all players. The Lorenz dominance relation is investigated in this respect. A crowding based differential evolution method is proposed for detecting the Lorenz-optimal solutions. Based on the Lorenz dominance relation, the Lorenz equilibrium for non-cooperative games is proposed. The Lorenz equilibrium consists of those Pareto-optimal solutions that are the most balanced and equitable solutions for all players. We propose to use Lorenz equilibrium for selecting one Nash equilibrium for games having several Nash equilibria.

14:32-14:58 ★On the Properties of the R2 Indicator

Dimo Brockhoff, Heike Trautmann, Tobias Wagner

In multiobjective optimization, set-based performance indicators are commonly used to assess the quality of a Pareto front approximation. Based on the scalarization obtained by these indicators, a performance comparison of multiobjective optimization algorithms becomes possible. The R2 and the Hypervolume (HV) indicator represent two recommended approaches which have shown a correlated behavior in recent empirical studies. Whereas the HV indicator has been comprehensively analyzed in the last years, almost no studies on the R2 indicator exist. In this paper, we thus perform a comprehensive investigation of the properties of the R2 indicator in a theoretical and empirical way. The influence of the number and distribution of the weight vectors on the optimal distribution of μ solutions is analyzed. Based on a comparative analysis, specific characteristics and differences of the R2 and HV indicator are presented.

EDA 2: Linkage Learning, Multiobjective EDAs

Session Chair: Peter A.N. Bosman

Room: Assembly C

13:40-14:06 Higher-Order Linkage Learning in the ECGA

David Iclănzan

In this paper, we present a higher-order dependency identification algorithm for binary variables that employs a novel metric to detect linkages. The proposed method applies an entropy distillation operation over bounded groups of variables. Lack of increase in randomness signals an underlying statistical dependence between the inputs. We incorporate the higher order linkage learning in the Extended Compact Genetic Algorithm (ECGA). Experiments show that the extended linkage learning enables the ECGA to correctly model and solve problems with bounded-order building-blocks that do not contain pairwise dependencies.

14:06-14:32 Predetermined versus Learned Linkage Models*Dirk Thierens, Peter Bosman*

The linkage tree genetic algorithm (LTGA) learns each generation a linkage model by building a hierarchical tree. We compare this dynamic model building with several predetermined linkage models. The predetermined models are matched to the underlying problem structure of 4 benchmark functions: onemax, deceptive trap functions, maximal overlapping nearest-neighbor NK-landscapes, and weighted maxcut problems. Although the a priori fixed models are specifically designed to capture the interactions between the problem variables, experimental results show that - for problem with intricate interaction structure - they are actually less efficient than LTGA that dynamically learns a hierarchical tree model. Some of these observations were unexpected and raise the question of what exactly is the optimal linkage structure for a given problem. In the case of the NK-problem a linkage model that is an accurate description of the underlying additively decomposable fitness structure is clearly not an optimal linkage model for the GOMEA algorithm.

14:32-14:58 Incremental Gaussian Model-Building in Multi-Objective EDAs with an Application to Deformable Image Registration*Peter Bosman, Tanja Alderliesten*

Estimation-of-Distribution Algorithms (EDAs) build and use probabilistic models during optimization in order to automatically discover and use an optimization problems' structure. This is especially useful for black-box optimization where no assumptions are made on the problem being solved, which is characteristic of many cases in solving complex real-world problems. In this paper we consider multi-objective optimization problems with real-valued variables. Although the vast majority of advances in EDA literature concern single-objective optimization, advances have also been made in multi-objective optimization. In this paper we bring together two recent advances, namely incremental Gaussian model building to reduce the required population size and a mixture-based multi-objective framework that has specific methods to better facilitate model-building techniques that span multiple generations. Significantly faster convergence to the optimal Pareto front is achieved on 6 out of 7 artificial benchmark problems from literature. Although results on two of these problems show that building models with higher-order interactions between variables is required, these problems are still artificial. We therefore also consider a more realistic optimization problem in image processing, namely deformable image registration. For this problem too, our results show the need for processing interactions between problem variables, stressing the importance of studying such models.

GDS 2: Morphogenetic Robotics**Session Chair: Gregory S. Hornby****Room: Ormandy East**

13:40-14:06 A Manifold Operator Representation for Adaptive Design*Jacob Beal, Hala Mostafa, Benjamin Axelrod, Annan Mozeika, Aaron Adler, Gretchen Markiewicz, Kyle Usbeck*

Many natural organisms exhibit canalization: small genetic changes are accommodated by adaptation in other systems that interact with them. Engineered systems, however, are typically quite brittle, making design automation extremely difficult. We propose to address this problem with a generative representation of design based on manifold operators. The operator set we propose combines the intuitive simplicity of top-down rewrite

rules with the flexibility and distortion tolerance of bottom-up GRN-based models. An embryogeny specified using this representation thus places constraints on a developing design, rather than specifying a fixed body plan, allowing canalization processes to modulate the design as it continues to develop. We demonstrate our ideas in the domain of electromechanical design and validate them with simulations at different levels of abstraction.

14:06-14:32 On the Relationship Between Environmental and Morphological Complexity in Evolved Robots

Joshua Auerbach, Joshua Bongard

The principles of embodied cognition dictate that intelligent behavior must arise out of the coupled dynamics of an agent's brain, body, and environment. While the relationship between controllers and morphologies (brains and bodies) has been investigated, little is known about the interplay between morphological complexity and the complexity of a given task environment. It is hypothesized that the morphological complexity of a robot should increase commensurately with the complexity of its task environment. Here this hypothesis is tested by evolving robot morphologies in a simple environment and in more complex environments. More complex robots tend to evolve in the more complex environments lending support to this hypothesis. This suggests that gradually increasing the complexity of task environments may provide a principled approach to evolving more complex robots.

14:32-14:58 A Cell-based Developmental Model to Generate Real Robot Morphologies

Sylvain Cussat-Blanc, Jordan Pollack

This paper presents a new method to generate the body plans of modular robots. In this work, we use a developmental model where cells are controlled by a gene regulatory network. Instead of using morphogens as in many existing works, we evolve a more flexible "hormonal system" that controls the inputs of the regulatory network. By evolving the regulatory network and the hormonal system in parallel, we have generated various virtual robots with interesting inherent properties such as regularity and symmetry. Robotic blocks that will be used to actually build the real machines are also presented in this paper.

PES: PES 1

Session Chair: Clara Pizzuti

Room: Aria AB

13:40-14:06 The Use of Reputation as Noise-resistant Selection Bias in a Co-evolutionary Multi-agent System

Nikolaos Chatzinikolaou, David Robertson

Little attention has been paid, in depth, to the relationship between fitness evaluation in evolutionary algorithms and reputation mechanisms in multi-agent systems, but if these could be related it opens the way for implementation of distributed evolutionary systems via multi-agent architectures. In this paper we investigate the effectiveness with which reputation can replace direct fitness observation as the selection bias in an evolutionary multi-agent system. We do this by implementing a peer-to-peer, self-adaptive genetic algorithm, in which agents act as individual GAs that, in turn, evolve

dynamically themselves in real-time. The evolution of the agents is implemented in two alternative ways: First, using the traditional approach of direct fitness observation (self-reported by each agent), and second, using a simple reputation model based on the collective past experiences of the agents. Our research shows that this simple model of distributed reputation can be successful as the evolutionary drive in such a system. Further, we discuss the effect of noise (in the form of "defective" agents) in both models. We show that, unlike the fitness-based model, the reputation-based model manages to identify the defective agents successfully, thus showing a level of resistance to noise.

14:06-14:32 A GPU-based Implementation of an Enhanced GEP Algorithm

Shuai Shao, Xiyang Liu, Mingyuan Zhou, Jiguo Zhan, Xin Liu, Yanli Chu, Hao Chen

Gene expression programming (GEP) is a functional genotype/phenotype system, and as a separation scheme, increases the efficiency and reliability of GEP. However, the computational cost increases considerably with the expansion of the scale of problems. In this paper, we introduce a GPU-accelerated hybrid variant of GEP named pGEP (parallel GEP). In order to find the optimal constant coefficients locally on the fixed function structure, the Method of Least Square (MLS) has been embedded into the GEP evolutionary process. We tested pGEP using a broad problem set with a varying number of instances. In the performance experiment, the GPU-based GEP, when compared with the traditional GEP version, increased speeds up by approximately 250. We compared pGEP with other well-known constant creation methods in terms of accuracy, demonstrating MLS performs at several orders of magnitude higher in both terms of the best residuals and average residuals.

14:32-14:58 Asynchronous Master/Slave MOEAs and Heterogeneous Evaluation Costs

Mouadh Yagoubi, Marc Schoenauer

Parallel master-slave evolutionary algorithms easily lead to linear speedups in the case of a small number of nodes... and homogeneous computational costs of the evaluations. However, modern computer now routinely have several hundreds of nodes -- and in many real-world applications in which fitness computation involves heavy numerical simulations, the computational costs of these simulations can greatly vary from one individual to the next. A simple answer to the latter problem is to use asynchronous steady-state reproduction schemes. But the resulting algorithms then differ from the original sequential version, with two consequences: First, the linear speedup does not hold any more; Second, the convergence might be hindered by the heterogeneity of the evaluation costs. The multi-objective optimization of a diesel engine is first presented, a real-world case study where evaluations are very heterogeneous in terms of CPU cost. Both the speedup of asynchronous parallel algorithms in case of large number of nodes, and their convergence toward the Pareto Front in case of heterogeneous computation times, are then experimentally analyzed on artificial test functions. An alternative selection scheme involving the computational cost of the fitness evaluation is then proposed, that counteracts the effects of heterogeneity on convergence toward the Pareto Front.

RWA 2

Session Chair: Martin Holena

Room: Ormandy West

13:40-14:06 Evolutionary Algorithms Applied to Elucidate Ionic Water Cluster Structure Formation

Omar Paranaíba Vilela Neto, André Pimentel, Marco Aurélio Pacheco, Ênio da Silveira

In this work we present two evolutionary algorithms applied to look for positive water cluster structures. Both algorithms were applied in order to simulate the formation of the aggregates using the neutral clusters as a precursor. In other words, we are not looking for the global minima positive water cluster structures, but rather than trying to find the most stable structures formed from neutral stable clusters. To achieve our goal three steps were executed. In the first one we looked

for the most stable structures for $(\text{H}_2\text{O})_n$ ($n = 2 - 8$), applying a genetic algorithm. In the second step we simulated that the found neutral clusters had lost one of their electrons, creating positive clusters $(\text{H}_2\text{O})_n^+$. Finally, in the last step we simulated the creation of positive cluster by the aggregation of one positive ion, forming $(\text{H}_2\text{O})_n\text{H}_2\text{O}^+$ clusters. In the latter stage we applied a quantum inspired evolutionary algorithm for numerical optimization (QIEA-R). Results of our search present innovative positive water structures and was able to compare two different ways for ionic cluster formation.

14:06-14:32 Darwinian Rivers: Evolving Stream Topographies to Match Hyporheic Residence Time Distributions

Forrest Stonedahl, Susa Stonedahl

We employed genetic algorithms to investigate the relationship between stream topographies and their associated hyporheic residence time distributions. A hyporheic residence time is the time it takes a water particle to enter the sediments below a stream, travel through the sediment, and re-enter the surface water of the stream. We used a multi-scale two-dimensional model, lightly adapted from three previous models, to calculate residence time distributions from system characteristics. Our primary contribution is the investigation of the "RTD inverse problem" -- discovering what stream topographies would generate a specified target residence time distribution (RTD). We approached this problem by using genetic algorithms to evolve the shape of stream topographies (represented as Fourier series) to discover shapes that closely match the target RTD (measured by a fitness/error function). This work offers the following contributions: a) the specification of the RTD inverse problem, b) evidence that genetic algorithms provide an effective/efficient method for approaching this problem, and c) the discovery of several interesting and unexpected patterns among the topographies that resulted from the search. This "inverse" technique for investigating properties of hyporheic systems seems promising, and we hope that this work will promote further applications of evolutionary computation to this field.

14:32-14:58 Surrogate Modeling in the Evolutionary Optimization of Catalytic Materials

Martin Holena, David Linke, Lukáš Bajer

The search for best performing catalysts leads to high-dimensional optimization tasks. They are by far most frequently tackled using evolutionary algorithms, usually implemented in systems developed specifically for the area of catalysis. Their fitness functions are black-box functions with costly and time-consuming empirical evaluation. This suggests to apply surrogate modeling. The paper points out three difficulties challenging the application of surrogate modeling to catalysts optimization: mixed-variables optimization, assessing the suitability of different models, and scalarization of multiple objectives. It then provides examples of how those challenges are tackled in real-world catalysts optimization tasks. The examples are based on results obtained in three such tasks using one of the leading specific evolutionary optimization systems for catalysis.

GBML 2: LCS Fundamentals

Session Chair: Stewart W. Wilson (Prediction Dynamics)

Room: Assembly F

13:40-14:06 Instance-Linked Attribute Tracking and Feedback for Michigan-Style Supervised Learning Classifier Systems

Ryan Urbanowicz, Ambrose Granizo-Mackenzie, Jason Moore

The application of learning classifier systems (LCSs) to classification and data mining in genetic association studies has been the target of previous work. Recent efforts have focused on: (1) correctly discriminating between predictive and non-predictive attributes, and (2) detecting and characterizing epistasis (attribute interaction) and heterogeneity. While the

solutions evolved by Michigan-style LCSs (M-LCSs) are conceptually well suited to address these phenomena, the explicit characterization of heterogeneity remains a particular challenge. In this study we introduce attribute tracking, a mechanism akin to memory, for supervised learning in M-LCSs. Given a finite training set, a vector of accuracy scores is maintained for each instance in the data. Post-training, we apply these scores to characterize patterns of association in the dataset. Additionally we introduce attribute feedback to the mutation and crossover mechanisms, probabilistically directing rule generalization based on an instance's tracking scores. We find that attribute tracking combined with clustering and visualization facilitates the characterization of epistasis and heterogeneity while uniquely linking individual instances in the dataset to etiologically heterogeneous subgroups. Moreover, these analyses demonstrate that attribute feedback significantly improves test accuracy, efficient generalization, run time, and the power to discriminate between predictive and non-predictive attributes in the presence of heterogeneity.

14:06-14:32 **Two-Cornered Learning Classifier Systems for Pattern Generation and Classification**
Syahaneim Marzukhi, Will Browne, Mengjie Zhang

Classifying objects and patterns to a certain category is crucial for both humans and machines, so that learnt knowledge may be applied across similar problem instances. Although autonomous learning of patterns by machines has advanced recently, it still requires humans to set up the problem at an appropriate level for the learning technique. If the problem is too complex the system does not learn; conversely, if the problem is too simple the system does not reach its full potential to be able to classify environmental examples. In this work, an automated evolving pattern generator and pattern recognizer has been created for pattern classification problems that can be manipulated autonomously using Learning Classifier Systems (LCSs) at different levels of difficulty. Experiments confirm that both of the agents (e.g. the pattern generation and the pattern classification agent) can be evolved autonomously and co-operatively. The novel contributions in this work enable the effect of domain features on classification performance to become human readable, i.e. possibly determine what features make it difficult for the classification algorithm to learn. This work provides a foundation for a co-evolutionary approach to problem domain creation and the associated learning, such that the agents will trigger evolution when necessary.

14:32-14:58 **Extracting and Using Building Blocks of Knowledge in Learning Classifier Systems**
Muhammad Iqbal, Will Browne, Mengjie Zhang

Human beings have the ability to apply the domain knowledge learned from a smaller problem to more complex problems of the same or a related domain, but currently machine learning techniques lack this ability. Hence learning techniques relearn from the start when the problem scales, increasing the time required and potentially limiting capability. In order to autonomously scale in a problem domain reusable building blocks of knowledge must be extracted. A richer encoding scheme than ternary alphabet has been constructed to identify building blocks. The novel work presented here is to extract useful building blocks from smaller problems and reuse them to learn complex problems in the domain. The proposed system has been compared with ternary alphabet based XCS for three different problem domains, i.e. multiplexer, carry, and even-parity problems. Autonomous scaling is shown possible for the first time in learning classifier systems. It improves effectiveness and reduces the number of training instances required in large problems, but requires more time due to more involved methods.

Theory 2

Session Chair: Carsten Witt

Room: Concerto AB

15:40-16:06 **Run-Time Analysis of the (1+1) Evolutionary Algorithm Optimizing Linear Functions Over a Finite Alphabet**

Benjamin Doerr, Sebastian Pohl

We analyze the run-time of the $(1+1)$ Evolutionary Algorithm optimizing an arbitrary linear function $f: \{0,1,\dots,r\}^n \rightarrow \mathbb{R}$. If the mutation probability of the algorithm is $p = c/n$, then $(1 + o(1)) (e^{c/c}) r n \log n + O(r^3 n \log \log n)$ is an upper bound for the expected time needed to find the optimum. We also give a lower bound of $(1+o(1)) (1/c) r n \log n$. Hence for constant c and all r slightly smaller than $(\log n)^{1/3}$, our bounds deviate by only a constant factor, which is $e(1+o(1))$ for the standard mutation probability of $1/n$. The proof of the upper bound uses multiplicative adaptive drift analysis as developed in a series of recent papers. We cannot close the gap for larger values of r , but find indications that multiplicative drift is not the optimal analysis tool for this case.

