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

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

2011

July 12-16, 2011
Dublin, Ireland

A recombination of the 20th International Conference on Genetic Algorithms (ICGA) and the 16th Annual Genetic Programming Conference (GP)

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GECCO is sponsored by the Association for Computing Machinery Special Interest Group on Genetic and Evolutionary Computation (SIGEVO). SIG Services: 2 Penn Plaza, Suite 701, New York, NY, 10121, USA, 1-800-342-6626 (USA and Canada) or +212-626-0500

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Welcome to GECCO-2011!

I am very glad and honored to welcome you to GECCO-2011 and to Dublin, the charming capital of Ireland. This year we have a rather rich conference program. GECCO-2011 received the largest number of submissions ever (686) of which 261 (or the 38%) have been accepted as full papers for oral presentation. In addition, the program includes 137 poster presentations, 12 workshops (with more than 90 presentations), 31 free tutorials, two keynotes, by Steen Rasmussen and Rebecca Schulman, and four special events: (i) the "Humies" Awards; (ii) the Evolutionary Computation in Practice (ECP) track, with five sessions; (iii) the GECCO Industrial Challenge; and (iv) five GECCO competitions.

Since "all work and no fun makes Jack a dull boy", GECCO-2011 also offers a rich program of social events including the traditional opening reception with a little surprise, the social event at the Guinness Storehouse offering a 360 degrees view of Dublin by night, the GDS pub night, and a cake-and-coffee event at the end of the conference.

Being the general chair of GECCO represents for me a once-in-a-lifetime opportunity and also a great challenge to match the exceptional work done by all the former chairs. However, it is easy to do this job with a team so motivated and so focused as the one I had the privilege to work with. Everybody in the GECCO-2011 organization went the extra mile to make this conference special and I am sure you will feel it as soon as you enter the conference hall.

The local organizers, Michael O'Neill, Anthony Brabazon, and Irene Ward did an exceptional job providing all the support that organizing GECCO entails. They found the best hotel deal to host the conference and the best place for the social event (you will love the Guinness Storehouse, believe me); they also obtained substantial sponsorships to support part of the conference costs, designed the conference mug, kept the contacts with all the suppliers for poster boards, buses, printers, etc. You name it, they did it!

The editor in chief, Natalio Krasnogor, and the 34 track chairs have been the guardians of the conference scientific quality; they did a tremendous work organizing the double blind review process and selecting the papers accepted for oral presentation, for poster presentation, and the best paper nominees. Furthermore, they helped me crosschecking the conference schedule, the proceedings and this volume, over and over until exhaustion.

The publicity chair, Xavier Llorà, worked with our webmaster, Gerardo Valencia, to spread the news about GECCO-2011 as much as possible through the website, Twitter, Google Wave, Buzz, and every possible mailing list available. The record number of submissions is also due to their hard work and commitment. The workshop chairs, Jaume Bacardit and Ivan Tanev, worked with all the workshop organizers to ensure that everything was right on schedule. Christian Blum and Miguel Nicolau worked their magic with two very special GECCO events, the Graduate Student Workshop and the Late-Breaking Abstract Workshop. The tutorial chair, Darrell Whitley, had the not easy task to select the tutorials, coordinate the speakers and, in his role of SIGEVO chair, provided me with guidance and good advices. Martin V. Butz, the competition chair, worked hard to provide GECCO with a rich program of scientific competitions. Finally, Joern Mehnen, Thomas Bartz-Beielstein, David Davis have been great in bringing high calibre speakers from several industry areas to GECCO, making the ECP track a magical place where academia and industry can meet.

I would have not been able to complete the proceedings nor this volume without Mark Montague from Linklings and Lisa Tolles from Sheridan Printing. Mark worked wonders to support the editor-in-chief and the track chairs during the review process. Then, he helped me during all the next steps making the scheduling of all the sessions, the editing of the proceedings, and this volume possible. Lisa walked me all the way through the editing of the proceedings. If you were able to register and you are now wearing a badge, you should thank Jill Skuba from ExecutiveEvents, who provided the support for everything related to registrations. The ACM team has provided invaluable support during this entire journey. I wish to thank Adrienne Griscti, Ann Lane, April Mosqus, Darren Ramdin, Donna Cappo, Irene Frawley, Julie Goetz, Maritza Nichols, and Stephanie Sabal.

I also wish to give my best wishes to Margaret Boden, our third keynote, who will not be able to come to Dublin. Dear Margaret, I hope that everything will resolve well and I look forward to meeting you sometime soon.

At the end, I wish to thank **you**. Whoever you are, an author, a presenter, a track chair, a reviewer, a keynote speaker, a session chair, a workshop organizer, a volunteer, or an attendee, you are GECCO, we are all here because of you and thank to you.

Pier Luca Lanzi, GECCO-2011 Conference Chair

GECCO 2011 delegates, welcome to Dublin, Ireland!

We are delighted to extend *Céad Mile Fáilte* (one hundred thousand welcomes!) to all GECCO 2011 delegates, and we hope you enjoy your stay with us in the Emerald Isle.

By now you should be familiar with the GECCO hotel, the Burlington. We would like to thank the Burlington team, in particular Ciara, Vicki and Mark for their patience and support in the preparation leading up to, and during GECCO.

In addition to the opening reception (with posters included) at the Burlington on Wednesday evening, we have also arranged a very special social event at one of Ireland's most popular tourist destinations, the Guinness Storehouse. We hope you enjoy the light entertainment, food & drink, and especially the 360^{o} panoramic views of Dublin afforded by the spectacular Gravity Bar. The Storehouse team have also agreed to leave the Guinness Store open for the start of the event should delegates wish to purchase those last minute souvenirs and gifts.

GECCO 2011 would not have been possible without the support, time, patience, dedication and enthusiasm of a large number of people. In particular, we are delighted to highlight the significant financial support, which we won through a competitive funding call from Science Foundation Ireland (SFI), which has significantly offset the overhead associated with moving GECCO from its traditional North American home. Fáilte Ireland also provided financial support, which has offset part of the cost of the social event at the Guinness Storehouse, and in the preparations and marketing leading up to GECCO 2011. We thank the SFI-funded Financial Mathematics & Computation Cluster (http://www.fmc-cluster.org) for generously giving up a part of Irene's time over the past year to focus on GECCO local arrangements. Put simply, Irene is GECCO 2011!