16:06-16:32 **Constant Time Steepest Ascent Local Search with Statistical Lookahead for NK-Landscapes**

Darrell Whitley, Wenxiang Chen

A modified form of steepest ascent local search is proposed that displays an average complexity of $O(1)$ time per move for NK-Landscape problems. The algorithm uses a Walsh decomposition to identify improving moves. In addition, it is possible to compute a Hamming distance 2 statistical lookahead: if x is the current solution and y is a neighbor of x , it is possible to compute the average evaluation of the neighbors of y . The average over the Hamming distance 2 neighborhood can be used as a surrogate evaluation function to replace f . The same modified form of steepest ascent can be executed in $O(1)$ time using the Hamming distance 2 neighborhood average as the fitness function. A modified form of steepest ascent is used to prove $O(1)$ complexity, but in practice the modifications can be relaxed. Finally, steepest ascent local search over the mean of the Hamming distance 2 neighborhood yields superior results compared to using the standard evaluation function for certain types of NK-Landscapes.

16:32-16:58 **Fixed Budget Computations: A Different Perspective on Run Time Analysis**

Thomas Jansen, Christine Zarges

Randomised search heuristics are used in practice to solve difficult problems where no good problem-specific algorithm is known. They deliver a solution of acceptable quality in reasonable time in many cases. When theoretically analysing the performance of randomised search heuristics one usually considers the average time needed to find an optimal solution or one of a pre-specified approximation quality. This is very different from practice where usually the algorithm is stopped after some time. For a theoretical analysis this corresponds to investigating the quality of the solution obtained after a pre-specified number of function evaluations called budget. Such a perspective is taken here and two simple randomised search heuristics, random local search and the $(1+1)$ evolutionary algorithm, are analysed on simple and well-known example functions. If the budget is significantly smaller than the expected time needed for optimisation the behaviour of the algorithms can be very different depending on the problem at hand. Precise analytical results are proven. They demonstrate novel and interesting challenges in the analysis of randomised search heuristics. The potential of this different perspective to provide a more practically useful theory is shown.

GP 1: Algorithm analysis and evaluation**Session Chair: Frank Neumann****Room: Maestro AB**

15:40-16:06 Computational Complexity Analysis of Multi-Objective Genetic Programming*Frank Neumann*

The computational complexity analysis of genetic programming (GP) has been started recently by analyzing simple (1+1) GP algorithms for the problems ORDER and MAJORITY. Often GP algorithms encounter the bloat problem which means that syntax trees grow without providing additional benefit to the problem that has to be solved. In this paper, we study how taking the complexity as an additional criteria influences the runtime behavior. We consider generalizations of ORDER and MAJORITY and present a computational complexity analysis of (1+1) GP using multi-criteria fitness functions that take into account the original objective and the complexity of a syntax tree as a secondary measure. Furthermore, we study the expected time until simple multi-objective genetic programming algorithms have computed the Pareto front when taking the complexity of a syntax tree as an equally important objective.

16:06-16:32 Evolving a Best Known Approximation to the Q Function*Dao Phong, Nguyen Hoai, Robert McKay, Constantin Siriteanu, Nguyen Uy*

The Gaussian Q-function is the integral of the tail of the Gaussian distribution; as such, it is important across a vast range of fields requiring stochastic analysis. However, no simple exact closed form of the Q-function is known. Consequently, a number of approximations have been proposed. Here, we use a Genetic Programming system (Tree Adjoining Grammar Guided Genetic Programming - TAG3P) with local search operators to evolve approximations of the Q-function in the simple form given by Benitez. We have found approximations that are more accurate than any previous approximation in the literature. The results also confirm the practical importance of local search operators in TAG3P.

16:32-16:58 GP Needs Better Benchmarks*James McDermott, David White, Sean Luke, Luca Manzoni, Mauro Castelli, Leonardo Vanneschi, Wojciech Jaskowski, krzysztof krawiec, Robin Harper, Kenneth De Jong, Una-May O'Reilly*

Genetic programming (GP) is not a field noted for the rigor of its benchmarking. Some of its benchmark problems are popular purely through historical contingency, and they can be criticized as too easy or as providing misleading information concerning real-world performance, but they persist largely because of inertia and the lack of good alternatives. Even where the problems themselves are impeccable, comparisons between studies are made more difficult by the lack of standardization. This situation represents both a challenge and an opportunity for GP researchers. We argue that the definition of standard benchmarks is an essential step in the maturation of the field. We make several contributions towards this goal. We motivate the development of a benchmark suite and define its goals; we survey existing practice; we enumerate many candidate benchmarks; we report progress on reference implementations; and we set out a concrete plan for gathering feedback from the GP community that would, if adopted, lead to a standard set of benchmarks.

EMO 3**Session Chair: Carlos A. Coello Coello****Room: Assembly E**

15:40-16:06 Adaptive Multi-objective Genetic Algorithm using Multi-Pareto-Ranking
Wahabou Abdou, Christelle Bloch, Charlet Damien, Francois Spies

This paper extends an elitist multi-objective evolutionary algorithm, named GAME, based on several Pareto fronts corresponding to various fitness definitions. An additional operator is defined to create an adaptive version of this algorithm, called aGAME. This new operator alternates different modes of exploration of the search space all through an aGAME execution. Mode switching is controlled according to the values of two performance indicators, in order to maintain a good compromise between the quality and diversity of the returned solutions. aGAME is compared with the previous version (GAME) and with the three best-ranking algorithms of the CEC 2009 competition, using seven bi-objective benchmarks and the rules of this competition. This experimental comparison shows that aGAME outperforms these four algorithms, which validates both the efficiency of the proposed dynamic adaptive operator and the algorithm performance.

16:06-16:32 Locality-based Multiobjectivization for the HP Model of Protein Structure Prediction
Mario Garza-Fabre, Gregorio Toscano-Pulido, Eduardo Rodriguez-Tello

Even under the rather simplified hydrophobic-polar (HP) model, protein structure prediction remains a challenging problem in combinatorial optimization. Recently, the multiobjectivization of this problem was proposed. By decomposing the original objective function, a two-objective formulation for the HP model was defined. Such an alternative formulation showed very promising results, leading to an increased search performance in most of the conducted experiments. In this paper, a new multiobjectivization by decomposition strategy for the HP model is presented. This approach is based on the locality notion of amino acid interactions. Using different evolutionary algorithms and a large set of test cases, the proposed formulation was statistically compared with respect to both the conventional single-objective and the recently reported multiobjective formulations. As the main finding, the proposed multiobjectivization achieved the best results in most of the cases.

16:32-16:58 A New Multi-Objective Evolutionary Algorithm Based on a Performance Assessment Indicator
Cynthia Rodríguez Villalobos, Carlos Coello Coello

An emerging trend in the design of multi-objective evolutionary algorithms (MOEAs) is to select individuals through the optimization of a quality assessment indicator. The most commonly adopted indicator in current use is the hypervolume which becomes very expensive as we increase the number of objectives. In this paper, we propose, instead, the use of another indicator called Δ_p . Although the Δ_p indicator is not Pareto compliant, we show here how it can be incorporated into the selection mechanism of an evolutionary algorithm (we adopt differential evolution as our search engine) in order to produce a MOEA. The resulting MOEA (Δ_p -Differential Evolution) is validated using standard test problems and performance indicators reported in the specialized literature. Our results are compared with respect to those obtained by both a Pareto-based MOEA (NSGA-II) and a hypervolume-based MOEA (SMS-EMOA). Our preliminary results indicate that our proposed approach is competitive with respect to these two MOEAs for problems having two and three objective functions. Additionally, our proposed approach is better than NSGA-II and provides competitive results with respect to SMS-EMOA for many-objective problems. However, in this case, the main advantage of our proposal is that its computational cost is significantly lower than that of SMS-EMOA.

ESEP 1

Session Chair: Hans-Georg Beyer

Room: Assembly C

15:40-16:06 Algorithm Selection Based on Exploratory Landscape Analysis and Cost-Sensitive Learning

Bernd Bischl, Olaf Mersmann, Heike Trautmann, Mike Preuss

The steady supply of new optimization methods makes the algorithm selection problem (ASP) an increasingly pressing and challenging task, especially for real-world black-box optimization problems. The introduced approach considers the ASP as a cost-sensitive classification task which is based on Exploratory Landscape Analysis. Low-level features gathered by systematic sampling of the function on the feasible set are used to predict a well-performing algorithm out of a given portfolio. Example-specific label costs are defined by the expected runtime of each candidate algorithm. We use one-sided support vector regression to solve this learning problem. The approach is illustrated by means of the optimization problems and algorithms of the BBOB'09/10 workshop.

16:06-16:32 Natural Evolution Strategies Converge on Sphere Functions

Tom Schaul

This theoretical investigation gives the first proof of convergence for (radial) natural evolution strategies, on d -dimensional sphere functions, and establishes the conditions on hyper-parameters, as a function of d . For the limit case of large population sizes, we show an asymptotic linear converge rate of $1/2$, and in the limit of small learning rates we give a full analytic characterization of the algorithm dynamics, decomposed into transient and asymptotic phases. Finally, we show why omitting the natural gradient from the algorithm is catastrophic.

GDS/EDA Best Papers**Session Chair: Gregory S. Hornby****Room: Ormandy East**

15:40-16:06 ★ Complex and Diverse Morphologies Can Develop from a Minimal Genome*Jose David Fernandez, Francisco Vico, Rene Doursat*

While development plays a critical role in the emergence of diversity, its mechanical and chemical actions are considered to be inextricably correlated with genetic control. Since in most extant species the complex growth from zygote to adult organism is orchestrated by a complex gene regulatory network (GRN), the prevalent view is that the evolution of diverse morphologies must result from the evolution of diverse GRN topologies. By contrast, this work focuses on the unique effect of developmental processes through an abstract model of self-regulated structure without genetic regulation---only modulation of initial conditions. Here, morphologies are generated by a simple evolutionary algorithm searching for the longest instances of unfolding dynamics based on tensegrity graphs. The usual regulatory function of the genome is taken over by physical constraints in the graphs, making morphological diversity a pure product of structural complexification. By highlighting the potential of structural development, our model is relevant to both "structuralist" biological models and bio-inspired systems engineering.

16:06-16:32 ★ A Memory Efficient and Continuous-valued Compact EDA for Large Scale Noisy Problems*Sergio Rojas-Galeano, Nestor Rodriguez*

This paper considers large-scale OneMax and RoyalRoad optimization problems with up to 106 variables within a compact Estimation of Distribution Algorithms (EDA) framework. Building upon the compact Genetic Algorithm (cGA), the continuous domain Population-Based Incremental Learning algorithm (PBILc) and the arithmetic-coding EDA, we define a novel method that is able to compactly solve regular and noisy versions of these problems with minimal memory requirements, regardless of problem or population size. This feature allows the algorithm to be run in a conventional desktop machine. Issues regarding probability model sampling, arbitrary precision of the arithmetic-coding decompressing scheme, incremental fitness function evaluation and updating rules for compact learning, are presented and discussed.

DETA/PES/BIO Best Papers**Room: Aria AB**

15:40-16:06 ★ An Improved CUDA-Based Implementation of Differential Evolution on GPU*Kai Qin, Federico Raimondo, Florence Forbes, Yew Soon Ong*

Modern GPUs has enabled widely affordable personal computers to carry out massively parallel computation. NVIDIA's CUDA technology provides a wieldy parallel computing platform. Many state-of-the-art algorithms arising from different fields have been redesigned based on CUDA to accelerate their computation speed. Differential evolution (DE), as a most promising evolutionary algorithm, is highly suitable for parallelization owing to its data-parallel algorithmic structure. However, most existing CUDA-based DE implementations suffer from excessive low-throughput memory access and less efficient device utilization. This work presented an improved CUDA-based DE to optimize memory and device utilization: several logically-related kernels are combined into one composite kernel to reduce global memory access; kernel execution configuration parameters are automatically determined to maximize the SM occupancy; streams are employed to enable concurrent kernel execution to maximize device utilization. Experimental results on several numerical

problems demonstrate superior computational efficiency of the proposed method over two recent CUDA-based DE and the sequential DE across varying problem dimensions and algorithmic population sizes.

16:06-16:32 A Novel Approach to Represent Time-delayed Genetic Interactions using S-System Model
Ahsan Chowdhury, Madhu Chetty, Xuan Vinh

The DNA microarray technology helps us to examine cellular dynamics under different experimental conditions and thousands of genes can be monitored simultaneously. The Gene Regulatory Network (GRN) is the collection of genes and interactions among them, which captures the mutual interactions among genes and helps in better understanding the regulatory information at cellular level. Amongst the various currently available models for inferring GRN, the S- System formalism is often considered as an excellent compromise between accuracy and mathematical tractability. But the model is limited to represent the instantaneous inter- actions only. In this paper, we propose the Time-delayed S-System model, an improved version of the traditional S- System model, capable of representing the delayed interactions present in the genetic network. To our best knowledge, this is the first attempt to represent time-delayed GRN using the S-System model. Moreover, the parameter learning for the model is carried out in an evolving manner using the versatile and robust Trigonometric Evolutionary Algorithm. The applicability and efficiency of the proposed model and the method is studied using a well-known and widely considered synthetic network with various delays in the interactions, and the performances are observed to be excellent.

16:32-16:58 ★ Accelerating Interactive Evolutionary Algorithms through Comparative and Predictive User Models
Gregory Hornby, Josh Bongard

Interactive Evolutionary Algorithms (IEAs) are a powerful explorative search technique that utilizes human input to make subjective decisions on potential problem solutions. But humans are much slower than computers and get bored and tired easily, limiting the usefulness of IEAs. Here two variations of a user-modeling approach are compared to determine if this approach can accelerate IEA search. The IEA system used for these comparisons is called The Approximate User (TAU). With TAU, as the user interacts with the IEA a model of the user's preferences is constructed and continually refined. The two user-modeling approaches compared are: 1. learning a classifier which correctly determines which of two designs is better; and 2. learning a model which predicts a fitness score. Rather than having people do the user-testing, we propose the use of a simulated user as an easier means to test IEAs. The TAU IEA and both variants of its user models is compared against a basic IEA and it is shown that TAU is up to 2.7 times faster and 15 times more reliable at producing near optimal results.

RWA 3

Session Chair: Adrian Agogino

Room: Ormandy West

15:40-16:06 Using Interactive Evolutionary Computation (IEC) with Validated Surrogate Fitness Functions for Redistricting
Christine Chou, Steven Kimbrough, John Sullivan, C. Woodard, Frederic Murphy

We describe a novel use of evolutionary computation to discover good districting plans for the Philadelphia City Council. We were able to discover 116 distinct, high quality, legally valid plans. These constitute a rich resource on which stakeholders may base deliberation. The exercise raised the issue of how to deal with large numbers of plans, especially with the aim of avoiding gerrymandering and promoting fairness. Interactive Evolutionary Computation (IEC) is a natural

approach here, if practicable. The paper proposes development of Validated Surrogate Fitness (VSF) functions as a workable and generalizable form of IEC.

16:06-16:32 Ant Colony Optimization Algorithm for Lifetime Maximization in Wireless Sensor Network with Mobile Sink

Jing-Hui Zhong, Jun Zhang

In wireless sensor networks (WSNs), sensors near the sink are usually burdened with heavy relaying traffic, which results in a short network lifetime. Using mobile sink is an effective way to tackle this issue. This paper presents an ant colony optimization algorithm (named ACO-MSS), to maximizing the lifetime of a WSN using mobile sink. The novelty of the proposed ACO-MSS is that it optimizes the movements of the sink and the flow routing simultaneously, and it can find the global or near global optimal solution with relatively low memory requirement. Moreover, multiple practical factors such as the forbidden regions and the maximum moving distance of the sink are taken into account to facilitate the real applications. New hybrid heuristic information is defined to improve the efficiency of the algorithm. The proposed ACO-MSS is validated by a series of simulations on WSNs with different characteristics. The simulation results demonstrate the effectiveness of the proposed algorithms.

16:32-16:58 Evolving Distributed Resource Sharing for CubeSat Constellations

Adrian Agogino, Chris HolmesParker, Kagan Tumer

Advances in miniaturization will allow for the commoditization of large numbers of tiny satellites, known as "CubeSats." However, current algorithms made for small tightly-managed space missions are ill-designed to take advantage of the huge amount of resources available in a decentralized collection of these CubeSats. We believe that multiagent evolutionary algorithms are ideally suited to exploit the distributed nature of this new problem. This paper presents a solution where a customer in need of satellite observations can reliably obtain these observations at low cost, through the help of a multiagent system as an intermediary. Each agent in this system is assigned to a single CubeSat. Given a set of the customer's observational needs, and models of the CubeSats' salient properties, the agents evolve policies that attempt to purchase an appropriate set of observations at a low price. This system is especially flexible as it demands no centralized resource broker, contracts or commitments of resources. We perform a series of experiments on an Earth-observation domain. The results show that the evolutionary methods combined with multiagent techniques have three times the performance of a simple hand-coded allocation algorithm, and twice the performance of simple evolving agents.

GBML 3: Optimisation and Feature Detection

Session Chair: Ryan Urbanowicz

Room: Assembly F

15:40-16:06 Genetic Programming for Edge Detection Using Blocks to Extract Features

Wenlong Fu, Mark Johnston, Mengjie Zhang

Single pixels can be directly used to construct low-level edge detectors but these detectors are not good for suppressing noise and some texture. In general, features based on a small area are used to suppress noise and texture. However, there is very little guidance in the literature on how to select the area size. In this paper, we employ Genetic Programming (GP) to evolve edge detectors via automatically searching for features based on flexible blocks rather than dividing a fixed window into small areas based on different directions. Experimental results for natural images show that using blocks to extract features obtains better performance than using single pixels only to construct detectors, and that GP can successfully choose the block size for extracting features.

16:06-16:32 **XCS-based versus UCS-based Feature Pattern Classification System**

Toktam Ebadi, Mengjie Zhang, Will Browne

Extracting features from images is an important task in order to identify (classify) the patterns contained. The Evolutionary Computation and Reinforcement Learning technique of Learning Classifier Systems (LCSs) have been successfully applied to classification tasks, but rarely to image pattern classification due to the large search space associated with pixel data. Recently, a Feature Pattern Classification System (FPCS), based on the XCS framework of LCS and utilising Haar-like features has been introduced with promising results in the image recognition domain. This system used a confusion-matrix to direct learning to classify hard classes, but due to its reinforcement learning nature was required to estimate the ground truth. The novel work presented here adopts a supervised learning (UCS-based) approach into the FPCS framework. This work is compared with the original XCS-based system, updated to include the known ground-truth of the confusion matrix to aid comparison, albeit no longer pure reinforcement learning. Results on the 10 class MNIST numerical digits recognition task show that the XCS-based FPCS produces better classification due to its complete mapping in guided learning. However, results on the 26 class NIST character recognition task show that the UCS-based scales better as it does not require the complete mapping.

16:32-16:58 **Multi-Objective Evolutionary Optimization for Generating Ensembles of Classifiers in the ROC Space**

Julien-Charles Levesque, Audrey Durand, Christian Gagné, Robert Sabourin

In this paper, we propose a novel approach for the multi-objective optimization of simple classifiers ensembles in the ROC space. We first evolve a pool of weak classifiers with NSGA-II using ROC curves as the optimization objectives. These weak classifiers are then combined at the decision level using the iterative Boolean combination method (IBC). This method produces multiple ensembles of classifiers optimized for various operating conditions. We perform a rigorous series of experiments to demonstrate the properties and behaviour of this approach. This allows us to propose interesting venues for future research on optimizing ensembles of classifiers using multi-objective evolutionary algorithms.

Theory/ESEP

Session Chair: Anne Auger

Room: Concerto AB

10:40-11:06 Analysis of a Variant of the CMA-ES on Quadratic Functions

Youhei Akimoto

In this paper we investigate the convergence properties of a variant of the Covariance Matrix Adaptation Evolution Strategies (CMA-ES), which is the state-of-the-art stochastic search algorithm for continuous optimization. Our study is based on the recent theoretical foundation that the rank- μ update CMA-ES estimates the natural gradient of an quasi-objective function and updates the parameters along the estimated natural gradient. We derive a novel variant of the natural gradient method where the parameter of the Gaussian distribution is updated to improve a newly defined function by using the natural gradient. We study this algorithm on quadratic functions under an ideal condition where we take infinite number of samples so that we can assume the natural gradient estimate meets the exact one. We prove that our algorithm adapts the covariance matrix of the Gaussian distribution so that it becomes proportional to the inverse of the Hessian of the original quadratic function and also show the speed of convergence of the covariance matrix adaptation and the speed of convergence of the parameters. We present some simulated results to evaluate how precisely the stochastic algorithm approximates the ideal one under finite samples and to see how similarly our algorithm and the CMA-ES perform.

11:06-11:32 Mutation Strength Control by Meta-ES on the Sharp Ridge

Hans-Georg Beyer, Michael Hellwig

This paper investigates mutation strength control using Meta-ES on the sharp ridge. The asymptotical analysis presented allows for the prediction of the dynamics in ridge as well as in radial direction. Being based on this analysis the problem of the choice of population size λ and isolation parameter γ will be tackled. Remarkably, the qualitative convergence behavior is not determined by γ alone, but rather by the number of function evaluations $\lambda\gamma$ devoted to the inner ES.

11:32-11:58 Self-Adaptive Surrogate-Assisted Covariance Matrix Adaptation Evolution Strategy

Ilya Loshchilov, Marc Schoenauer, Michele Sebag

This paper presents a general mechanism to adapt surrogate-assisted population-based algorithms. This mechanism is applied to ACM-ES, a recently proposed surrogate-assisted variant of CMA-ES. The resulting algorithm, s*ACM-ES, adjusts online the lifelength of the current surrogate model (the number of CMA-ES generations before learning a new surrogate) and the surrogate hyper-parameters. Both heuristics significantly improve the quality of the surrogate model, yielding a significant speed-up of s*ACMES compared to the ACM-ES and CMA-ES baselines. The empirical validation of s*ACM-ES on the BBOB-2010 noiseless testbed demonstrates the efficiency and the scalability w.r.t the problem dimension and the population size of the proposed approach, that reaches new best results on some of the benchmark problems.

GP 2: Algorithm design, representation and parameter tuning

Session Chair: Conor Ryan

Room: Maestro AB

10:40-11:06 Automatic Generation of Graph Models For Complex Networks by Genetic Programming

Alexander Bailey, Mario Ventresca, Beatrice Ombuki-Berman

Complex networks have attracted a large amount of research attention, especially over the past decade, due to their prevalence and importance in our daily lives. Numerous human-designed models have been proposed that aim to capture

and model different network structures, for the purpose of improving our understanding the real-life phenomena and its dynamics in different situations. Groundbreaking work in genetics, medicine, epidemiology, neuroscience, telecommunications, social science and drug discovery, to name some examples, have directly resulted. Because the graph models are human made (a very time consuming process) using a small subset of example graphs, they often exhibit inaccuracies when used to model similar structures. This paper represents the first exploration into the use of genetic programming for automating the discovery and algorithm design of graph models, representing a totally new approach with great interdisciplinary application potential. We present exciting initial results that show the potential of GP to replicate existing complex network algorithms.

11:06-11:32 Parameter Tuning of Evolutionary Reactions Systems

Mauro Castelli, Luca Manzoni, Leonardo Vanneschi

Reaction systems is a formalism inspired by chemical reactions introduced by Rozenberg and Ehrenfeucht. Recently, an evolutionary algorithm based on this formalism, called Evolutionary Reaction Systems, has been presented. This new algorithm proved to have comparable performances to other well-established machine learning methods, like genetic programming, neural networks and support vector machines on both artificial and real-life problems. Even if the results are encouraging, to make Evolutionary Reaction Systems an established evolutionary algorithm, an in depth analysis of the effect of its parameters on the search process is needed, with particular focus on those parameters that are typical of Evolutionary Reaction Systems and do not have a counterpart in traditional evolutionary algorithms. Here we address this problem for the first time. The results we present show that one particular parameter, between the ones tested, has a great influence on the performances of Evolutionary Reaction Systems, and thus its setting deserves practitioners' particular attention: the number of symbols used to represent the reactions that compose the system. Furthermore, this work represents a first step towards the definition of a set of default parameter values for Evolutionary Reaction Systems, that should facilitate their use for beginners or inexperienced practitioners.

11:32-11:58 Sensitive Ants Are Sensible Ants

Muhammad Rezaul Karim, Conor Ryan

This paper introduces an approach to evolving computer programs using an Attribute Grammar (AG) extension of Grammatical Evolution (GE) to eliminate ineffective pieces of code with the help of context-sensitive information. The standard Context Free Grammars (CFGs) used in GE, Genetic Programming (GP) (which uses a special type of CFG with just a single non-terminal) and most other grammar based system are not well-suited for codifying information about context. AGs, on the other hand, are grammars that contain functional units that can help determine context which, as this paper demonstrates, is key to removing ineffective code. The results presented in this paper indicate that, on a selection of grammars, the prevention of the appearance of ineffective code through the use of context analysis significantly improves the performance of and resistance to code bloat over both standard GE and GP for both Santa Fe Trail (SFT) and Los Altos Hills (LAH) trail version of the ant problem with same amount of energy used.

ECOM 1**Room: Assembly E**

10:40-11:06 A hybrid heuristic/metaheuristic algorithm for Flexible Job-Shop Scheduling problems with transportation constraints

Qiao Zhang, Hervé Manier, Marie-Ange Manier

In this paper, we aim at solving flexible job shop scheduling problems with transportation constraints and bounded processing times. We propose a hybrid method of genetic algorithm, tabu local search and a modified shifting bottleneck

procedure. The genetic algorithm is used to generate and evolve assignment for each task (processing tasks and transportation tasks). The modified shifting bottleneck procedure is used to generate initial solutions and regenerate solutions when no improvement occurs during some generations. The tabu local search is then used to improve initial solutions during a limited number of iterations. To evaluate solutions, we elaborate a modified disjunctive graph which contains not only processing nodes, but also transportation and storage nodes. There are positive and negative arcs for bounded processing times, transportation times and minimum and maximum allowed storage time before and after each processing task. Our objective is to minimize makespan. Various types of instances with fixed or bounded processing times are tested. Computational results show that this hybrid method is able to solve efficiently these kinds of problems.

11:06-11:32 Towards a Population-based Framework for improving Stochastic Local Search Algorithms
Ignacio Araya, Leslie Perez, Maria Cristina Riff

In this paper, we introduce a method which goal is to help the search done by a Stochastic Local Search algorithm. Given a set of initial configurations, our algorithm dynamically discriminates the ones that seems to give more promising solutions, discarding at the same time those which did not help. The concept of diversity is managed in our framework in order to both avoid stagnation and to explore the search space. To evaluate our method, we use a well-known local search algorithm. This algorithm has been specially designed for solving instances of the challenging Traveling Tournament Problem. We compare the performance obtained running different configurations of the local search algorithm to the ones using our framework. Our results are very encouraging in terms of both the quality of the solutions and the execution time required.

11:32-11:58 A Hybrid Heuristic For The k-medoids Clustering Problem
Mariá Nascimento, Franklina Toledo, Andre Carvalho

Clustering is an important tool for data analysis, since it allows the exploration of datasets with no or very little prior information. Its main goal is to group a set of data based on their similarity (dissimilarity). A well known mathematical formulation for clustering is the k-medoids problem. Current versions of k-medoids rely on heuristics, with good results reported in the literature. However, few methods that analyze the quality of the partitions found by the heuristics have been proposed. In this paper, we propose a hybrid Lagrangian heuristic for the k-medoids. We compare the performance of the proposed Lagrangian heuristic with other heuristics for the k-medoids problem found in literature. Experimental results presented that the proposed Lagrangian heuristic outperformed the other algorithms.

IGEC/SS/SBSE Best Papers**Room: Assembly C**

10:40-11:06 ★ A Hyper-Heuristic Evolutionary Algorithm for Automatically Designing Decision-Tree Algorithms
Rodrigo Barros, Márcio Basgalupp, André de Carvalho, Alex Freitas

Decision tree induction is one of the most employed methods to extract knowledge from data, since the representation of knowledge is very intuitive and easily understandable by humans. The most successful strategy for inducing decision trees, the greedy top-down approach, has been continuously improved by researchers over the years. This work, following recent breakthroughs in the automatic design of machine learning algorithms, proposes a hyper-heuristic evolutionary algorithm for automatically generating decision-tree induction algorithms, named HEAD-DT. We perform extensive experiments in 20 public data sets to assess the performance of HEAD-DT, and we compare it to traditional decision-tree

algorithms such as C4.5 and CART. Results show that HEAD-DT can generate algorithms that significantly outperform C4.5 and CART regarding predictive accuracy and F-Measure.

11:06-11:32 ★ Evolutionary Algorithm for Prioritized Pairwise Test Data Generation

Javier Ferrer, Peter Kruse, Francisco Chicano, Enrique Alba

Combinatorial Interaction Testing (CIT) is a technique used to discover faults caused by parameter interactions in highly configurable systems. These systems tend to be large and exhaustive testing is generally impractical. Indeed, when the resources are limited, prioritization of test cases is a must. Important test cases are assigned a high priority and should be executed earlier. On the one hand, the prioritization of test cases may reveal faults in early stages of the testing phase. But, on the other hand the generation of minimal test suites that fulfill the demanded coverage criteria is an NP-hard problem. Therefore, search based approaches are required to find the (near) optimal test suites. In this work we present a novel evolutionary algorithm to deal with this problem. The experimental analysis compares five techniques on a set of benchmarks. It reveals that the evolutionary approach is clearly the best in our comparison. The presented algorithm can be integrated into a professional tool for CIT.

11:32-11:58 ★ Representations and Operators for Improving Evolutionary Software Repair

Claire Le Goues, Westley Wemer, Stephanie Forrest

Evolutionary computation is a promising technique for automating time-consuming and expensive software maintenance tasks, including bug repair. The success of this approach, however, depends at least partially on the choice of representation, fitness function, and operators. Previous work on evolutionary software repair has employed different approaches, but they have not yet been evaluated in depth. This paper investigates representation and operator choices for source-level evolutionary program repair in the GenProg framework, focusing on: (1) representation of individual variants, (2) crossover design, (3) mutation operators, and (4) search space definition. We evaluate empirically on a dataset comprising 8 C programs totaling over 5.1 million lines of code and containing 105 reproducible, human-confirmed defects. Our results provide concrete suggestions for operator and representation design choices for evolutionary program repair. When augmented to incorporate these suggestions, GenProg repairs 5 additional bugs (60 vs. 55 out of 105), with a decrease in repair time of 17--43% for the more difficult repair searches.

GDS 4: Architectural, Chemical & Behavioral Diversity

Session Chair: Rene Doursat

Room: Ormandy East

10:40-11:06 Novel Embryogeny for Architectural Design

Daniel Richards

We present a developmental genotype-phenotype growth process, or embryogeny, which is used to evolve, in silico, efficient three-dimensional structures that exhibit real-world architectural performance. The embryogeny defines an asynchronous assembly of architectural components within a three-dimensional volume, and indirectly establishes a regulatory network of components based on the principles of gene regulation. The implicitly regulated phenotypes suggest advances for the automatic design of physical structures, by improving scalability of the genotype encoding and embedding real-world constraints. We demonstrate that our model can evolve novel, yet efficient, architectural structures which exhibit emergent shape, topology and material distribution. Finally, we compare evolved structures against a “hand-coded” solution to illustrate that our model produces competitive results without prior knowledge of the design solution or direct human guidance.

11:06-11:32 Morphologies of Self-Organizing Swarms in 3D Swarm Chemistry*Hiroki Sayama*

A three-dimensional version of the Swarm Chemistry model is presented. Self-organization and morphogenesis of heterogeneous swarms in the 3D model were compared to those in the original 2D version. It was observed that the resulting patterns generally had remarkable robustness against dimensionality change, while some swarms were susceptible to the change. Further experiments showed that it was often sufficient to make minimal parameter adjustments in order to recover the original topological and dynamical properties of those susceptible swarms in 3D, although the dependence on parameters varied case by case with no generic parameter mapping between 2D and 3D.

11:32-11:58 Distance Measures for HyperGP with Fitness Sharing*Jan Drchal, Miroslav Šnorek*

In this paper we propose a new algorithm called HyperGPEFS (HyperGP with Explicit Fitness Sharing). It is based on a HyperNEAT, which is a well-established evolutionary method employing indirect encoding of artificial neural networks. Indirect encoding in HyperNEAT is realized via special function called Compositional and Pattern Producing Network (CPPN), able to describe a neural network of arbitrary size. CPPNs are represented by network structures, which are evolved by means of a slightly modified version of another, well-known algorithm, the NEAT (NeuroEvolution of Augmenting Topologies). HyperGP is a variant of HyperNEAT, where the CPPNs are optimized by Genetic Programming (GP). Published results reported promising improvement in the speed of convergence. Our approach further extends HyperGP by using fitness sharing to promote a diversity of a population. Here, we thoroughly compare all three algorithms on six different tasks. Fitness sharing demands a definition of a tree distance measure. Among other five, we propose a generalized distance measure which, in conjunction with HyperGPEFS, significantly outperforms HyperNEAT and HyperGP on all, but one testing problems. Although this paper focuses on indirect encoding, the proposed distance measures are generally applicable.