We are also grateful for the support of our host institution University College Dublin (UCD), especially our respective Heads and Deans of Schools (Prof Joe Carthy and Prof Tom Begley) for their understanding with the added demands on our time, the UCD Complex & Adaptive Systems Lab (Prof David Coker and Barry Hogan), UCD's President Dr Hugh Brady and UCD's VP for Research Prof Des Fitzgerald each for their continued support, encouragement and enthusiasm.

It goes without saying GECCO 2011 could not have happened without the extended GECCO family, in particular, Pier Luca, Wolfgang Banzhaf, Una-May O'Reilly and Darrell Whitley all deserve special recognition for their dedication to the event.

Most especially we extend a very special thank you to all members of the UCD Natural Computing Research & Applications Group (http://ncra.ucd.ie) for their never-ending enthusiasm, support and patience over the past year, and for volunteering their time to help with the local organisation before and during GECCO. On many occasions meetings spontaneously rescheduled themselves as the demands of local organisation beckoned our immediate attention. We are truly privileged to be working with such an amazing team.

Should you have any questions during your time with us, please don't hesitate to ask any one of your local organising team.

Your Local Organising team,

Michael O'Neill, Anthony Brabazon & Irene Ward
Natural Computing Research & Applications Group
University College Dublin

Instructions for Session Chairs and Paper Presenters

Instructions for Session Chairs

First of all, thank you for your participation and cooperation! Session chairs are essential to keep sessions on schedule and moderate question periods. If a session is without a chair, we ask the last scheduled speaker to perform those duties.

- Arrive a few minutes early to check on room and equipment setup
- Please let conference organizers at the Registration Desk know immediately if problems arise or adjustments are needed
- Keep the session on schedule
- Please adhere to 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 early, as participants may be moving between sessions/presentations
- Introduce each speaker
- **Each presentation has a 25 minutes slot including setup and question time: 20 minutes for setup and presentation, followed by 5 minutes for questions**
- Moderate questions

Instructions for Paper Presenters

Thank you for your participation and cooperation. There would be no GECCO without you!

- GECCO provides an LCD projector in each meeting room
- Presenters must bring their own laptop, or arrange to use a laptop for their presentation
- **Each presentation has a 25 minutes slot including setup and question time: 20 minutes for set up and presentation, followed by 5 minutes for questions**
- If a session is without a chair, we ask the last scheduled speaker to perform those duties
- If you have to perform the chair duties, please adhere to the session chair instructions above

Track List

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

Tuesday July 12 – Tutorials and Workshops

8:00 – 12:30 14:00 – 15:50	Registration desk

Room	8:30-10:20	10:40-12:30	14:00-15:50	16:10-18:00
Lansdowne	Genetic Algorithms (tut01)	Genetic Programming (tut02)	Evolutionary Computation WITH GPUs (tut16)	Representations for evolutionary algorithms (tut18)
Pembroke	Evolutionary Game Theory (tut30)	Evolution Strategies (tut03)	Evolution Strategies and CM Adaptation (tut08)	Probabilistic Model-building Genetic Algorithms (tut05)
Ulster	**MEDGEC (1)**	**MEDGEC (2)**	**ECDGA (1)**	**ECDGA (2)**
Munster	**GREENIT (1)**	**BIS-WSN (1)**	Learning Classifier Systems (tut06)	Large scale data mining using Genetics-Based Machine Learning (tut22)
Leinster	Ant Colony Optimization (tut07)	Synthetic Biology (tut17)	Geometry of Evolutionary Algorithms (tut29)	Genetic Algorithms Theory (tut11)
Connaught 1	**GSW (1)**	**GSW (2)**	**GSW (3)**	**GSW (4)**
Connaught 2	**LBAW (1)**	**LBAW (2)**	**LBAW (3)**	**LBAW (4)**
Elgin	Evolution of Digital Circuits (tut25)	Evolving Quantum Computer Algorithms (tut13)	Handling Bloat in GP (tut31)	Cartesian GP (tut21)

Tutorials

Workshops

Wednesday July 13 – Tutorials and Workshops

8:00 – 12:30 14:00 – 15:50	Registration desk

Room	8:30-10:20	10:40-12:30	14:00-15:50	16:10-18:00
Lansdowne	Evolutionary Neural Networks (tut10)	Evolutionary Multiobjective Optimization (tut14)	Foundations of Evolutionary Multi-Objective Optimization (tut19)	Evolutionary Computation: A unified view (tut04)
Pembroke	Statistical Analysis for Evolutionary Computation: Introduction (tut09)	Automatic and Interactive Tuning of Algorithms (tut26)	setup for the poster session and reception	
Ulster	**VIZGEC (1)**	**VIZGEC (2)**	**ECOMASS (1)**	**ECOMASS (2)**
Munster	**SRAMW (1)**	**SRAMW (2)**	**OBUPM (1)**	**OBUPM (2)**
Leinster	Computational Complexity and EC (tut12)	Theory of Randomized Search Heuristics (tut20)	Theory of Swarm Intelligence (tut27)	Drift Analysis (tut23)
Connaught 1	**CIGPU (1)**	**CIGPU (2)**	**CIGPU (3)**	**CIGPU (4)**
Connaught 2	**IWLCS (1)**	**IWLCS (2)**	**IWLCS (3)**	**IWLCS (4)**
Elgin	**SBLPA (1)**	Constraint-Handling Techniques used with Evolutionary Algorithms (tut15)	**ECT-CH (1)**	**ECT-CH (2)**
O'Connell			Automated Heuristic Design (tut24)	Algorithm and Experiment Design with HeuristicLab (tut28)

19:00-22:00	Poster Session and Welcome Reception

Tutorials

Workshops

Thursday July 14 – Paper Presentations

8:30 – 12:20 14:40 – 16:20	Registration desk

Room	8:30-9:00	9:00-10:20	10:40-12:20	14:40-16:20	16:50-18:55
Lansdowne	Conference Opening	Keynote	GA1	GA2	EDA1
Pembroke		Steen Rasmussen	GP1	GP2	GDS1
Ulster			ESEP1	GA3	PS1
Munster			EMO1	DETA1	EMO2
Leinster			SS1	ECP2	THEORY1 Best Papers
Connaught 1			ACO-SI1	ACO-SI2	BIO1
Connaught 2			RWA1	RWA2	RWA3
Elgin			ECOM1	ALIFE1	ECOM2
O'Connell			SBSE1	SBSE2	GBML1
Clanwilliam			ECP1		

12:20-14:40	2011 "Humies" Awards (Lansdowne)

Friday July 15 – Paper Presentations

8:30 – 12:20	Registration desk

Room	8:50-9:00	9:00-10:20	10:40-12:20	14:40-16:20	16:50-18:30
Lansdowne	Day Opening	Keynote Rebecca Schulman	GA4 Best Papers	EDA2 Best Papers	GA7
Pembroke			GP3	GDS2 Best Papers	GP4 Best Papers
Ulster			GA5	GA6	ESEP2 Best Papers
Munster			EMO3	EMO4 Best Papers	DETA2 Best Papers
Leinster			SS2	ECP4	SS3 Best Papers
Connaught 1			BIO2 Best Papers	ACO-SI3	ACO-SI4 Best Papers
Connaught 2			RWA4	RWA5	RWA6 Best Papers
Elgin			ALIFE2	ECOM3 Best Papers	ALIFE3 Best Papers
O'Connell			GBML2	GBML3 Best Papers	SBSE3 Best Papers
Clanwilliam			ECP3		

12:20-14:40	GECCO Competitions Finalist Presentations (Lansdowne)
13:40-14:40	Industrial Challenge Presentations (Pembroke)

19:00-22:00	Social Event at Guinness Storehouse

22:00-?	GDS Pub Night (all the attendees are welcome!) Location: TBD - Ask Jeff Clune or Greg Hornby

Saturday July 16 – Paper Presentations

8:30 – 12:20	Registration desk

Room	8:30-10:20	10:40-12:20	14:40-16:20
Lansdowne	SIGEVO Meeting	GA8	GA9
Pembroke		GP5	GP6
Ulster		PS2	ESEP3
Munster		EMO5	EMO6
Leinster		THEORY2	DETA3
Connaught 1		ACO-SI5	GA10
Connaught 2		ECP5	RWA7
Elgin		ECOM4	ALIFE4

Paper Presentations by Track

ACO Ant Colony Optimization and Swarm Intelligence

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Connaught 1	ACO-SI1: Ant Colony Optimization and Swarm Intelligence (Session 1)	Mohammad Majid al-Rifiae
July 14	2:40PM - 4:20PM	Connaught 1	ACO-SI2: Ant Colony Optimization and Swarm Intelligence (Session 2)	Stephen Y. Chen
July 15	2:40PM - 4:20PM	Connaught 1	ACO-SI3: Ant Colony Optimization and Swarm Intelligence (Session 3)	Mohammed El-Abd
July 15	4:50PM - 6:30PM	Connaught 1	ACO-SI4: Ant Colony Optimization and Swarm Intelligence (Best Paper Nominees)	Dalila Martins Fontes
July 16	10:40AM - 12:20PM	Connaught 1	ACO-SI5: Ant Colony Optimization and Swarm Intelligence (Session 5)	Dhananjay Thiruvady

ALIFE Artificial Life/Robotics/Evolvable Hardware

Day	Time	Room	Session Title	Session Chair
July 14	2:40PM - 4:20PM	Elgin	ALIFE1: Robotics	Giovanni Squillero
July 15	10:40AM - 12:20PM	Elgin	ALIFE2: Digital Organisms	Giovanni Squillero
July 15	4:50PM - 6:30PM	Elgin	ALIFE3: Best Paper Nominees	Giovanni Squillero
July 16	2:40PM - 4:20PM	Elgin	ALIFE4: Theory	Giovanni Squillero

BIO Bioinformatics, Computational, Systems, and Synthetic Biology

Day	Time	Room	Session Title	Session Chair
July 14	4:50PM - 6:55PM	Connaught 1	BIO1: Bioinformatics, Computational, Systems, and Synthetic Biology (Session 1)	William Bush
July 15	10:40AM - 12:20PM	Connaught 1	BIO2: Bioinformatics, Computational, Systems, and Synthetic Biology (Best Paper Nominees)	Alex A. Freitas

DETA Digital Entertainment Technologies and Arts

Day	Time	Room	Session Title	Session Chair
July 14	2:40PM - 4:20PM	Munster	DETA1: Games	Mike Preuss
July 15	4:50PM - 6:30PM	Munster	DETA2: Best Paper Nominees	Risto Miikkulainen
July 16	2:40PM - 4:20PM	Leinster	DETA3: Music and Arts	Christian Gagné

ECOM Evolutionary Combinatorial Optimization and Metaheuristics

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Elgin	ECOM1: Scheduling, Timetabling, and Constraint Satisfaction	Dan Qaurooni
July 14	4:50PM - 6:55PM	Elgin	ECOM2: Graph and Knapsack Problems	Ruben Ruiz-Torrubiano
July 15	2:40PM - 4:20PM	Elgin	ECOM3: Best Paper Nominees	Petrica Pop
July 16	10:40AM - 12:20PM	Elgin	ECOM4: New Algorithmic Strategies	Shu Liu

ECP Evolutionary Computation in Practice

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Clanwilliam	ECP1 - Ask the Experts: EC questions from the audience	Jorn Mehnen
July 14	2:40PM - 4:20PM	Leinster	ECP2 - Managing an EC project for success	David Davis
July 15	10:40AM - 12:20PM	Clanwilliam	ECP3 - EC in Design and Optimization	Jorn Mehnen
July 15	2:40PM - 4:20PM	Leinster	ECP4 - EC in Statistics and EA consultancy	Thomas Bartz-Beielstein
July 16	10:40AM - 12:20PM	Connaught 2	ECP5 - Getting a Job: What to do and what not to do	Jorn Mehnen