GA 1: Linkage Learning**Session Chair: Daniel R. Tauritz****Room: Aria AB**

10:40-11:06 Linkage Tree Genetic Algorithms: Variants and Analysis*Brian Goldman, Daniel Tauritz*

Discovering and exploiting the linkage between genes during evolutionary search allows the Linkage Tree Genetic Algorithm (LTGA) to maximize crossover effectiveness, greatly reducing both population size and total number of evaluations required to reach success on decomposable problems. This paper presents a comparative analysis of the most prominent LTGA variants and a newly introduced variant. While the deceptive trap problem (trap-k) is one of the canonical benchmarks for testing LTGA, when LTGA is combined with applying steepest ascent hill climbing to the initial population, as is done in all significant LTGA variations, trap-k is trivially solved. This paper introduces the deceptive step trap problem (steptrap-ks), which shows the novel combination of smallest first subtree ordering with global mixing (LTS-GOMEA) is effective for black box optimization, while least linked first subtree ordering (LT-GOMEA) is effective on problems where partial reevaluation is possible. Finally, nearest neighbor NK landscapes show that global mixing is not effective on problems with complex overlapping linkage structure that cannot be modeled correctly by a linkage tree,

emphasizing the need to extend how LTGA stores linkage to allow the power of global mixing to be applied to these types of problems.

11:06-11:32 Linkage Neighbors, Optimal Mixing and Forced Improvements in Genetic Algorithms
Peter Bosman, Dirk Thierens

Recent literature introduced the Linkage Tree Genetic Algorithm (LTGA), one of the latest developments in a line of EA research that studies building models to capture and exploit linkage information between problem variables. LTGA exhibits excellent performance on several benchmark problems, mainly attributed to use of the LT linkage model. In this paper we consider a different linkage model, Linkage Neighbors (LN), that is more flexible, yet can be learned equally efficiently from data. We test the associated EA, that we call Linkage Neighbors Genetic Algorithm (LNGA), on three common linkage benchmark problems and on a combinatorial optimization problem: weighted MAXCUT. LNGA outperforms LTGA on the benchmark problems in required number of evaluations and population size, even with the simplest learning approach. However, for comparable performance on weighted MAXCUT, a more involved multiscale LN variant is required, indicating the importance of considering problems other than common linkage-learning benchmark problems.

11:32-11:58 Off-Line Building Block Identification
Hsuan Lee, Tian-Li Yu

This paper aims at detecting the existence of building blocks directly from the fitness function without performing genetic algorithms. To do so, this paper extends the convergence time model and the gambler's ruin model so they can be applied to a larger variety of problems. With proposed models, the number of fitness evaluations can be estimated for both of these two cases: (1) some genes are transferred together in crossover (treated as a building block); (2) the genes are transferred separately. Therefore, we can compare the number of fitness evaluations and identify the existence of building blocks for a large family of fitness functions without actually performing a genetic algorithm.

RWA 4

Session Chair: Nuno Horta

Room: Ormandy West

10:40-11:06 Multi-Container Loading with Non-Convex 3d Shapes
Philipp Nebel, Gunther Richter, Karsten Weicker

A genetic algorithm is developed for a multi-container problem and integrated into a commercial software product. The considered problem is characterized by specific requirements, e.g. non-convex 3d shapes composed of several cuboids and a broad range of constraints. The algorithm uses the packing list as genotype, the first-fit heuristic for placing the items, and a set of problem-specific operators. The algorithm is tested on simple examples, benchmarks by Bischoff/Ratcliff and Loh/Nee, and real-world customer data. The proposed algorithm proves to be an all-rounder that excels on non-convex problems and delivers acceptable results on regular (benchmark) problems.

11:06-11:32 Metaheuristic Approaches to Tool Selection Optimisation*Alexander Churchill, Phil Husbands, Andrew Philippides*

In this paper we discuss our approach to solving the tool selection problem, specifically applied to rough machining. A simulation is used to evaluate tool sequences, which provides accurate values for tool paths and a 3D model of the final machined part. This allows for a largely unrestricted search using different tool types, making this approach more useful for real world applications than previous attempts at solving the problem. An exhaustive search of every valid tool sequence is executed and shows that assumptions present in related research can prevent the optimal solution from being discovered. Metaheuristic algorithms are used to traverse the search space because of its complex combinatorial properties. Four algorithms are tested - Genetic Algorithm, Stochastic Hill Climbing, Hybrid Genetic Algorithm and Random Restart Stochastic Hill Climbing. Evaluating their performance at coping with two competing demands, finding optimal solutions and keeping the number of potentially expensive evaluations low, it is shown that RRS HC performs best in terms of solution accuracy but at the greatest computational cost. SHC finds the optimum sequence less frequently but needs far fewer evaluations and the HGA lies somewhere in between, making it a good choice if the problem domain is not well-specified.

11:32-11:58 LAYGEN II – Automatic Analog ICs Layout Generator based on a Template Approach*Ricardo Martins, Nuno Lourenço, Nuno Horta*

This paper describes an innovative analog IC layout generation tool based on evolutionary computation techniques. The designer provides the high level layout guidelines through an abstract layout template. This template contains placement and routing constraints independently from technology, and can be used hierarchically in the definition of templates for complex circuits. This expert knowledge is used to guide the evolutionary optimization kernels during the automatic generation of the layout for the target technology. Some tasks of the proceeding can range from a template-based approach to an automatic generation. Routing is automatically generated even if only connectivity is provided. The LAYGEN II tool is demonstrated for the layout generation of two typical analog circuit structures and the results validated by Calibre® design rule check tool.

GBML 4: Reinforcement Learning**Session Chair: Daniele Loiacono****Room: Assembly F**

10:40-11:06 CMA-TWEANN: Efficient Neuroevolution via Synthetic Evolution of Network Topology and Synaptic Weights*Hirota Moriguchi, Shinichi Honiden*

We proposed CMA-TWEANN by synthesizing efficient weight optimization via CMA-ES and topological evolution. Topologies are augmented without loss of efficiency by using seamless mutation operators with corresponding update rules for the covariance matrix and the step-size parameter. Experiments on pole-balancing benchmark tasks empirically proved that CMA-TWEANN outperforms conventional TWEANN as well as state-of-the-art non-TWEANN such as CMA-NeuroES and CoSyNE. To the best of our knowledge, our results are the best reported so far. Since the pole-balancing task abstracts wider range of AI problems, CMA-TWEANN is potentially applicable to more practical problems. We further discussed why CMA-TWEANN outperforms CMA-NeuroES, which has much in common with CMA-TWEANN. Experiments revealed that there are two fundamental reasons that make CMA-TWEANN superior to CMA-NeuroES. First, in the case of pole-balancing, extremely small topology can solve the problem if it is supplied a well-optimized set of connection weights. Since CMA-NeuroES used a fixed redundant topology, CMA-TWEANN could optimize the weight faster than that. Second, topological evolution lets the search population escape from fitness plateau.

If we run CMA-NeuroES with minimal topology, it often gets stuck in local optima. However, topological evolution of CMA-TWEANN helps the search population to explore.

11:06-11:32 Sample Aware Embedded Feature Selection for Reinforcement Learning

Steven Loscalzo, Robert Wright, Kevin Acunto, Lei Yu

Reinforcement learning (RL) is designed to learn optimal control policies from unsupervised interactions with the environment. Many successful RL algorithms have been developed, however, none of them can efficiently tackle problems with high-dimensional state spaces due to the "curse of dimensionality," and so their applicability to real-world scenarios is limited. Here we propose a Sample Aware Feature Selection algorithm embedded in NEAT, or SAFS-NEAT, to help address this challenge. This algorithm builds upon the powerful evolutionary policy search algorithm NEAT, by exploiting data samples collected during the learning process. This data permits feature selection techniques from the supervised learning domain to be used to help RL scale to problems with high-dimensional state spaces. We show that by exploiting previously observed samples, on-line feature selection can enable NEAT to learn near optimal policies for such problems, and also outperform an existing feature selection algorithm which does not explicitly make use of this available data.

11:32-11:58 Accelerating Evolution via Egalitarian Social Learning

Wesley Tansey, Eliana Feasley, Risto Miikkulainen

Social learning is an extension to evolutionary algorithms that enables agents to learn from observations of others in the population. Historically, social learning algorithms have employed a student-teacher model where the behavior of one or more high-fitness agents is used to train a subset of the remaining agents in the population. This paper presents ESL, an egalitarian model of social learning in which agents are not labeled as teachers or students, instead allowing any individual receiving a sufficiently high reward to teach other agents to mimic its recent behavior. We validate our approach through a series of experiments in a robot foraging domain, including comparisons of egalitarian social learning with simple neuroevolution and a variant of student-teacher social learning. ESL converges to near-optimal strategies faster than either benchmark approach, outperforming both in a complex foraging task by more than an order of magnitude. The results indicate that egalitarian social learning is a promising new paradigm for social learning in intelligent agents.

Alife 1**Session Chair: Giovanni Squillero****Room: Concerto AB**

13:40-14:06 How to be a Successful App Developer: Lessons from the Simulation of an App Ecosystem
Soo Ling Lim, Peter Bentley

App developers are constantly competing against each other to win more downloads for their apps. With hundreds of thousands of apps in these online stores, what strategy should a developer use to be successful? Should they innovate, optimise their own apps or just copy the apps of others? Looking more deeply, how does a complex app ecosystem perform when developers choose to use different strategies? This paper investigates these questions using AppEco, the first Artificial Life model of mobile application ecosystems. A distinguishing feature of AppEco is the explicit modelling of apps as artefacts. In AppEco, developer agents build and upload apps to the app store; user agents browse the store and download the apps. In this work we use AppEco to simulate Apple's iOS app ecosystem and investigate common developer strategies. The main lesson gained from our experiments is: flexible developers who can adapt are more likely to improve their success rate. No single strategy tends to be a guaranteed winner, but innovators and optimisers often do well; copycats are the least viable strategy across an ecosystem.

14:06-14:32 Evolving Flexible Joint Morphologies
Jared Moore, Philip McKinley

Transferring virtual robotic designs into physical robots has become possible with the development of 3-D printers. Accurately simulating the performance of real robots in a virtual environment requires modeling a variety of conditions, including the physical composition of the robots themselves. In this paper, we investigate how modeling material flexibility through the use of a passive joint affects the resulting arm morphology and gait of a crawling virtual robot. Results indicate that flexibility can be a beneficial characteristic of robotic morphology design while also providing insight into the benefits of modeling material properties in a simulation environment.

14:32-14:58 Evolving Axonal Delay Neural Networks for Robot Control
Francis Jeanson, Anthony White

This paper investigates the dynamical and control properties of a discrete spiking neural network model with axonal delays. After examining contemporary work on spike timing as a mechanism for neural coding, we introduce a simple axonal delay network model which, via coincidence detection, demonstrates the presence of biologically observed regimes such as sustained firing and the emergence of synchrony. We establish delay criteria allowing for the classification of three distinct regimes including global synchrony, complex firing, and dissipation. We then proceed to test this model in a robot light seeking task. Results show that evolving network delays is sufficient for solving the task. We conclude by hypothesizing that global synchronous firing is more suited to reactive behaviours while complex firing patterns may serve as an organizing mechanism for more indirect processing.

GP 3: Algorithm design and applications

Session Chair: Una-May O'Reilly

Room: Maestro AB

13:40-14:06 A Developmental Solution to (Dynamic) Capacitated Arc Routing Problems using Genetic Programming

Thomas Weise, Alexandre Devert, Ke Tang

A developmental, ontogenic approach to Capacitated Arc Routing Problems (CARPs) is introduced. The genotypes of this method are constructive heuristics specified as trees of mathematical functions which are evolved with Genetic Programming (GP). In a genotype-phenotype mapping, they guide a virtual vehicle which starts at the depot. The genotype is used to compute a heuristic value for each edge with unsatisfied demands. Local information such as the visiting costs from the current position, the remaining load of the vehicle, and the edge demands are available to the heuristic. The virtual vehicle then serves the edge with the lowest heuristic value and is located at its end. This process is repeated until all requirements have been satisfied. The resulting phenotypes are sets of tours which, in turn, are sequences of edges. We show that our method has three advantages: 1) The genotypes can be reused to seed the population in new GP runs. 2) The size of the genotypes is independent from the problem scale. 3) The evolved heuristics even work well in modified or dynamic scenarios and are robust in the presence of noise.

14:06-14:32 GP under Streaming Data constraints: A case for Pareto archiving?

Aaron Atwater, Malcolm Heywood, Nur Zincir-Heywood

Classification as applied to streaming data implies that only a small number of new training instances appear at each generation and are never explicitly reintroduced by the stream. Pareto competitive coevolution provides a potential framework for archiving useful training instances between generations under an archive of finite size. Such a coevolutionary framework is defined for the online evolution of classifiers under genetic programming. Benchmarking is performed under multi-class data sets with class imbalance and training partitions with between thousands to hundreds of thousands of instances. The impact of enforcing different constraints for accessing the stream are investigated. On data sets for which 'low' error rates are possible, enforcing streaming access policies results in a strong preference for Pareto archiving. Conversely, when ambiguity appears in the underlying data, Pareto archiving might not perform any better than stochastic sampling. Moreover, no performance benefit is found for supporting variable length versus finite length sliding windows. This is significant as the finite sliding window constraint is fundamental to supporting streaming applications in general.

14:32-14:58 An Investigation of Local Patterns For Estimation of Distribution Genetic Programming

Erik Hemberg, Kalyan Veeramachaneni, James McDermott, Una-May O'Reilly

We present an improved estimation of distribution (EDA) genetic programming (GP) algorithm which does not rely upon a prototype tree. Instead of using a prototype tree, Operator-Free Genetic Programming learns the distribution of ancestor node chains, "n-grams", in a fraction of each generation's population. It then uses this information, via sampling, to create trees for the next generation. Ancestral n-grams are used because an analysis of a GP run conducted by learning depth first graphical models for each generation indicated their emergence as substructures of conditional dependence. We are able to show that our algorithm, without an operator and a prototype tree, achieves, on average, performance close to conventional tree based crossover GP on the problem we study. Our approach sets a direction for pattern-based EDA GP which offers better tractability and improvements over GP with operators or EDAs using prototype trees.

ECOM:

Session Chair: Frank Neumann

Room: Assembly E

13:40-14:06 An Efficient Genetic Algorithm for Subgraph Isomorphism

Jaeun Choi, Yourim Yoon, Byung-Ro Moon

In this paper we propose a multi-objective genetic algorithm for the subgraph isomorphism problem. Usually, the number of different edges between two graphs has been used as a fitness function. This approach has limitations in that it only considers directly-visible characteristics of current solutions, not considering the potential for being an optimal solution. We designed a fitness function in which solutions with higher potential can be rated high. This new fitness function has good properties such as transforming the solution space globally convex and improving the performance of local heuristics and genetic algorithms. Experimental results show that the suggested approach brings a considerable improvement in performance and efficiency.

14:06-14:32 Challenging Heuristics: Evolving Binary Constraint Satisfaction Problems

Jorge Moreno-Scott, Jose Carlos Ortiz-Bayliss, Hugo Terashima-Marin

In computer science it is a common practice to evaluate the performance of algorithms using a set of benchmark or randomly generated instances. However, following that approach, the weaknesses of the algorithms may not be exposed. This work is the first phase of research project on coevolution of solutions methods versus problem instances. The goal of study is to generate a method to find difficult to solve problem instances capable of challenging the solution methods or algorithms under analysis, helping to discover opportunities for improvement. An evolutionary model is proposed to find hard binary constraint satisfaction problem instances for different variable ordering heuristics. We characterize the search space by generating random instances with different values for the constraint density and tightness. For all the heuristics, the most difficult problems are located in the same region of the space near to the phase transition. However, there are certain regions of the search space where a heuristic dominates the others, especially where the problems are solvable. Finally, we compare the hardest instances found during the search space exploration with the outcome instances of the evolutionary model. The results show that evolved instances are harder to solve than the ones randomly generated.

14:32-14:58 A Parameterized Runtime Analysis of Evolutionary Algorithms for MAX-2-SAT

Andrew Sutton, Jareth Day, Frank Neumann

We investigate the MAX-2-SAT problem and study evolutionary algorithms by parameterized runtime analysis. The parameterized runtime analysis of evolutionary algorithms has been started recently and reveals new insights into which type of instances of NP-hard combinatorial optimization problems are hard to solve by evolutionary computing methods. We show that a variant of the (1+1) EA is a fixed-parameter evolutionary algorithm with respect to the standard parameterization for MAX-2-SAT. Furthermore, we study how the dependencies between the variables affect problem difficulty and present fixed-parameter evolutionary algorithms for the MAX-(2,3)-SAT problem where the studied parameter is the diameter of the variable graph.

SS 1

Session Chair: Gisele Lobo Pappa

Room: Assembly C

13:40-14:06 **Adaptive Differential Evolution with Optimization State Estimation***Wei-jie Yu, Jun Zhang*

The performance of differential evolution (DE) largely depends on an appropriate selection of the values of the algorithmic parameters. In this paper, a novel adaptive parameter control scheme is proposed for DE. Improving from existing parameter control schemes, the parameters F and CR in DE are adaptively controlled according to the optimization states, namely, exploration state and exploitation state in each generation. These optimization states are estimated by measuring the population distribution. During the optimization process of DE, the distribution of population varies and reflects the search maturity. In the exploration state, individuals in the population distribute evenly in the search space. As the optimization matures, the population gradually converges on a global or local optimum in the exploitation state. This feature enables parameter adaptation with a fuller utilization of the prevailing optimization information and hence reduces inappropriate adjustments. The proposed adaptive parameter control scheme is applied to a classic DE and a DE with novel mutation strategy. Experimental results show that this scheme can effectively improve the efficiency and robustness of the algorithms. Moreover, the adaptive DE with novel mutation strategy is competitive with four existing state-of-the-art DE variants.