EDA Estimation of Distribution Algorithms

Day	Time	Room	Session Title	Session Chair
July 14	4:50PM - 6:55PM	Lansdowne	EDA1: Estimation of Distribution Algorithms (Session 1)	Peter A.N. Bosman
July 15	2:40PM - 4:20PM	Lansdowne	EDA2: Best Paper Nominees	John McCall

EMO Evolutionary Multiobjective Optimization

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Munster	EMO1: Diversity and Algorithmic Developments	Evan J. Hughes
July 14	4:50PM - 6:55PM	Munster	EMO2: Applications I	Irina Harris
July 15	10:40AM - 12:20PM	Munster	EMO3: Decision Making and Visualization	Carlos A. Coello Coello
July 15	2:40PM - 4:20PM	Munster	EMO4: Best Paper Nominees	Oliver Schuetze
July 16	10:40AM - 12:20PM	Munster	EMO5: Applications II & Theory	Boris Naujoks

ESEP Evolution Strategies and Evolutionary Programming

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Ulster	ESEP1: Evolution Strategies and Evolutionary Programming (Session 1)	Dirk V. Arnold
July 15	4:50PM - 6:30PM	Ulster	ESEP2: Evolution Strategies and Evolutionary Programming (Best Paper Nominees)	Steffen Finck
July 16	2:40PM - 4:20PM	Ulster	ESEP3: Evolution Strategies and Evolutionary Programming (Session 3)	Nikolaus Hansen

GA Genetic Algorithms

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Lansdowne	GA1: Adaptation	A.E. Eiben
July 14	2:40PM - 4:20PM	Lansdowne	GA2: Applications	Evert Haasdijk
July 14	2:40PM - 4:20PM	Ulster	GA3: Philosophy/Theory	Thomas Jansen
July 15	10:40AM - 12:20PM	Lansdowne	GA4: Linkage (Best Paper Nominees)	Jim Smith
July 15	10:40AM - 12:20PM	Ulster	GA5: Representations	Franz Rothlauf
July 15	2:40PM - 4:20PM	Ulster	GA6: Niching & Speciation	Maribel Garcia Arenas
July 15	4:50PM - 6:30PM	Lansdowne	GA7: Differential Evolution	Nasimul Noman
July 16	10:40AM - 12:20PM	Lansdowne	GA8: Co-evolution	Kenneth De Jong
July 16	2:40PM - 4:20PM	Lansdowne	GA9: Selection	David Corne
July 16	2:40PM - 4:20PM	Connaught 1	GA10: Optimization	Antonio M. Campoy

GBML Genetics-Based Machine Learning

Day	Time	Room	Session Title	Session Chair
July 14	4:50PM - 6:55PM	O'Connell	GBML1: Genetics Based Machine Learning (Session 1)	Martin Butz
July 15	10:40AM - 12:20PM	O'Connell	GBML2: Genetics Based Machine Learning (Session 2)	Jaume Bacardit
July 15	2:40PM - 4:20PM	O'Connell	GBML3: Genetics Based Machine Learning (Best Paper Nominees)	Will Neil Browne

GDS Generative and Developmental Systems

Day	Time	Room	Session Title	Session Chair
July 14	4:50PM - 6:55PM	Pembroke	GDS1: Generative and Developmental Systems (Session 1)	Jeff Clune
July 15	2:40PM - 4:20PM	Pembroke	GDS2: Generative and Developmental Systems (Best Paper Nominees)	Gregory S. Hornby

GP Genetic Programming

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Pembroke	GP1: Optimisation and Selection	Raja Muhammad Atif Azad
July 14	2:40PM - 4:20PM	Pembroke	GP2: Classification	Leonardo Trujillo
July 15	10:40AM - 12:20PM	Pembroke	GP3: Representations	Anthony Brabazon
July 15	4:50PM - 6:30PM	Pembroke	GP4: Best Paper Nominees and Modularity	Lee Spector
July 16	10:40AM - 12:20PM	Pembroke	GP5: Applications	Peter Alexander Whigham
July 16	2:40PM - 4:20PM	Pembroke	GP6: Difficulty	Leonardo Vanneschi

PS Parallel Evolutionary Systems

Day	Time	Room	Session Title	Session Chair
July 14	4:50PM - 6:55PM	Ulster	PS1: Parallel Evolutionary Systems (Session 1)	Pierre Collet
July 16	10:40AM - 12:20PM	Ulster	PS2: Parallel Evolutionary Systems (Session 2)	Man Leung Wong

RWA Real World Application

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Connaught 2	RWA1: Networks	Zorana Bankovic
July 14	2:40PM - 4:20PM	Connaught 2	RWA2: Finance & Linear Genetic Programming	
July 14	4:50PM - 6:55PM	Connaught 2	RWA3: Algorithms	Andrea G. B. Tettamanzi
July 15	10:40AM - 12:20PM	Connaught 2	RWA4: Optimization	Martin Lukasiewycz
July 15	2:40PM - 4:20PM	Connaught 2	RWA5: Human Behavior & Evolutionary Strategies	Thomas Baeck
July 15	4:50PM - 6:30PM	Connaught 2	RWA6: Differential Evolution & Evolutionary Strategies	Steven Gustafson
July 16	10:40AM - 12:20PM	Connaught 2	RWA7: Multiobjective	Rituparna Datta

SBSE Search-Based Software Engineering

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	O'Connell	SBSE1: Search-Based Software Engineering (Session 1)	Simon Poulding
July 14	2:40PM - 4:20PM	O'Connell	SBSE2: Search-Based Software Engineering (Session 2)	Shin Yoo
July 15	4:50PM - 6:30PM	O'Connell	SBSE3: Search-Based Software Engineering (Best Paper Nominees)	Moshe Sipper

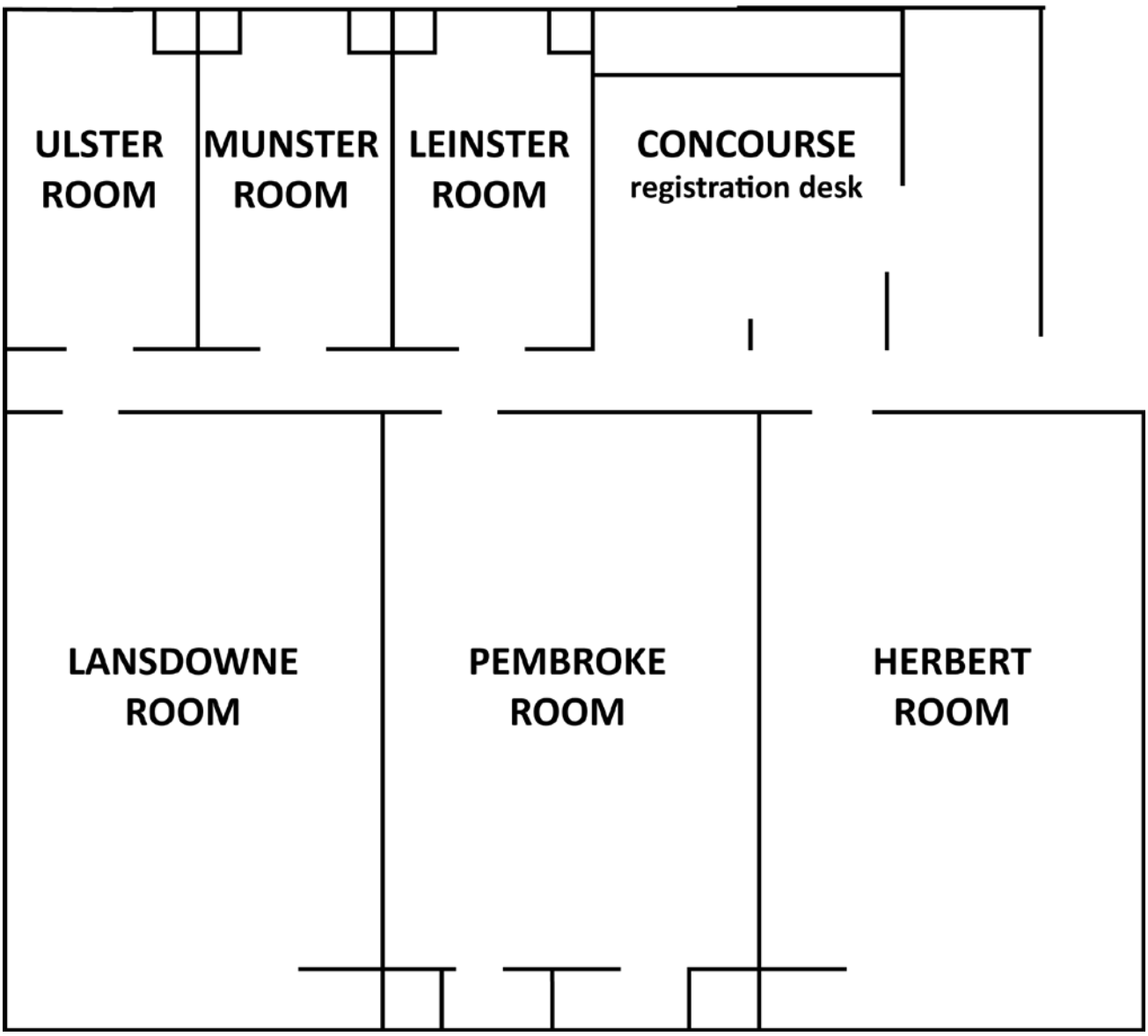
SS Self-* Search

Day	Time	Room	Session Title	Session Chair
July 14	10:40AM - 12:20PM	Leinster	SS1: Self-* Search (Session 1)	Sebastien Verel
July 15	10:40AM - 12:20PM	Leinster	SS2: Self-* Search (Session 2)	Andrew J. Parkes
July 15	4:50PM - 6:30PM	Leinster	SS3: Self-* Search (Best Paper Nominees)	Marc Schoenauer

THEORY Formal Theory

Day	Time	Room	Session Title	Session Chair
July 14	4:50PM - 6:55PM	Leinster	THEORY1: Best Paper Nominees	Per Kristian Lehre
July 16	10:40AM - 12:20PM	Leinster	THEORY2: Runtime Analysis	Carola Winzen