14:06-14:32 **Meta-Optimization for Parameter Tuning With a Flexible Computing Budget***Juergen Branke, Jawad Elomari*

Meta-optimization techniques for tuning algorithm parameters usually try to find optimal parameter settings for a given computational budget allocated to the lower-level algorithm. If the available computational budget changes, parameters have to be optimized again from scratch, as they usually depend on the available time. For example, a small computational budget requires a focus on exploitation, while a larger budget allows more exploration. In situations where the optimization problem is expected to be solved for various computational budgets, meta-optimization is very time consuming. The method proposed in this paper can, in a single run, identify the best parameter settings for all possible computational budgets up to a specified maximum, hence saving a lot of time.

14:32-14:58 **On Neighborhood Tree Search***Houda Derbel, Bilel Derbel*

We consider the neighborhood tree induced by alternating the use of different neighborhood structures within a local search descent. We investigate the issue of designing a search strategy operating at the neighborhood tree level by exploring different paths of the tree in a heuristic way. We show that allowing the search to 'backtrack' to a previously visited solution and resuming the iterative variable neighborhood descent by 'pruning' the already explored neighborhood branches leads to the design of effective and efficient search heuristics. We describe this idea by discussing its basic design components within a generic algorithmic scheme and we propose some simple and intuitive strategies to guide the search when traversing the neighborhood tree. We conduct a throughout experimental analysis of this approach by considering two different problem domains, namely, the Total Weighted Tardiness Problem (SMTWTP), and the more sophisticated Location Routing Problem (LRP). We show that independently of the considered domain, the approach is highly competitive. In particular, we show that using different branching and backtracking strategies when exploring the neighborhood tree allows us to achieve different trade-offs in terms of solution quality and computing cost.

IGEC 1: Multi-agent systems**Session Chair: Dirk Thierens****Room: Ormandy East**

13:40-14:06 Automated Mechanism Design with Co-Evolutionary Hierarchical Genetic Programming Techniques*John Doucette, Darren Abramson*

We present a novel form of automated game theoretic mechanism design in which mechanisms and players co-evolve. We also model the memetic propagation of strategies through a population of players, and argue that this process represents a more accurate depiction of human behavior than conventional economic models. The resulting model is evaluated by evolving mechanisms for the ultimatum game, and replicates the results of empirical studies of human economic behaviors, as well as demonstrating the ability to evaluate competing hypotheses for the creation of economic incentives.

14:06-14:32 Evolutionary advantage of foresight in markets*Daniel Hennes, Daan Bloembergen, Michael Kaisers, Karl Tuyls, Simon Parsons*

We analyze the competitive advantage of price signal information for traders in simulated double auctions. Previous work has established that more information about the price development does not guarantee higher performance. In particular, traders with limited information perform below market average and are outperformed by random traders; only insiders beat the market. However, this result has only been shown in markets with a few traders and a uniform distribution over information levels. We present additional simulations of several more realistic information distributions, extending previous findings. In addition, we analyze the market dynamics with an evolutionary model of competing information levels. Results show that the highest information level will dominate if information comes for free. If information is costly, less-informed traders may prevail reflecting a more realistic distribution over information levels.

GA 2: Dynamic Optimization & Exploration Techniques**Session Chair: Daniel R. Tauritz****Room: Aria AB**

13:40-14:06 How long should we run in dynamic optimization?*Briseida Sarasola, Enrique Alba*

The problem of measuring performance in Dynamic Optimization is still an open issue. The most popular procedure consists in choosing one measure from the standard evolutionary optimization domain, such as the best fitness in the current population, and averaging it across the number of generations (sometimes, the number of periods). Generally, it is assumed that the measure of our election has been sufficiently exposed to the changing landscape, although there is no way of actually checking whether this exposition has taken place or not. Our purpose is proposing here for the first time a way of determining how long we should run our experiments in order to get meaningful conclusions in a changing environment after a representative number of changes. The new stopping condition is based in the convergence of the algorithm for the dynamic problem at hand, thus globally useful.

14:06-14:32 Enhancing the Virtual Loser Genetic Algorithm for Dynamic Environments

Anabela Simões, Ernesto Costa

In recent years, several memory schemes have been used in Evolutionary Algorithms (EAs) for dynamic optimization problems (DOPs). The Virtual Loser Genetic Algorithm (VLGA), recently proposed, uses a novel type of associative memory to deal with DOPs. This memory scheme memorizes past errors concerning the performed mutations and uses this information to create new individuals when a change in the environment occurs. In this paper VLGA is further investigated in order to enhance its performance in different types of DOPs: the influence of an important parameter is analyzed, and the interaction between the memory scheme and the use of immigrants is also investigated. A novel immigrant scheme is proposed and compared with the random immigrants approach. The results show that the investigated methods significantly enhances the previous version of VLGA for cyclic and random environments.

14:32-14:58 Estimating the Evolution Direction of Populations To Improve Genetic Algorithms

Andrea De Lucia, Massimiliano Di Penta, Rocco Oliveto, Annibale Panichella

Meta-heuristics have been successfully used to solve a wide variety of problems. However, one issue many techniques have is their risk of being trapped into local optima, or to create a limited variety of solutions (problem known as "population drift"). During recent and past years, different kinds of techniques have been proposed to deal with population drift, for example hybridizing genetic algorithms with local search techniques or using niche techniques. This paper proposes a techniques, based on Singular Value Decomposition (SVD), to enhance Genetic Algorithms (GAs) population diversity. SVD helps to estimate the evolution direction and drive next generations towards orthogonal dimensions. The proposed SVD-based GA has been evaluated on 9 benchmark problems and compared with a simple GA and a GA with a distance crowding schema. Results indicate that SVD-based GA achieves significantly better solutions and exhibits a quicker convergence than the alternative techniques.

RWA 5 Best Papers**Session Chair: Taras Kowaliw****Room: Ormandy West**

13:40-14:06 ★Evolving Large Scale UAV Communication System*Adrian Agogino, Chris HolmesParker, Kagan Tumer*

Unmanned Aerial Vehicles (UAVs) have traditionally been used for short duration missions involving surveillance or military operations. Advances in batteries, photovoltaics and electric motors though, will soon allow large numbers of small, cheap, solar powered unmanned aerial vehicles (UAVs) to fly long term missions at high altitudes. This will revolutionize the way UAVs are used, allowing them to form vast communication networks. However, to make effective use of thousands (and perhaps millions) of UAVs owned by numerous disparate institutions, intelligent and robust coordination algorithms are needed, as this domain introduces unique congestion and signal-to-noise issues. In this paper, we present a solution based on evolutionary algorithms to a specific ad-hoc communication problem, where UAVs communicate to ground-based customers over a single wide-spectrum communication channel. To maximize their bandwidth, UAVs need to optimally control their output power levels and orientation. Experimental results show that UAVs using evolutionary algorithms in combination with appropriately shaped evaluation functions can form a robust communication network and perform 180% better than a fixed baseline algorithm as well as 90% better than a basic evolutionary algorithm.

14:06-14:32 A New SAX-GA Methodology applied to Investment Strategies Optimization*António Canelas, Rui Neves, Nuno Horta*

This paper presents a new computational finance approach, combining a Symbolic Aggregate approXimation (SAX) technique together with an optimization kernel based on genetic algorithms (GA). The SAX representation is used to describe the financial time series, so that, relevant patterns can be efficiently identified. The evolutionary optimization kernel is here used to identify the most relevant patterns and generate investment rules. The proposed approach was tested using real data from S&P500. The achieved results show that the proposed approach outperforms both B&H and other state-of-the-art solutions.

14:32-14:58 ★The Unconstrained Automated Generation of Cell Image Features for Medical Diagnosis*Taras Kowaliw, Wolfgang Banzhaf*

An extension to a non-linear offline method for generating features for image recognition is introduced. It aims at generating low-level features automatically when provided with some arbitrary image database. First, a general representation of prioritized pixel- neighbourhoods is described. Next, genetic programming is used to specify functions on those representations. The result is a set of transformations on the space of grayscale images. These transforms are utilized as a step in a classification process, and evolved in an evolutionary algorithm. The technique is shown to match the efficiency of the state-of-the-art on a medical image classification task. Further, the approach is shown to self-select an appropriate solution structure and complexity. Finally, we show that competitive co-evolution is a viable means of combating over-fitting. It is concluded that the technique generally shows good promise for the creation of novel image features in situations where pixel-level features are complex or unknown, such as medical images.

ACO 1 Best Papers

Session Chair: Kalyan Veeramachaneni

Room: Assembly F

13:40-14:06 ★ Gaussian mixture modeling for dynamic particle swarm optimization of recurrent problems

Eduardo Vellasques, Robert Sabourin, Eric Granger

In dynamic optimization problems, the optima location and fitness value change over time. Techniques in literature for dynamic optimization involve tracking one or more peaks moving in a sequential manner through the parameter space. However, many practical applications in, e.g., video and image processing involve optimizing a stream of recurrent problems, subject to noise. In such cases, rather than tracking one or more moving peaks, the focus is on managing a memory of solutions along with information allowing to associate these solutions with their respective problem instances. In this paper, Gaussian Mixture Modeling (GMM) of Dynamic Particle Swarm Optimization (DPSO) solutions is proposed for fast optimization of streams of recurrent problems. In order to avoid costly re-optimizations over time, a compact density representation of previously-found DPSO solutions is created through mixture modeling in the optimization space, and stored in memory. For proof of concept simulation, the proposed hybrid GMM-PSO technique is employed to optimize embedding parameters of a bi-tonal watermarking system on a heterogeneous database of document images. Results indicate that the computational burden of this watermarking problem is reduced by up to 92.9% with negligible impact on accuracy.

14:06-14:32 ★ Learning Fuzzy Cognitive Maps from Data by Ant Colony Optimization

Ye Chen, Lawrence Mazlack, Long Lu

Fuzzy Cognitive Maps (FCMs) are a flexible modeling technique with the goal of modeling causal relationships. Learning FCMs from data can be a difficult task because of the large number of candidate FCMs. The FCM learning problem is formulated as the minimization of the difference between desired response of the system and the estimated response based on the learned FCM model. A FCM learning algorithm based on Ant Colony Optimization (ACO) is presented in order to learn FCMs from multiple desired response sequences. Experiments on simulated data suggest that the proposed ACO based FCM learning algorithm is capable of learning FCM with at least 40 nodes. The performance of the algorithm is tested on both single response sequence and multiple response sequences. The test results on single response sequence are compared to several algorithms such as genetic algorithms and nonlinear Hebbian Learning rule based algorithms. The accuracy of the learned model is better than these algorithms in terms of sensitivities and specificities. The effect of number of response sequences and the effect of number of nodes is discussed.

Alife 2 Best Papers

Session Chair: Nicolas Bredeche

Room: Concerto AB

15:40-16:06 **★ Hierarchical task decomposition through Symbiosis in reinforcement learning**

John Doucette, Peter Lichodziejewski, Malcolm Heywood

Adopting a symbiotic model of evolution separates context for deploying an action from the action itself. Such a separation provides a mechanism for task decomposition in temporal sequence learning. Moreover, previously learnt policies are taken to be synonymous with meta actions. Should solutions to the task not be forthcoming in an initial round of evolution, then solutions from the earlier round represent the (meta) actions for a new round of evolution. This provides the basis for evolving policy trees, thus decomposition is conducted both hierarchically and laterally. A benchmarking study is performed using the Acrobot handstand task. Solutions to date from reinforcement learning have not been able to approach those established 13 years ago using an A* search and a priori knowledge regarding the Acrobot energy equations. The proposed symbiotic approach is able to match and, for the first time, better these results. Moreover, unlike previous works, solutions are tested under a broad range of Acrobot initial conditions, with hierarchical solutions providing significantly better generalization performance.

16:06-16:32 **★ A Comparison of a Communication Strategies in Cooperative Learning**

Michael Solomon, Terence Soule, Robert Heckendorn

In the wild groups of hyenas are often observed to cooperate in driving lions away from a kill in order to claim it for themselves. Because lions are much larger and can easily injure or kill a single hyena, this is a difficult, high-risk, high-reward behavior requiring complex cooperation by the hyenas and depends on their ability to use communication to coordinate their attack. In this paper we attempt to evolve hyena behaviors that successfully drive-off simulated lions. We are particularly interested in how the type of communication influences the evolution of successful strategies. Several forms of communication are tested including two inspired by hyena behavior. The first is a generalized vocalization or "call" which can be either local or global and used by any hyena. The second mimics the recognition of a special hyena, which we refer to as the "flag-bearer". Our results show that the presence of a flag-bearer leads to the evolution of significantly more effective coordination than either purely local or name based communication. These results suggest that there may be a "sweet spot" between too little information, which makes coordination difficult, and too much information which makes both evolutionary learning and coordination difficult.

GP 4 Best Papers**Session Chair: Aniko Ekart****Room: Maestro AB**

15:40-16:06 ★ Spatial Co-Evolution - quicker, fitter and less bloated*Robin Harper Harper*

Operator equalisation is a methodology inspired by the cross-over bias theory that attempts to limit bloat in genetic programming (\emph{GP}). This paper examines a two variable regression problem and demonstrates that operator equalisation suffers from bloat when attempting to solve this problem. This is in contrast to a spatial co-evolutionary mechanism (\emph{SCALP}) that appears to avoid bloat, without any need for express bloat control mechanisms. A previously analysed real world problem (human oral bioavailability prediction) is examined. The behaviour of SCALP on this problem is quite different from that of standard GP and operator equalisation leading to short, general solutions.

16:06-16:32 ★ Symbolic Regression of Multiple-Time-Scale Dynamical Systems*Theodore Cornforth, Hod Lipson*

Genetic programming has been successfully used for symbolic regression of time series data in a wide variety of applications. However, previous approaches have not taken into account the presence of multiple-time-scale dynamics despite their prevalence in both natural and artificial dynamical systems. Here, we propose an algorithm that first decomposes data from such systems into components with dynamics at different time scales and then performs symbolic regression separately for each scale. Results show that this divide-and-conquer approach improves the accuracy and efficiency with which genetic programming can be used to reverse-engineer multiple-time-scale dynamical systems.

ECOM 3: Best Papers**Room: Assembly E**

15:40-16:06 ★ A Hybridization between Memetic Algorithm and Semidefinite Relaxation for the Max-Cut Problem*Bo Song, Victor O. K. Li*

The Max-Cut problem is a classical NP-hard combinatorial optimization problem. It consists of dividing the vertices of a weighted graph into two subsets, such that the sum of the weights of the edges connecting the two subsets is maximized. Although semidefinite relaxation algorithms for Max-Cut have been proved to be of high quality and offer performance guarantees, in practice, metaheuristic algorithms are still the first option to solve large Max-Cut instances. In this paper, we present the first effort at combining semidefinite programming (SDP) with metaheuristic algorithm (Memetic Algorithm) to solve the Max-Cut problem. Based on the solution of semidefinite relaxation, we use Goemans-Williamson Algorithm to seed high quality solutions to the initial population for the memetic algorithm. Experimental results on well-known benchmark problems show that our new hybrid algorithm is capable of obtaining better solutions in the initial population generation stage than previous algorithms, and the overall performance of our algorithm is better than one of the best existing algorithms. Besides, new best solutions for six benchmark problems were found by our algorithm.

16:06-16:32 **★ An Evolutionary Algorithm with Solution Archives and Bounding Extension for the Generalized Minimum Spanning Tree Problem**
Bin Hu, Günther Raidl

We consider the recently proposed concept of enhancing an evolutionary algorithm (EA) with a complete solution archive storing evaluated solutions during the optimization in order to detect duplicates and to efficiently transform them into yet unconsidered solutions. For this approach we introduce the so-called bounding extension in order to identify and prune branches in the trie-based archive which only contain inferior solutions. This extension enables the EA to concentrate the search on promising areas of the solution space. Similarly to the classical branch-and-bound technique, bounds are obtained via primal and dual heuristics. As an application we consider the generalized minimum spanning tree problem where we are given a graph with nodes partitioned into clusters and exactly one node from each cluster must be connected in the cheapest way. As the EA uses operators based on two dual representations, we also apply two corresponding tries that complement each other. Test results on TSPLib instances document the strength of this concept and that it can compete with the leading metaheuristics for this problem from the literature.

SS 2

Session Chair: Marc Schoenauer

Room: Assembly C

15:40-16:06 **A Dynamic Island Model for Adaptive Operator Selection**
Caner Candan, Adrien Goeffon, Frederic Lardeux, Frederic Saubion

In this paper we propose a generic description of Dynamic Island Models, which can be used as an original approach for the adaptative selection of operators in evolutionary algorithms. We show that in assigning a variation operator to each island, the dynamic regulation of migrations, which takes into account the pertinence of recent migrations, distribute the individuals on the most promising islands, that is the most efficient operators at each stage of the search. The efficiency of this approach is assessed in comparing, for the One-Max Problem, theoretical ideal results to those obtained by the dynamic island model. Experiments show that the model has the expected behavior.