Conference Floorplan: First Level



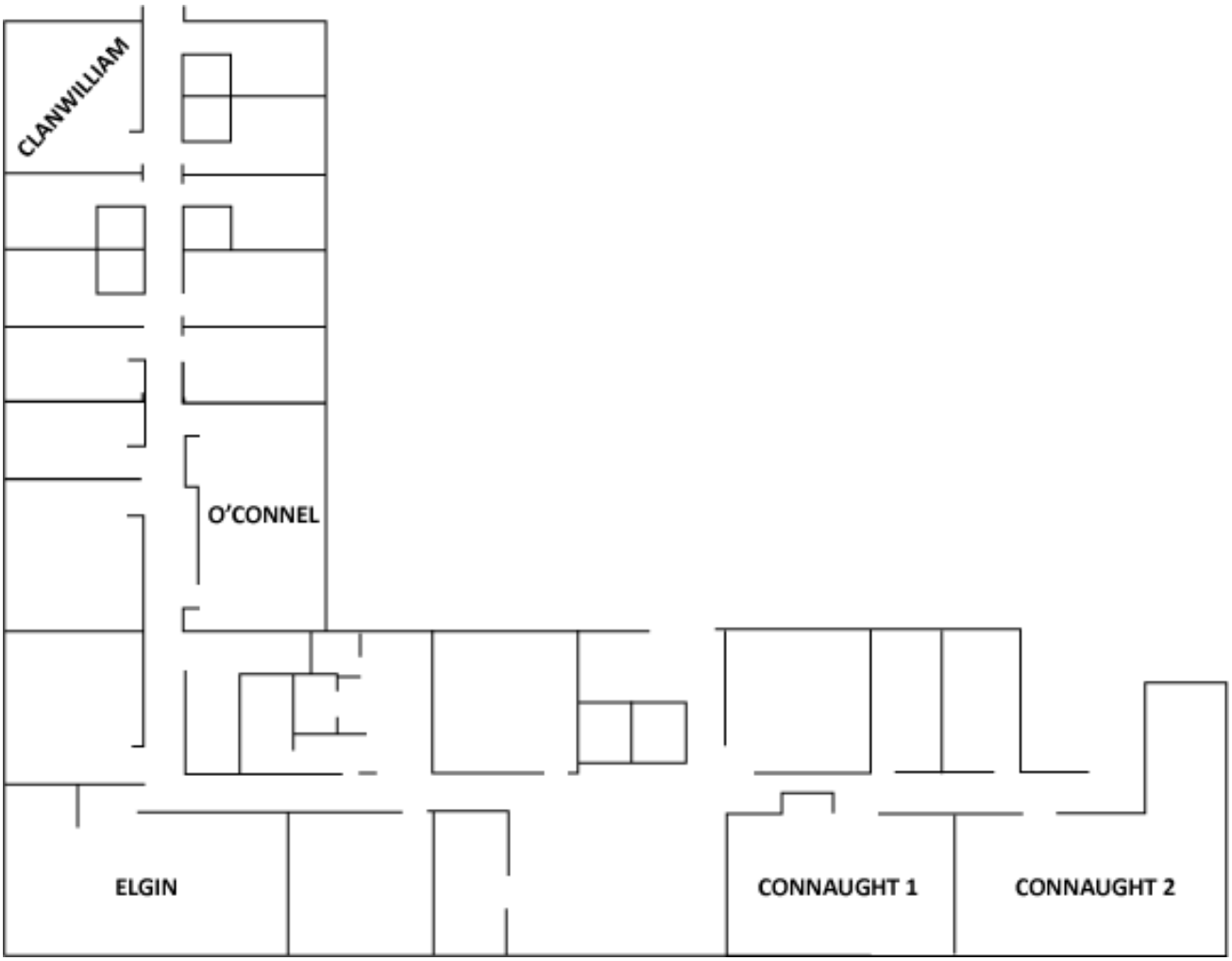
Registration Desk: Concourse
Open Hours

Tuesday:	8:00 – 12:30 and 14:00 – 15:50
Wednesday:	8:00 – 12:30 and 14:00 – 15:50
Thursday:	8:30 – 12:20 and 14:40 – 16:20
Friday:	8:30 – 12:20
Saturday:	8:30 – 12:20

Coffee Breaks: Concourse & Herbert room

Opening Reception and Posters, Wednesday, July 13, 19:30 – 22:00, Pembroke, Herbert Room & Concourse.

Conference Floorplan: Second Level



GECCO-2011 Conference Organizers

Conference Chair:	**Pier Luca Lanzi** *(Politecnico di Milano, Italy)*
Editor-in-Chief:	**Natalio Krasnogor** *(University of Nottingham, UK)*
Business Committee:	**Wolfgang Banzhaf** *(Memorial University of Newfoundland, Canada)* **Una-May O'Reilly** *(MIT, USA)*
Publicity Chair:	**Xavier Llorà** *(Google Inc., USA)*
Local Chair	**Michael O´Neill** *(University College Dublin, Ireland)* **Anthony Brabazon** *(University College Dublin, Ireland)*
Tutorials Chair:	**Darrell Whitley** *(Colorado State University, USA)*
Workshops Chair:	**Jaume Bacardit** *(University of Nottingham, UK)* **Ivan Tanev** *(Doshisha University, Japan)*
Late Breaking Papers Chair:	**Christian Blum** *(Universitat Politècnica de Catalunya, Barcelona, Spain)*
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Ferrante Neri, *University of Jyväskylä*
Frank Neumann, *University of Adelaide*
Hoai Nguyen Xuan, *Hanoi University, Vietnam*
Giuseppe Nicosia, *University of Catania*
Julio Cesar Nievola, *PUCPR*
Yusuke Nojima, *Osaka Prefecture University*
Ann Nowe, *Vrije Universiteit Brussel, Computational Modeling Lab*
Mel Ó Cinnéide, *National University of Ireland, Dublin*
Colm O'Riordan, *NUI, Galway*
Conall O'Sullivan, *University College Dublin, Ireland*
Toby O'Hara, *University of the West of England*
Michael O'Neill, *University College Dublin*
Jiri Ocenasek, *Magwel*
Gabriela Ochoa, *University of Nottingham*
Charles Ofria, *Michigan State University*
Choong Kun Oh, *U.S. Naval Research Laboratory*
Gustavo Olague, *CICESE*
Pedro N. F. P. Oliveira, *University of Minho*
Pietro S. Oliveto, *University of Birmingham*
Mohammed Omran, *Gulf University for Science & Technology*
Michael Orlov, *Ben-Gurion University*
Albert Orriols-Puig, *Google Inc.*
Julio Ortega
Lisa Osadciw, *Syracuse University*
Ender Ozcan, *University of Nottingham*
Norman Packard
Vasile Palade, *Oxford University, UK*
Luis Paquete, *University of Coimbra*
Andrew J Parkes, *University of Nottingham, UK*
Konstantinos Parsopoulos, *University of Ioannina*
Chandana Paul, *Harvard University*
Gerulf K. M. Pedersen, *University of Wuerzburg*
Castillo Pedro, *UGR*
Martin Pelikan, *University of Missouri in St. Louis*
Paola Pellegrini, *IRIDIA-CoDE ULB*
David Pelta, *University of Granada*
Francisco Baptista Pereira, *Instituto Superior de Engenharia de Coimbra, Portugal*
Sanja Petrovic
Jorge Peña, *University of Lausanne*
Jose-Maria Peña
Rolf Pfeifer, *University of Zurich*
Steve Phelps, *University of Essex, UK*
Andrew Philippides, *University of Sussex*
Nelishia Pillay, *University of KwaZulu-Natal*
Sandro Pirkwieser, *Vienna University of Technology*
Daniel Polani, *University of Hertfordshire*
Silvia Poles, *EnginSoft*
Jordan Pollack, *Coevolution*
Petrica Pop, *North University of Baia Mare, Romania*
Elena Popovici, *Icosystem Corp.*
Walter Potter, *University of Georgia*
Simon Poulding, *University of York*
Petr Pošík, *Czech Technical University in Prague*
Steve Prestwich, *University College Cork*
Kenneth Price
Christian Prins, *University of Technology of Troyes*
Adam Prugel-bennett, *University of Southampton*
Jakob Puchinger, *AIT - Austrian Institute of Technology*
Jose Miguel Puerta, *UCLM*
Rong Qu, *University of Nottingham, UK*
Nguyen Quang Huy, *Singapore Institute of Manufacturing Technology*
Günther R. Raidl, *Vienna University of Technology*
Helena Ramalhinho-lourenço, *Universitat Pompeu Fabra*
Rafael Ramirez, *Universitat Pompeu Fabra, Barcelona*
Marcus Christian Randall, *School of Information Technology, Bond University*
Ranji S. Ranjithan, *North Carolina State Univ*
Khaled Rasheed, *University of Georgia*
Steen Rasmussen
Tapabrata Ray, *School of Aerospace, Civil and Mechanical Engineering*
Tom Ray, *University of Oklahoma*
Patrick Michael Reed, *Pennsylvania State University*
David Reif, *U.S. Environmental Protection Agency*
Alan Reynolds
Craig Reynolds, *Sony Computer Entertainment*
Phill Kyu Rhee, *Inha University, Korea*
John Rieffel, *Tufts University*
Sebastian Risi, *University of Central Florida*
Marylyn Ritchie, *Vanderbilt University*
Wille Robert, *University of Bremen*
Denis Robilliard, *Univ Lille-Nord de France*
Luis M. Rocha, *Indiana University*
Daniel Rodriguez, *The University of Alcala*
Daniel Roggen, *ETH Zurich*
Philipp Rohlfshagen, *University of Essex*