16:06-16:32 **An Exploration-Exploitation Compromise-Based Adaptive Operator Selection for Local Search**
Nadarajen Veerapen, Jorge Maturana, Frédéric Saubion

This paper deals with the adaptive selection of operators in the context of local search (LS). Inspired by the concept of diversity in evolutionary algorithms, the similarity between the candidate solution and the solutions in the search trajectory is considered, together with the solution quality, in order to evaluate the performance of each operator. A new utility measure for LS operators, evaluating relative distances between the operators, is introduced. It is compared with an existing measure based on the Pareto dominance relationship using some basic selection schemes. An adaptive version of the algorithm is also examined. Validation of the proposed methods is carried out on the Quadratic Assignment Problem and Asymmetric Traveling Salesman Problem.

16:32-16:58 Improving the Performance of Vector Hyper-heuristics through Local Search

José Carlos Ortiz-Bayliss, Hugo Terashima-Marín, Santiago Enrique Conant-Pablos, Ender Özcan, Andrew J. Parkes

Hyper-heuristics are methodologies that allow us to selectively apply the most suitable heuristic given the properties of the problem at hand. They can be applied in CSP in different ways, but one way which has received attention in recent years is variable ordering by using hyper-heuristics. To select the next variable, a set of heuristics exist and the hyper-heuristic decides, considering the features that describe the instance at hand, which heuristic is more suitable to be applied at the moment. This paper explores a hyper-heuristic model for variable ordering within CSP based on vector hyper-heuristics. Each hyper-heuristic is represented as a set of vectors that maps instance features to heuristics. These vector hyper-heuristics are constructed by going into a local search method that modifies the hyper-heuristics. The results suggest that the approach is able to combine the strengths of different heuristics to perform well on a wide range of instances and compensate for their weaknesses on specific instances, resulting in an improvement in the performance of the search compared against the heuristics applied in isolation.

IGEC 2: Differential Evolution and Coevolution

Session Chair: Dirk Thierens

Room: Ormandy East

15:40-16:06 SDE: A Stochastic Coding Differential Evolution for Global Optimization

Jing-hui Zhong, Jun Zhang

Differential Evolution is a new paradigm of evolutionary algorithm which has been widely used to solve nonlinear and complex problems. The performance of DE is mainly dependent on the parameter settings, which relate to not only characteristics of the specific problem but also the evolution state of the algorithm. Hence, determining the suitable parameter settings of DE is a promising but challenging task. This paper presents an enhanced algorithm, namely, the stochastic coding differential evolution, to improve the robustness and efficiency of DE. Instead of encoding each individual as a vector of floating point numbers, the proposed SDE represents each individual by a multivariate normal distribution. In this way, individuals in the population can be more sensible to their surrounding regions and the algorithm can explore the search space region-by-region. In the SDE, a newly designed update operator and a random mutation operator are incorporated to improve the algorithm performance. Traditional DE operators such as the mutation scheme and the crossover operator are also accordingly extended. The proposed SDE has been validated by nine benchmark test functions with different characteristics. Five EAs are compared in the experiment study. The comparison results demonstrate the effectiveness and efficiency of the SDE.

16:06-16:32 An Approach for Estimating Separability and its Application on High Dimensional Optimization

Ricardo Landa, Yazmin Rojas, Gregorio Toscano-Pulido

In this paper, we propose an approach for measuring the level of separability (in a relaxed sense) among variables, making use of the rectangle condition for separable functions. This approach is then used in a differential evolution-based algorithm for high dimensional optimization. The decision variables are associated into groups by their estimated level of separability. Such estimation is refined throughout generations, depending on the area being currently explored. Results are shown from 50 to 10,000 variables. The experiments are performed with unimodal, multimodal, separable and non-

separable functions. Comparison are shown with differential evolution alone, and with other algorithms of the state of the art.

16:32-16:58 **Co-evolutionary Predictors for Kinematic Pose Inference**

Daniel Ly, Ashutosh Saxena, Hod Lipson

Markerless pose inference of arbitrary subjects is a primary problem for a variety of applications, including robot vision and teaching by demonstration. Unsupervised kinematic pose inference is an ideal method for these applications as it provides a robust, training-free approach with minimal reliance on prior information. However, these methods have been considered intractable for complex models due to multi-modal fitness metrics, high dimensional parameter spaces and the vast data content in a single depth image. This paper presents a general framework for inferring poses from a single depth image given an arbitrary kinematic structure without prior training. A co-evolutionary algorithm, consisting of pose and predictor populations, is applied to overcome the traditional limitations in kinematic pose inference. Evaluated on test sets of 256 synthetic and 52 real images, our algorithm shows consistent pose inference for 34 and 78 degree of freedom models with images containing over 40,000 points, even in cases of significant self-occlusion. Compared to various baselines, the co-evolutionary algorithm provides at least a 3.5-fold increase in pose accuracy and a two-fold reduction in computational effort for articulated models.

GA 3 Best Papers

Session Chair: Daniel R. Tauritz

Room: Aria AB

15:40-16:06 **★ Crossover Speeds Up Building-Block Assembly**

Dirk Sudholt

We re-investigate a fundamental question: how effective is crossover in combining building blocks? Although this has been discussed controversially for decades, we are still lacking a rigorous and intuitive answer. We provide such answers for royal road functions and OneMax, where every bit is a building block. For the latter we prove that a simple GA with uniform crossover is twice as fast as the fastest EA using only mutation, up to small-order terms. The reason is that crossover effectively turns neutral mutations into improvements by combining the right building blocks at a later stage. Compared to mutation-based EAs, this makes multi-bit mutations more useful. Introducing crossover changes the optimal mutation rate on OneMax from $1/n$ to $(1+\sqrt{5})/2 \cdot 1/n \approx 1.618/n$. Similar results are proved for k -point crossover. Experiments and statistical tests confirm that our findings apply to a broad class of building-block functions.

16:06-16:32 **★ Runtime Analysis of Convex Evolutionary Search**

Alberto Moraglio, Dirk Sudholt

Geometric crossover formalises the notion of crossover operator across representations. In previous work, it was shown that all evolutionary algorithms with geometric crossover (but with no mutation) do a generalised form of convex search. Furthermore, it was suggested that these search algorithms could perform well on concave and approximately concave fitness landscapes. In this paper, we study the runtime of a generalised form of convex search on concave fitness landscapes. This is a first step towards linking a geometric theory of representations and runtime analysis in the attempt to (i) set the basis for a more general/unified approach for the runtime analysis of evolutionary algorithms across

representations, and (ii) identify the essential matching features of evolutionary search behaviour and landscape topography that cause polynomial performance.

RWA 6

Session Chair: **Bradley James Alexander**

Room: **Ormandy West**

15:40-16:06 **Evolving a Conspicuous Point Detector based on an Artificial Dorsal Stream - SLAM System**

Daniel Hernandez, Gustavo Olague, Eddie Clemente, Leon Dozal

The goal of purposive or behavioral vision is to study the interactions of a visual system with the real world, creating a balance between perception and action. It is said that a system that accomplishes a visuomotor task needs to implement a selective perception process allowing a specific motion-action commands. This combination is understood as a visual behavior. This paper describes a real-working system, consisting of a robotic manipulator in a hand-eye configuration which is used as a research platform in order to evolve a specialized visual routine capable of estimating specific motion-actions. The core idea is to evolve an conspicuous point detector, based on the artificial dorsal stream model, with the purpose of using this detector inside a simultaneous localization and map building system. Experimental results show as a proof-of-concept several interesting ideas, first, that it is in fact possible to find prominent points in an image through a visual attention process, and second, that the proposed system is able to design a specific visual behavior for the case of a straight-line displacement with the advantage of eliminating a number of heuristics.

16:06-16:32 **Hybrid Metaheuristic particle filters for stochastic volatility estimation**

Robert Smith, Muhammad Hussain

In this paper we propose hybrid metaheuristic particle filters for the dual estimation of state and parameters in a stochastic volatility estimation problem. We use evolutionary strategies and real coded genetic algorithms as the metaheuristics. The hybrid metaheuristic particle filters provide accurate results while using lesser number of particles for this high dimension estimation problem. We compare the performance of our hybrid algorithms with a sequential importance resampling particle filter (SIR) and the parameter learning algorithm (PLA). Our hybrid particle filters out perform both these algorithms for this particular dual estimation problem.

16:32-16:58 **Application of Evolutionary Methods to 3D Geoscience Modelling**

Bradley Alexander, Stephan Theil, Jared Peacock

Geoscience modelling plays a vital role in mapping and tracking the earth's resources. Magnetotellurics, which maps the electrical resistivity of the subsurface, is a useful and cost-effective sounding-technique for sensing over a broad scale at depth. However, due to the inherent difficulty in sensing at depth, models produced using MT have a degree of uncertainty. Geoscientists can reduce this uncertainty by producing multiple alternative models, and using multiple modelling techniques and settings, to correlate robust model features with field data responses. Population-based evolutionary search techniques are of interest to MT modelling because they offer an alternative to deterministic

techniques, and are able to produce multiple models for analysis. Unfortunately, evolutionary techniques have not been successfully applied to 3D MT modelling. In this work we describe a new, more compact, representation of MT models using volumetric functions. Using this representation we successfully apply evolutionary search techniques to 3D MT modelling for both artificial and real models and show how the development of large scale features during modelling can be correlated with the model's fit to field data.

ACO 2

Session Chair: Mohammed El-Abd

Room: Assembly F

15:40-16:06 CGrAnt: a Swarm Intelligence-based Routing Protocol for Delay Tolerant Networks

Ana Kochem Vendramin, Anelise Munaretto, Myriam Delgado, Aline Viana

This paper presents a new routing protocol for Delay Tolerant Networks (DTNs), based on a distributed swarm intelligence approach. The protocol is called Cultural Greedy Ant (CGrAnt), as it uses a Cultural Algorithm (CA) and a greedy version of the Ant Colony Optimization (ACO) metaheuristic. The term greedy implies the use of a deterministic transition rule to exploit previously found good paths or explore new paths by selecting, from among a set of candidates, the most promising message forwarders. CGrAnt chooses each next node toward the message destination based on pheromone concentration (i.e., global information) whenever it is available. However, as the pheromone is not always available due to connectivity partitions, local information (i.e., heuristic function) captured from DTN nodes also supports a routing decision. Specific metrics and information gathered from the evolution are stored in Situational, Domain, and Historical Knowledge. The knowledge composes the CA's belief space, which is used to guide and improve the search. CGrAnt is compared with two DTN routing protocols (Epidemic and PROPHET) in an activity-based scenario. The results show that CGrAnt achieves a higher delivery ratio and lower byte redundancy than Epidemic and PROPHET.

16:06-16:32 DACCO: A Discrete Ant Colony Algorithm to Cluster Geometry Optimization

Nuno Lourenço, Francisco Pereira

We present a discrete ant colony algorithm to cluster geometry optimization. To deal with this continuous problem, the optimization framework includes functions to map solutions across the discrete and continuous spaces. Results obtained with short-ranged Morse clusters show that the proposed approach is effective, scalable and is competitive with state-of-the-art optimization methods specifically designed to tackle continuous domains. A detailed analysis is presented to help to gain insight into the role played by several components of the ant colony algorithm.

16:32-16:58 Ants Easily Solve Stochastic Shortest Path Problems

Benjamin Doerr, Ashish Hota, Timo Kötzing

The first rigorous theoretical analysis (Horoba, Sudholt (GECCO 2010)) of an ant colony optimizer for the stochastic shortest path problem suggests that ant system experience significant difficulties when the input data is prone to noise. In this work, we propose a slightly different ant optimizer to deal with noise. We prove that under mild conditions, it finds the paths with shortest expected length efficiently, despite the fact that we do not have convergence in the classic sense. To prove our results, we introduce a stronger drift theorem that can also deal with the situation that the progress is faster when one is closer to the goal.

Alife 3

Session Chair: Stéphane Doncieux

Room: Concerto AB

10:40-11:06 On the Cumulative Effect of Bloat and Genetic Transposition on the Efficiency of Incremental Evolution of Snake-like Robot

Ivan Tanev, Tuze Kuyucu, Katsunori Shimohara

We present a study on the cumulative effect of the bloat and the seeding of the initial population, inspired by genetic transposition (GT), on the efficiency of incremental evolution of simulated snake-like robot (Snakebot). In the proposed incremental genetic programming (IGP), the task of coevolving the locomotion gaits and sensing of the bot in a challenging environment is decomposed into two sub-tasks, implemented as two consecutive evolutionary stages. First, we use genetic programming (GP) with two ways of bloat management, (i) parsimony pressure which penalizes the bloat and (ii) no bloat control, to evolve two pools of sensor-less Snakebots. During the second stage of IGP, we use these pools to seed the initial population of Snakebots applying two methods of seeding: canonical seeding and GT-inspired seeding. The empirical results indicate that the efficiency of the first stage of IGP for both bloat control techniques is similar. However, the bloated bots contribute to a much more efficient second stage of evolution. Compared to the canonical seeding with parsimony bots, the GT-inspired seeding with bloated Snakebots yields about five times higher probability of success and similar decrease of computational effort of the second stage of IGP.

11:06-11:32 Exploring and Evolving Process-oriented Control for Real and Virtual Fire Fighting Robots

Kathryn Hardey, Eren Corapcioglu, Molly Mattis, Mark Goadrich, Matthew Jadud

Current research in evolutionary robotics is largely focused on creating controllers by either evolving neural networks or refining genetic programs based on grammar trees. We propose the use of the parallel, dataflow languages for the construction of effective robotic controllers and the evolution of new controllers using genetic programming techniques. These languages have the advantages of being built on concurrent execution frameworks that lend themselves to formal verification along with being visualized as a dataflow graph. In this paper, we compare and contrast the development and subsequent evolution of one such process-oriented control algorithm. Our control software was built from composable, communicating processes executing in parallel, and we tested our solution in an annual fire-fighting robotics competition. Subsequently, we evolved new controllers in a virtual simulation of this parallel dataflow domain, and in doing so discovered and quantified more efficient solutions. This research demonstrates the effectiveness of using process networks as the basis for evolutionary robotics.

11:32-11:58 Evolving Network Motifs based Morphogenetic Approach for Self-Organizing Robotic Swarms

Yan Meng, Hongliang Guo

In order to traverse through a complex environment, swarm robotic systems need to self-organize themselves to form different yet suitable shapes dynamically to adapt to unknown environments. Biological morphogenetic networks, such as gene regulatory networks (GRNs), are modular with independent units and often show the reuse of recurring patterns termed network motifs. Inspired by the biological morphogenesis and the evolution and structure of network motifs in

biology, in this paper, we propose an evolving GRN-based approach for self-organizing robotic swarms to autonomously generate dynamic patterns in unknown environments. The basic idea of this GRN-based model is: first, several network motifs are predefined as the basic building blocks for GRNs, then an evolutionary algorithm is applied to evolve parameters and the structures of the GRNs model. Simulation and experimental results demonstrate that the proposed bio-inspired model is effective for complex shape generation and robust to environmental changes in complex unknown environments.

GP 5: Empirical studies

Session Chair: Krzysztof. Krawiec

Room: Maestro AB

10:40-11:06 MT-CGP: Mixed Type Cartesian Genetic Programming

Simon Harding, Vincent Graziano, Jürgen Leitner, Jürgen Schmidhuber

The majority of genetic programming implementations build expressions that only use a single data type. This is in contrast to human engineered programs that typically make use of multiple data types, as this provides the ability to express solutions in a more natural fashion. In this paper, we present a version of Cartesian Genetic Programming that handles multiple data types. We demonstrate that this allows evolution to quickly find competitive, compact, and human readable solutions on multiple classification tasks.

11:06-11:32 Exploring Boundaries: Optimising Individual Class Boundaries for Binary Classification Problem

Jeannie Fitzgerald, Conor Ryan

This paper explores a range of class boundary determination techniques that can be used to improve performance of Genetic Programming (GP) on binary classification tasks. These techniques involve selecting an individualised boundary threshold in order to reduce implicit bias that may be introduced through employing arbitrarily chosen values. Individuals that can choose their own boundaries and the manner in which they are applied, are freed from having to learn to force their outputs into a particular range or polarity and can instead concentrate their efforts on seeking a problem solution. Our investigation suggests that different boundary selection methods may deliver better performance for a given problem but that no single method performs best on all problems studied. We propose a new flexible combined technique which delivers near optimal performance across each of the binary classification tasks undertaken. This method together with seven other techniques is tested on six benchmark binary classification data sets. Experimental results obtained suggest that the strategy can improve test fitness, produce smaller less complex individuals and deliver reduced run times. Our approach is benchmarked against a standard GP system, and is shown to deliver superior results.