Andrea Roli, *Alma Mater Studiorum Universita' di Bologna*
Marc Roper, *University of Strathclyde*
Brian J. Ross, *Brock University*
Peter M. Ross, *Napier University*
Franz Rothlauf, *University of Mainz*
Jonathan Rowe, *University of Birmingham*
Rajkumar Roy, *Cranfield University*
Guenter Rudolph, *TU Dortmund University*
Sarker Ruhul, *University of New South Wales*
Conor Ryan, *University of Limerick*
Ramon Sagarna, *University of the Basque Country*
Erol Sahin
Maria Salamo, *University of Barcelona*
Sancho Salcedo-Sanz, *Universidad de Alcala*
Michael Sampels, *Université Libre de Bruxelles*
Ernesto Sanchez, *Politecnico di Torino*
Luciano Sanchez, *Universidad de Oviedo*
Rian Sanderson, *Carnegie Mellon West*
Roberto Santana, *Universidad Politecnica de Madrid*
Luis Vicente Santana-quintero, *George Mason University*
Iván Santibáñez Koref, *Technical Univ. Berlin*
Kumara Sastry, *Intel Corp*
Hiroyuki Sato, *The University of Electro-Communications*
Yuji Sato, *Hosei University*
Fredéric Saubion, *University of Angers, France*
Hideyuki Sawada, *Kagawa University, Japan*
Daniel Sawitzki, *Nevigo GmbH, Bochum*
Andrea Schaerf, *University of Udine*
Tom Schaul, *IDSIA*
Juergen Schmidhuber, *IDSIA / USI / SUPSI*
Karlheinz Schmitt, *German National Library*
Marc Schoenauer, *INRIA Saclay*
Oliver Schuetze, *CINVESTAV-IPN*
Sonia Schulenburg, *Level E Limited*
Michele Sebag, *Université Paris-Sud*
Giovanni Sebastiani, *Department of Mathematics, Sapienza University of Rome*
Yann Semet
Sandip Sen, *University of Tulsa*
Bernhard Sendhoff, *Honda Research Institute Europe*
Kevin Seppi, *Brigham Young University*
Martin Serpell, *University of the West of England*
Christian Setzkorn, *University of Liverpool,UK*
Marc Sevaux, *Université de Bretagne-Sud - Lab-STICC*
Kamran Shafi, *UNSW@ADFA*
Fatima Shaheen, *Loughborough University*
Siddhartha Shakya, *Business Modelling & Operational Transformation Practice, BT*
Jonathan Lee Shapiro, *University of Manchester*
Yang Shengxiang, *Brunel Unviersity*
David James Sherman, *INRIA, Bordeaux – Sud-Ouest*
Yuhui Shi
Patrick Siarry, *University of Paris-Est Créteil*
Sara Silva, *INESC-ID Lisboa*
Harding Simon
Moshe Sipper, *Ben-Gurion University*
Alexei N. Skurikhin, *Los Alamos National Laboratory*
Will Smart, *Victoria University of Wellington, NZ*
Selmar Smit, *VU University Amsterdam*
Jim Smith, *University of the West of England*
Kate Smith-Miles, *Monash University, Australia*
Christine Solnon, *LIRIS, University of Lyon 1*
Jerffeson Souza, *State University of Ceara*
Lee Spector, *Hampshire College*
Giandomenico Spezzano, *ICAR-CNR*
Giovanni Squillero
Patrick O. Stalph, *University of Würzburg*
Kenneth O. Stanley, *University of Central Florida*
Chris Stephens, *Instituto de Ciencias Nucleares, UNAM*
Adrian Stoica, *NASA-JPL*
Wolfgang Stolzmann, *Daimler AG*
Kasper Stoy, *University of Southern Denmark*
Umberto Straccia, *ISTI-CNR, ITALY*
Thomas Stützle, *Université Libre de Bruxelles*
Tatsuya Suda, *University of California, Irvine*
Dirk Sudholt, *University of Birmingham*
Ponnuthurai Suganthan, *NTU*
Yi Sun, *IDSIA*
Reiji Suzuki
El-ghazali Talbi, *INRIA Futurs*
Keiki Takadama, *UEC*
KC Tan, *NUS*
Ying Tan, *Peking University*
Kiyoshi Tanaka, *Shinshu University*
Ivan Tanev, *Faculty of Engineering, Doshisha University*
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 Marín, *ITESM – CSI*
German Terrazas Angulo, *University of Nottingham*
Andrea G. B. Tettamanzi, *Università degli Studi di Milano*
Christof Teuscher, *Portland State University*
Olivier Teytaud, *TAO, INRIA*
Madeleine Theile, *TU Berlin*
Lothar Thiele, *ETH Zurich*
Dirk Thierens, *Universiteit Utrecht*
Weise Thomas
Adrian Thompson, *University of Sussex*
Christian Thurau, *Fraunhofer-Institut für Intelligente Analyse- und Informationssysteme*
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, *ITU*
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Alexander Topchy, *Nielsen Media Research*
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Gregorio Toscano-pulido, *Cinvestav-Tamaulipas*
Heike Trautmann, *TU Dortmund, Germany*
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Vito Trianni, *ISTC-CNR*
Shigeyoshi Tsutsui, *Hannan University*
Okabe Ttsuya
Elio Tuci, *Aberystwyth University*
Gunnar Tufte, *NTNU*
Cem Celal Tutum, *Technical University of Denmark*
Jamie Twycross, *University of Nottingham*