11:32-11:58 On Relationships between Semantic Diversity, Complexity and Modularity of Programming Tasks

Krzysztof Krawiec

We investigate semantic properties of linear programs, both internally, by analyzing the memory states they produce during execution, and externally, by inspecting program outcome. The main concept of the formalism we propose to this aim is program trace, which reflects the behavior of program in semantic space. It allows us to characterize programming tasks in terms of traces of programs that solve them, and to propose certain measures that reveal their properties. We are

primarily interested in measures that quantitatively characterize functional (semantic, behavioral) modularity of programming tasks. The experiments conducted on large samples of linear programs written in Push demonstrate that semantic structure varies from task to task, and reveal patterns of different forms of modularity. In particular, we identify also interesting relationships between modularity, complexity, and program length.

ECOM: ECOM 4

Room: Assembly E

10:40-11:06 An Evolutionary Approach for the Dubins' Traveling Salesman Problem with Neighborhoods

Douglas Guimaraes Macharet, Armando Alves Neto, Vilar Fiuza da Camara Neto, Mario Montenegro Campos

In this work we propose an efficient and simple three-stage evolutionary algorithm to tackle the difficult problem of planning shorter paths through regions of an environment which are feasible for a nonholonomic vehicle with curvature constraints (e.g. Dubins' vehicle). Our method is able to efficiently solve both the combinatorial and the continuous steps of the problem in a combined manner. In the first phase, the method varies the position of the waypoints within the boundaries of each region, it then optimizes the path orientation at each waypoint, and finally it chooses the best actual sequence of visit. Numerous trials, under different scenarios in a simulated environment, were executed providing a thorough evaluation and validation of the methodology. The results show that a substantial improvement was obtained on the search for optimal paths in the DTSPN over current works in the literature. Numerical simulations also exhibit a significant performance improvement when compared with classical solutions that use the Alternating Algorithm, and they also show that our method outperforms a random sampling based technique. Our results present a reduction on the final path length of about 25% on average when compared to paths generated by the aforementioned methods.

11:06-11:32 On the Efficiency of an Order-based Representation in the Clique Covering Problem
David Chalupa

Although the (vertex) clique covering problem (CCP) is a classical NP-hard problem, it is still quite overlooked in the fields of heuristics and evolutionary algorithms. We present two main results concerning this problem. First, we propose a genotype-phenotype mapping algorithm for an order-based representation of the CCP, called greedy clique covering (GCC), and prove that for an arbitrary graph, there exists a permutation, for which GCC will construct the optimal solution. Although the greedy graph coloring can also be used as genotype-phenotype mapping, we show that GCC is much more efficient for sparse graphs. Secondly, we adapt a mutation-based stochastic metaheuristic algorithm using the order-based representation - iterated greedy (IG), to solve the CCP. On graphs with planted cliques, we provide empirical evidence that IG outperforms an exact algorithm. This result is supported by a runtime analysis of IG using the recent techniques of nature inspired algorithm analysis on several subclasses of graphs with planted cliques. We include experimental results of IG on random graphs, several DIMACS instances and social graphs. Its comparison to the related existing approaches shows that our IG algorithm outperforms the standard approaches in almost all instances.

11:32-11:58 **A Genetic and Insertion Heuristic algorithm for solving the dynamic ridematching problem with time windows**

Wesam Herbawi, Michael Weber

In this paper, we address the dynamic ridematching problem with time windows in dynamic ridesharing. The dynamic ridesharing is a special type of ridesharing where the participants form ridesharing on short notice. The ridematching problem is to assign riders to drivers and to define the ordering and timing of the riders' pickup and delivery. Because not all information is known in advance, the problem is dynamic. This is an optimization problem where we optimize a multicriteria objective function. We consider minimizing the total travel distance and time of the drivers and the total travel time of the riders and maximizing the number of the transported riders. We propose a genetic and insertion heuristic algorithm for solving the addressed problem. In the first stage, the algorithm works as a genetic algorithm while in the second stage it works as an insertion heuristic that modifies the solution of the genetic algorithm to do ridematching in real-time. In addition, we provide datasets for the ridematching problem, derived from realistic data, to test the algorithm. Experimentation results indicate that the algorithm can successfully solve the problem by providing answers in real-time and it can be easily tuned between response time and solution quality.

SBSE 1

Room: Assembly C

10:40-11:06 **An Analysis of the Effects of Composite Objectives in Multiobjective Software Module Clustering**

Marcio Barros

The application of multiobjective optimization to address Software Engineering problems is a growing trend. Multiobjective algorithms provide a balance between the ability of the computer to search a large solution space for valuable solutions and the capacity of the human decision-maker to select an alternative when two or more incomparable objectives are presented. However, when more than a single objective is available, the set of objectives to be considered by the search becomes part of the decision. In this paper, we address the efficiency and effectiveness of using two composite objectives while searching solutions for the software clustering problem. We designed an experimental study which shows that a multiobjective genetic algorithm can find a set of solutions with increased quality and using less processing time if these composite objectives are suppressed from the formulation for the software clustering problem.

11:06-11:32 **Evolutionary Algorithms for the Project Scheduling Problem: Runtime Analysis and Improved Design**

Leandro Minku, Dirk Sudholt, Xin Yao

The project scheduling problem (PSP) has the goal of assigning employees to tasks in such a way to minimize the cost and completion time of the project, considering the employees' skills, maximum dedication and task precedence constraints. Even though genetic algorithms (GAs) have been used by many researchers to solve this problem, it is not well understood which problem characteristics make it difficult to solve by evolutionary algorithms. We present the first runtime analysis for the PSP, revealing what problem features can make PSP easy or hard. This allows to assess the performance of GAs and to make informed design choices. In our case theory inspired a new evolutionary design, including normalisation of employees' dedication for different tasks to eliminate the problem of exceeding their maximum dedication. Theoretical and empirical results show that our design is very effective in terms of hit rate and solution quality.

11:32-11:58 **Multi-Objective Coevolutionary Automated Software Correction**

Josh Wilkerson, Daniel Tauritz, James Bridges

For a given program, testing, locating the errors identified, and correcting those errors is a critical, yet expensive process. The field of Search Based Software Engineering (SBSE) addresses these phases by formulating them as search problems. The Coevolutionary Automated Software Correction (CASC) system targets the correction phase by coevolving test cases and programs at the source code level. This paper presents the latest version of the CASC system featuring multi-objective optimization and an enhanced representation language. Results are presented demonstrating CASC's ability to successfully correct five seeded bugs in two non-trivial programs from the Siemens test suite. Additionally, evidence is provided substantiating the hypothesis that multi-objective optimization is beneficial to SBSE.

GA 4: Distance Measures & Recombination

Session Chair: Robert D. Collier

Room: Aria AB

10:40-11:06 **An Empirical Approach to the Measurement of Interchromosomal Distances in the Genetic Algorithm**

Robert Collier, Mark Wineberg

Data visualizations, population diversity measurements, and cluster analyses are all invariably constructed from measures of distance or dissimilarity, and it is recognized that any measure of the distance between points should represent the manner and ease with which an algorithm or process can move from one point towards another. For the genetic algorithm, this traversal is largely accomplished by mutation and recombination, but in spite of this, measures like the Hamming distance and the edit distance are still used to assess the distance between population members. This represents a significant problem, because these measures were not designed with the genetic algorithm in mind and they do not consider how the genetic operators will actually traverse genotypic space. The need for distance measures to be accurate and representative cannot be overstated, but for the complex traversals of the genetic algorithm, it is exceedingly difficult to determine whether one measure is any more representative than another. To address this need, this paper will introduce an empirical approach to distance measurement, and since the resultant values are derived from actual traversals, the distance measured is guaranteed representative, and can be used as a baseline against which other measures can be evaluated.

11:06-11:32 **Dynamic Segregative Genetic Algorithm for Optimizing the Variable Ordering of ROBDDs**

Cristian Rotaru, Octav Brudaru

In this paper an efficient dynamic segregative genetic algorithm for optimizing variable order in Reduced Ordered Binary Decision Diagrams is presented. The approach integrates a basic genetic algorithm and uses a feature function in order to define a similarity measure between chromosomes. Subpopulations of individuals, formed by applying a clustering procedure in the feature space, are explored in parallel by multiple copies of the basic genetic algorithm. A communication protocol preserves the similarity inside each subpopulation during the evolution process. The redundant exploration of the search space is avoided by using a tabu search associative memory. Genetic material from yet unexplored regions of the search space is managed and organized in order to explicitly guide the search process to yet

undiscovered local optima. The experimental evaluation of the algorithm uses classical benchmark problems, known to be difficult. Experiments suggest that our approach has a better performance in terms of stability and quality of the solution, when compared to other heuristics, such as local search methods, basic genetic algorithms, a cellular genetic algorithm and the static segregative genetic algorithm that was the starting point of this work. The quality of the distributed implementation and the communication protocol are thoroughly analyzed.

11:32-11:58 Depictions of Genotypic Space for Evaluating the Suitability of Different Recombination Operators

Robert Collier, Christian Fobel, Gary Grewal, Mark Wineberg

When the genetic algorithm recombines two parent genotypes, the differences between them define a genotypic subspace, and any offspring produced should be confined to this subspace. Although this might seem insignificant, those recombination (or crossover) operators that violate this principle can direct a search away from the region (in genotypic space) that contains the two parent genotypes. This is contrary to the task for which the recombination operator was originally developed and can be detrimental, so this paper introduces a visualization that can be used to detect violations of this principle. The methodology also inspired the development of a different approach to recombining permutations, and a brief case study shows that an alternative recombination operator that does not violate this principle can be used to achieve a performance improvement over previous attempts to optimize Field-Programmable Gate-Array placements using a genetic algorithm. We believe that this technique will be invaluable for developing additional recombination operators.

RWA 7

Session Chair: Joseph Krupa

Room: Ormandy West

10:40-11:06 A Preference-Based Bi-Objective Approach to the Payment Scheduling Negotiation Problem with the Extended r-Dominance and NSGA-II

Wei-neng Chen, Jun Zhang

This paper addresses a complicated problem in project management termed the payment scheduling negotiation problem. The problem is a practical extension of the classical multi-mode resource constrained project scheduling problem and it considers the financial aspects of both the project client and contractor in a contracting project. The client and contractor negotiate with each other to determine an optimal payment schedule and an activity schedule so as to maximize their net present values (NPVs). As the NPV of the client and the NPV of the contractor are conflicting objectives, this paper first formulates the PSNP as a bi-objective optimization problem. To solve this problem effectively, a non-dominated sorting genetic algorithm II (NSGA-II) approach is proposed. In the negotiation, the client and contractor may have two preferences: the ideal NPVs for the client and the contractor, and the optimization degree of the activity schedule. In order to tackle these preferences, this paper further introduces a new dominance relation named the extended r-dominance relation. The er-dominance relation extends the r-dominance relation and is able to deal with multiple preferences described by aspiration functions. Experimental results show that by incorporating the NSGA-II with the er-dominance, the proposed approach is promising for the PSNP.

11:06-11:32 **Evaluation of the Performance of Evolutionary Algorithms for Optimization of Low-Enthalpy Geothermal Heating Plants**

Markus Beck, Michael de Paly, Jozsef Hecht-Méndez, Peter Bayer, Andreas Zell

In this paper, we present the application of Evolutionary Algorithms (EAs) and linear programming for minimizing thermal impacts in the ground by operating a low-enthalpy geothermal plant with a field of multiple borehole heat exchangers (BHEs). The new methodology is demonstrated on two synthetic, reality-oriented case studies with 36 BHEs that are operated to produce given seasonal heating energy demand. We compare the performance of eight different Evolutionary Algorithms (EAs) (two Differential Evolution variants, Particle Swarm Optimization, three Evolution-Strategy based Algorithms, real valued Genetic Algorithm, Monte-Carlo random search) to find the optimal BHE positions. Additionally, linear programming is applied to adjust the energy extraction (loads) for the individual BHEs in the field. Both optimization steps are applied separately and in combination, and the achieved system improvements are compared to the conditions for the non-optimized case. The EAs were able to find constellations that cause less pronounced temperature changes in the subsurface (18% -25%) than those associated with non-optimized BHE fields. Further, we could show that exclusive optimization of BHE energy extraction rates delivers slightly better results than the optimization of BHE positions. Combining both optimization approaches is the best choice and, ideally, adjusts the geothermal plant.

11:32-11:58 **Evolutionary Exploratory Association Discovery: A Plug-in Hybrid Vehicle Adoption Application**

Joseph Krupa, Somdeb Chatterjee, Ethan Eldridge, Donna Rizzo, Margaret Eppstein

We present a real-world application utilizing a Genetic Algorithm (GA) for exploratory multivariate association analysis of a large consumer survey designed to assess potential consumer adoption of Plug-in Hybrid Electric Vehicles (PHEVs). The GA utilizes an intersection/union crossover operator, in conjunction with high background mutation rates, to achieve rapid multivariate feature selection. We experimented with two alternative fitness measures based on classification results of a naïve Bayes quadratic discriminant analysis; one fitness function rewarded only for correct classifications, and the other penalized for the degree of misclassification using a quadratic penalty function. We achieved high classification accuracy for three different survey outcome questions (with 3-, 5-, and 7- outcome classes, respectively). The quadratic penalty function yielded better overall results, returning smaller feature sets and overall more accurate contingency tables of predicted classes. Our results help to identify what consumer attributes best predict their likelihood of purchasing a PHEV. These findings will be used to better inform an existing agent-based model of PHEV market penetration, with the ultimate aim of helping auto manufacturers and policy makers identify leverage points in the system that will encourage PHEV market adoption.

ACO 3

Session Chair: Marco A. Montes de Oca

Room: Assembly F

10:40-11:06 **Why Six Informants is Optimal in PSO**

Jose Garcia-Nieto, Enrique Alba

In a previous work, it was empirically shown that certain numbers of informants different from the standard "two" and the expensive "all" may provide the Particle Swarm Optimization (PSO) with new essential information about the search landscape, leading this algorithm to perform more accurately than other existing versions of it. Here, we extend this study by analyzing the internal behavior of PSO from the point of view of the evolvability. Our motivation is to find evidences of why such number of 6+/-2 informant particles, perform better than other neighborhood formulations of PSO. For this task, we have evaluated different combinations of informants for an extensive set of problem functions. Using fitness-distance correlation and fitness-fitness cloud analyses we have tested the accuracy of the resulting landscape characterizations. The results suggest that, in spite of certain deviation to the global optimum, a number of 6 informants in PSO can generate good particles for a longer time, even in complex problems with multi-funnel landscapes.

11:06-11:32 **Integrating Particle Swarm Optimization with Reinforcement Learning in Noisy Problems**

Grigoris Piperagkas, George Georgoulas, Konstantinos Parsopoulos, Chrysostomos Stylios, Aristidis Likas

Noisy optimization problems arise very often in real-life applications. A common practice to tackle problems characterized by uncertainties, is the re-evaluation of the objective function at every point of interest for a fixed number of replications. The obtained objective values are then averaged and their mean is considered as the approximation of the actual objective value. However, this approach can prove inefficient, allocating replications to unpromising candidate solutions. We propose a hybrid approach that integrates the established Particle Swarm Optimization algorithm with the Reinforcement Learning approach to efficiently tackle noisy problems by intelligently allocating the available computational budget. Two variants of the proposed approach, based on different selection schemes, are assessed and compared against the typical alternative of equal sampling. The results are reported and analyzed, offering significant evidence regarding the potential of the proposed approach.

11:32-11:58 **Optimal Cyclic Replacement Policy in MSS Maintenance via Binomial-PSO**

Angel Muñoz Zavala, Evelyn Hernández Ramos

Several systems can perform their intended functions at more than two different levels, from perfectly working to completely failed. These kind of systems are known as multi-state systems. In many complex and sophisticated systems, reliability and maintainability theory plays a very important role in maintaining such systems. The purpose of MSS maintenance optimization is to extend system lifetime, or at least the mean time to the next failure whose repair may be costly. Furthermore, it is expected that effective maintenance policies can increase system availability and reduce the consequences of unavailability (unaccomplished demand). In this study, we consider cyclic replacement policy in a preventive maintenance planning for a component subject to failure. This paper introduces a new approach based on PSO with constraints handling for MSS maintenance optimization problems. The universal generating function is applied in this work to evaluate MSS reliability. Our approach is tested in a real MSS maintenance problem in full measure in the \textit{state-of-the-art}. The main advantage of the suggested approach is that it can be easily implemented in practice for maintenance of real MSS.

Alife 4**Session Chair: Stefano Cagnoni****Room: Concerto AB**

13:40-14:06 Impact of Neuron Models and Network Structure on Evolving Robot Neural Network Controllers*Leo Cazenille, Nicolas Bredeche, Heiko Hamman, Juergen Stradner*

This paper investigates the properties required to evolve Artificial Neural Networks for distributed control in modular robotics, which typically involves non-linear dynamics and complex interactions in the sensori-motor space. We investigate the relation between macro-scale properties (such as modularity and regularity) and micro-scale properties in Neural Network controllers. We show how neurons capable of multiplicative-like arithmetic operations may increase the performance of controllers in several ways whenever challenging control problems with non-linear dynamics are involved. This paper provides evidence that performance and robustness of evolved controllers can be improved by a combination of carefully chosen micro- and macro-scale neural network properties.

14:06-14:32 Open-ended coevolution and the emergence of complex irreducible functional units in iterated number sequence games*Benjamin Inden*

We present three related number sequence games as simple models of coevolution and demonstrate that they produce escalating arms races and irreducible functional units of unbounded size. We argue that our results imply that the models also show unbounded evolutionary activity according to a previous formal definition. Furthermore, we examine the robustness of the coevolutionary dynamics under different parameter regimes. We propose number sequence games as benchmarks for coevolutionary algorithms, and make some suggestions on adjusting task difficulty and choosing selection methods in coevolutionary robotics.

GP 6: Theory and representations**Session Chair: Lee Spector****Room: Maestro AB**

13:40-14:06 A New Methodology for the GP Theory Toolbox*Jeffrey Bassett, Uday Kamath, Kenneth De Jong*

Recently Quantitative Genetics has been successfully employed to understand and improve operators in some EA implementations. This theory offers a phenotypic view of an algorithm's behavior at a population level, and suggests new ways of quantifying and measuring concepts such as exploration and exploitation. In this paper, we extend the quantitative genetics approach in combination with some existing diversity and bloat measurement tools to measure, analyze and predict the evolutionary behavior of GP. GP specific benchmark problems, such as ant trail and symbolic regression, are used to provide new insight into how various evolutionary forces work in combination to affect the search process.

Finally, using the tool, a multivariate phenotypic crossover is designed to both improve the performance and control bloat of the difficult ant trail problem.

14:06-14:32 Comparing Methods for Module Identification in Grammatical Evolution

John Mark Swafford, Miguel Nicolau, Erik Hemberg, Michael O'Neill, Anthony Brabazon

Modularity has been an important vein of research in evolutionary algorithms. Past research in evolutionary computation has shown that techniques able to decompose the benchmark problems examined in this work into smaller, more easily solved, sub-problems have an advantage over those which do not. This work describes and analyzes a number of approaches to discover sub-solutions (modules) in the grammatical evolution algorithm. Data from the experiments carried out show that particular approaches to identifying modules are better suited to certain problem types, at varying levels of difficulty. The results presented here show that some of these approaches are able to significantly outperform standard grammatical evolution and grammatical evolution using automatically defined functions on a subset of the problems tested. The results also point to a number of possibilities for extending this work to further enhance approaches to modularity.

14:32-14:58 Tag-based Modularity in Tree-based Genetic Programming

Lee Spector, Kyle Harrington, Thomas Helmuth

Several techniques have been developed for allowing genetic programming systems to produce programs that make use of subroutines, macros, and other modular program structures. A recently proposed technique, based on the "tagging" and tag-based retrieval of blocks of code, has been shown to have novel and desirable features but this was demonstrated only within the context of the PushGP genetic programming system. Following a suggestion in the GECCO-2010 publication on this technique we show here how tag-based modules can be incorporated into a more standard tree-based genetic programming system. We describe the technique in detail along with some possible extensions, outline arguments for its simplicity and potential power, and present results obtained using the technique on problems for which other modularization techniques have been shown to be useful. The results are mixed; substantial benefits are seen on the lawnmower problem but not on the Boolean even-4-parity problem. We discuss the observed results and directions for future research.

ECOM 5

Room: Assembly E

13:40-14:06 PSO Based on Surrogate Modelling as Meta-Search to Optimise Evolutionary Algorithms Parameters

Ahmed Kattan, Mohammed Arif

The problem of setting suitable parameters for population-based Evolutionary Algorithms (EA) is not new. However, the process of tuning the EA parameters is still challenging, since their sensitivity to the given problem is highly non-linear. This paper proposes a framework that uses Particle Swarm Optimisation (PSO) based on Surrogate Modelling (SM) to optimise population-based EA parameters before they can be applied to solve problems. The proposed framework is comprised of two components; PSO that searches the parameters space and a Radial Basis Function Networks (RBFN)

surrogate model to guide it. The main advantage of our model that it optimises the EA parameters in a way that ensures that EA searches the problem within a limited number of evaluations. Experiments with three different benchmark problems demonstrate that our proposed framework managed to assist a Genetic Algorithm (GA) in order to optimise its parameters and achieves better solutions than the use of Standard PSO without surrogate assistance to optimise the GA parameters, Standard GA that is applied directly to the problem with fixed parameters settings, Standard 1+1 Evolutionary Strategy (ES) applied directly to the problem and simple Random Search.

14:06-14:32 **From Neighbors to Global Neighbors in Collaborative Filtering: an Evolutionary Optimization Approach**

Amine Boumaza, Armelle Brun

The accuracy of recommendations of collaborative filtering based recommender systems mainly depends on which users (the neighbors) are exploited to estimate a user's ratings. We propose a new approach of neighbor selection, which adopts a global point of view. This approach defines a unique set of possible neighbors, shared by all users, referred to as Global Neighbors (GN). We view the problem of defining GN as a combinatorial optimization problem and propose to use an evolutionary algorithm to tackle this search. Our aim is to find a relatively small GN as the size of the resulting model, as well as the complexity of the computation of recommendations highly depend on the size of GN. We present experiments and results on a standard benchmark data-set from the recommender system community that support our choice of the evolutionary approach and show that it leads to a high accuracy of recommendations and a high coverage, while dramatically reducing the size of the model (by 84%). We also show that the evolutionary approach produces results able to generate accurate recommendations to unseen users, while easily allowing the insertion of new users in the system with little overhead.

14:32-14:58 **Local Optima Networks and the Performance of Iterated Local Search**

Fabio Daolio, Marco Tomassini, Gabriela Ochoa, Sebastien Verel

Local Optima Networks (LONs) have been recently proposed as an alternative model of combinatorial fitness landscapes. The model compresses the information given by the whole search space into a smaller mathematical object that is the graph having as vertices the local optima and as edges the possible weighted transitions between them. A new set of metrics can be derived from this model that capture the distribution and connectivity of the local optima in the underlying configuration space. This paper departs from the descriptive analysis of local optima networks, and actively studies the correlation between network features and the performance of a local search heuristic. The NK family of landscapes and the Iterated Local Search metaheuristic are considered. With a statistically-sound approach based on multiple linear regression, it is shown that some LONs' features strongly influence and can even partly predict the performance of a heuristic search algorithm. This study validates the expressive power of LONs as a model of combinatorial fitness landscapes.

GA 5: Applications

Session Chair: Daniel R. Tauritz

Room: Aria AB

13:40-14:06 Efficient Filters for the Simulated Evolution of Small Sorting Networks

Drue Coles

A sorting network is a mathematical model of a sorting algorithm in which all comparisons take place in a fixed order at predetermined positions in the list. It can be realized in hardware as a circuit comprised of simple logic gates called comparators that test the values on two wires and swap them if they are out of order. The search for sorting networks of optimal size is an old problem. Asymptotically optimal networks of size $O(n \log n)$ are known, where n is the number of inputs, but the hidden constants are enormous. Genetic algorithms have been used to search for small sorting networks in a number of studies since the 1990s. We introduce the concept of a filter as a fixed sequence of comparisons to be extended to a sorting network through some kind of stochastic process, and we present a new construction that works for any perfect square number of inputs. In the case of 9 inputs, we extend the filter to a sorting network of size 25, attaining the best known bound. For 16 and 25 inputs, we present a simple genetic algorithm that extends the filter to produce small sorting networks with highly regular structure.

14:06-14:32 Image Segmentation using a Genetic Algorithm and Hierarchical Local Search

Mark Hauschild, Sanjiv Bhatia, Martin Pelikan

This paper proposes a hybrid genetic algorithm to perform image segmentation based on applying the q-state Potts spin glass model to a grayscale image. First, the image is converted to a set of weights for a q-state spin glass and then a steady-state genetic algorithm is used to evolve candidate segmented images until a suitable candidate solution is found. To speed up the convergence to an adequate solution, hierarchical local search is used on each evaluated solution. The results show that the hybrid genetic algorithm with hierarchical local search is able to efficiently perform image segmentation. The necessity of hierarchical search for these types of problems is also clearly demonstrated.

14:32-14:58 A Genetic Algorithm for Designing Ensemble Methods of Neural Networks

Symone Soares, Carlos Antunes, Rui Araújo

Ensemble Methods (EMs) are sets of models that combine their decisions, or their learning algorithms, or different data to obtain good predictions. The motivations are the possibility of improving the generalization capability and the overall system performance. However, several issues are at stake in EM development, such as the design of models that disagree as much as possible on the same data, the selection of some of them and their optimal combination to enhance the robustness of the EM. Since there is no unified procedure to implement these steps, this paper proposes a new methodology for designing EMs of Neural Networks (NNs) using a Genetic Algorithm (GA). Firstly, a set of NNs with high degree of diversity is produced. The aim is to draw a different training dataset for each NN by applying bootstrap. The architecture of the NN is selected by varying the number of hidden neurons, activation functions and initialization of weights. Secondly, a GA is employed to select both the best subset of NNs and the optimal combination strategy for ensuring the accuracy and the robustness of the EM. Experiments on well-known datasets are reported to evaluate the effectiveness of the proposed methodology.

RWA 8

Session Chair: Brian J. Ross

Room: Ormandy West

13:40-14:06 **GENOM-POF: Multi-Objective Evolutionary Synthesis of Analog ICs with Corners Validation**

Nuno Lourenço, Nuno Horta

In this paper, a multi-objective design methodology for automatic analog IC synthesis is presented that takes into account the effects of process variations. By varying the technological and environmental parameters, the robustness of the solutions is enhanced. The automatic analog IC sizing tool GENOM-POF was implemented and used to demonstrate the methodology, and to verify the effects of corner cases on the Pareto optimal front (POF). The influences of the NSGA-II parameters when it is applied to analog circuit sizing were investigated, and three different design strategies were tested in a benchmark circuit, showing the effectiveness of multi-objective design of analog cells.

14:06-14:32 **tk-SA: Accelerated Simulated Annealing Algorithm for Application Mapping on Networks-on-Chip**

Bo Yang, Liang Guang, Tero Säntti, Juha Plosila

Simulated Annealing (SA) algorithm is a promising method for solving combinatorial optimization problems. The only limitation of applying the SA algorithm to application mapping problem on many-core networks-on-chip (NoCs) is its low speed. To alleviate this limitation, an accelerated SA algorithm called tk-SA algorithm is proposed in this work. The tk-SA algorithm starts the annealing process from a lower initial temperature t_k with an optimized initial mapping solution. Based on the analysis of the typical behavior of the general SA algorithm, an efficient method is proposed for determining the temperature t_k . Quantitative evaluations verify that the method is capable of obtaining an appropriate t_k such that the tk-SA algorithm can reproduce the behavior of the full-range SA from temperature t_k . Experimental results show that compared with a parameter-optimized SA algorithm, the proposed tk-SA algorithm achieves an average speedup of 1.55 without loss of solution quality.

14:32-14:58 **Evolutionary Approaches to the Generation of Optimal Error Correcting Codes**

Daniel McCarney, Sheridan Houghten, Brian Ross

Error-correcting codes allow for reliable transmission of data over mediums subject to interference. They guarantee detection and recovery from a level of transmission corruption. Larger error-correcting codes increase the maximum sizes of messages transmittable, which improves communication efficiency. However, discovering optimal error-correcting codes for different code specifications is equivalent to the NP-Hard problem of determining maximum cliques of a graph. In this research, three different binary error correcting code problems are considered. Both genetic algorithm and genetic programming are examined for generating optimal error correcting codes for these problems. A new chromosome representation of the GA system is examined, which shows some benefits in certain conditions. The use of GP is novel in this problem domain, and in combination with the Baldwin effect, it is shown to be a promising new approach for code discovery.

ACO 4**Session Chair: Jose Garcia-Nieto****Room: Assembly F**

13:40-14:06 Might There Be a Computational Advantage to Representing Evaporation Rate in Ant Colony Optimization as a Gaussian Random Variable?*Ashraf Abdelbar*

We propose an ACO (Ant Colony Optimization) variation in which the evaporation rate, instead of being constant as is common in standard ACO algorithms, is a Gaussian random variable with non-negligible variance. In experimental results in the context of MAX-MIN Ant System (MMAS) and the Traveling Salesman Problem (TSP), we find that our variation performs considerably better than MMAS when the number of iterations is small, and that its performance is slightly better than MMAS when the number of iterations is large.

14:06-14:32 Multi-Objective Particle Swarm Optimisation (PSO) for Feature Selection*Bing Xue, Mengjie Zhang, Will N. Browne*

Feature selection (FS) is an important data preprocessing technique, which has two goals of minimising the classification error and minimising the number of features. However, not much work has been conducted on solving FS as a multi-objective problem. Based on particle swarm optimisation (PSO), this paper proposes two multi-objective algorithms for selecting the Pareto front of non-dominated solutions (feature subsets). The first algorithm introduces the idea of non-dominated sorting based multi-objective genetic algorithm II into PSO for FS. In the second algorithm, multi-objective PSO uses the ideas of crowding, mutation and dominance to search for the Pareto front solutions. The two algorithms are compared with two single objective FS methods and a conventional FS method on nine datasets. Experimental results show that both proposed algorithms can automatically evolve a smaller number of features and achieve better classification performance than using all features and feature subsets obtained from the two single objective methods and the conventional method. Both the continuous and the binary versions of PSO are investigated in the two proposed algorithms and the results show that continuous version generally achieves better performance than the binary version. The second new algorithm outperforms the first algorithm in both continuous and binary versions.

14:32-14:58 A Study of Different Quality Evaluation Functions in the cAnt-Miner PB Classification Algorithm*Matthew Medland, Fernando Otero*

Ant colony optimization (ACO) algorithms for classification in general employ a sequential covering strategy to create a list of classification rules. A key component in this strategy is the selection of the rule quality function, since the algorithm aims at creating one rule at a time using an ACO-based procedure to search the best rule. Recently, an improved strategy has been proposed in the cAnt-MinerPB algorithm, where an ACO-based procedure is used to create a complete list of rules instead of individual rules. In the cAnt-MinerPB algorithm the rule quality function has a smaller role and the search is guided by the quality of a list of rules. This paper sets out to determine the effect of different rule and list quality functions in term of both predictive accuracy and size of the discovered model in cAnt-MinerPB. The comparative analysis is performed using 12 data sets from the UCI Machine Learning repository and shows that the effect of the rule quality functions in cAnt-MinerPB is different from the results previously presented in the literature.

Differential Evolution Algorithm with PCA-based Crossover

Yuan-Long Li, Jun Zhang

Enhance Differential Evolution with Random Walk

Zhi-Hui Zhan

Adaptive Genetic Algorithm Based on Density Distribution of Population

Ni Chen, Jun Zhang, Ou Liu

Naive and Heuristic Permutation-Coded Genetic Algorithms for the Quadratic Knapsack Problem

Bryant A. Julstrom

An Evolutionary Approach to Define Investment Strategies based on Macroeconomic Indicators and VIX Data

Oleksandr Yefimochkin, Rui Neves, Nuno Horta

Co-Evolution of the Dynamics in Population Games: the Case of Traffic Flow Assignment

Ana L. C. Bazzan

Full Model Selection in the Space of Data Mining Operators

Quan Sun, Bernhard Pfahringer, Michael Mayo

Clans and Cooperation in the Iterated Prisoner's Dilemma

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New Evolutionary Approaches to High-Dimensional Data

Luis Matoso, Felipe Junior, Adriano Pereira, Adriano Veloso, Wagner Meira Jr.

Multiobjective Optimization for Project Portfolio Selection

Marcio de Oliveira Barros, Hélio Rodrigues Costa, Fábio Vitorino Figueiredo, Ana Regina Cavalcanti da Rocha

Automated Passive Filter Design Using Multi-objective Genetic Algorithms with Variable Parameters

José Pinto, Nuno Horta

Comparing the Robustness of Grammatical Genetic Programming Solutions for Femtocell Algorithms

Erik Hemberg, Lester Ho, Michael O'Neill, Holger Claussen

A Spatial Random-Meaningful Neighbourhood Topology in PSO for Edge Detection in Noisy Images

Mahdi Setayesh, Mengjie Zhang, Mark Johnston

Genetic Programming for Edge Detection Based on Figure of Merit

Wenlong Fu, Mark Johnston, Mengjie Zhang

Gene Regulatory Network Reverse Engineering using Population Based Incremental Learning and K-means

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Optimization of Technical Indicators in real time with Multiobjective Evolutionary Algorithms

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Improving the Performance of MAX-MIN Ant System on the TSP Using Stubborn Ants

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An Efficient GPU Implementation of a Multi-Start TSP Solver for Large Problem Instances

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Continuous Space Pattern Reduction for Genetic Clustering Algorithm

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Affective Content Based Music Video Paring System Using Real Coded GA

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Growing and Evolving Soft Robots with a Face-Encoding Tetrahedral Grammar

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Matt Ryerkerk, Ron Averill, Kalyanmoy Deb, Erik Goodman

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