Andy Tyrrell, *University of York*
Ryan Urbanowicz
Neil Urquhart, *Edinburgh Napier University*
A. Sima Uyar, *Istanbul Technical University*
David Van Veldhuizen, *US Air Force Research Laboratory*
H. Jaap Van Den Herik, *Tilburg University*
Leonardo Vanneschi, *University of Milano-Bicocca*
Igor Vatolkin, *TU Dortmund*
Sebastian Ventura, *Universidad de Cordoba*
Sebastien Verel, *university of Nice Sophia Antipolis*
Alessandro Vespignani
Ekaterina Vladislavleva, *University of Antwerp, Belgium*
Paul Vogt, *Tilburg University*
Tanja Vos, *Universidad Politecnica de Valencia*
Michael N. Vrahatis, *University of Patras*
Markus Wagner, *University of Adelaide*
Naoki Wakamiya, *Osaka University*
James Alfred Walker, *University of York*
Paul Walsh, *Cork Institute of Technology*
Ray Walshe, *Dublin City University*
Jean-paul Watson, *Sandia National Laboratories*
Richard A. Watson, *University of Southampton*
Karsten Weicker, *HTWK Leipzig*
Westley Weimer, *University of Virginia*
Justin Werfel, *Harvard University*
Peter Alexander Whigham, *Univ. of Otago*
Ronald Lyndon While, *The University of Western Australia*
David R. White, *University of York*
Tony White, *Carleton University*
Darrell Whitley, *Colorado State University*
Joerg Wichard, *Institute of Molecular Pharmacology, Berlin*
Paweł Widera, *University of Nottingham*
Paul R. Wiegand, *Institute for Simulation and Training/UCF*
Tiffani L. Williams, *Texas A&M University*
Garnett Wilson, *Memorial University of Newfoundland*
Stewart W. Wilson, *Prediction Dynamics*
Stephan Winkler, *Upper Austria University of Applied Sciences*
Carola Winzen, *Max-Planck-Institut fuer Informatik*
Carsten Witt, *Technical University of Denmark*
M. L. Dennis Wong, *Swinburne University of Technology Sarawak Campus*
Man Leung Wong, *Lingnan University, Hong Kong*
John Woodward, *Nottingham University*
Alden H. Wright, *University of Montana*
Jonathan Wright, *Loughborough University*
Annie S. Wu, *University of Central Florida*
Zheng Yi Wu, *Bentley Systems*
Fatos Xhafa, *Birkbeck, University of London*
Huayang Xie, *Victoria University of Wellington*
Xiao-feng Xie, *HKBU*
Larry Yaeger, *Indiana University*
Takeshi Yamada, *NTT Communication Science Labs.*
Masayuki Yamamura, *Tokyo Institute of Technology, Japan*
Wei Yan, *Department of Computer Science*
Georgios Yannakakis, *IT University of Copenhagen*
Zhang Yanqing, *Georgia State University*
Tian-li Yu, *Taiwan Evolutionary Intelligence Lab*
Tina Yu, *Memorial University*
Yeboon Yun, *Kagawa University*
Daniela Zaharie, *West University of Timisoara*
Saúl Zapotecas Martínez, *CINVESTAV-IPN*
Christine Zarges, *TU Dortmund*
Ricardo Zebulum, *Jet Propulsion Laboratory*
Andreas Zell
Zhu Zexuan
Byoung-tak Zhang, *Seoul National University*
Mengjie Zhang, *Victoria University of Wellington*
Qingfu Zhang, *University of Essex*
Yi Zhang, *IESD, De Montfort Univeristy*
Yuanyuan Zhang, *King's College London*
Aimin Zhou, *Department of Computer Science, East China Normal University*
Eckart Zitzler
Albert Zomaya
Philippe Collard, *laboratoire I3S (UNSA / CNRS)*
Xiaohui Cui, *Oak Ridge National Laboratory*
Bart De Boer
Luis De La Ossa
Eelco Den Heijer, *Vrije Universiteit*
Elena Marchiori, *VUA*
Chilukuri K. Mohan, *Syracuse University*
Marco Tomassini, *University of Lausanne*
Antoine Van Kampen, *Bioinformatics Laboratory*
Frans Van Den Bergh, *Meraka, CSIR, South Africa*

GECCO-2011 Best Paper Nominees

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. Best Paper winners are posted on the conference website. The titles and authors of all nominated papers, as well as the page numbers where to find them in the Proceedings, are given below:

Ant Colony Optimization and Swarm Intelligence (page 92)

An Incremental ACOR with Local Search for Continuous Optimization Problems
Tianjun Liao (IRIDIA, CoDE, Universite Libre de Bruxelles), Marco Montes de Oca (IRIDIA, CoDE, Universite Libre de Bruxelles), Dogan Aydin (Ege University), Thomas Stützle (IRIDIA, CoDE, Universite Libre de Bruxelles), Marco Dorigo (IRIDIA, CoDE, Universite Libre de Bruxelles)

Artificial Life/Robotics/Evolvable Hardware (page 94)

Evolution of Neural Symmetry and its Coupled Alignment to Body Plan Morphology
Ben Jones (University of Birmingham), Andrea Soltoggio (University of Bielefeld)

Spontaneous Evolution of Structural Modularity in Robot Neural Network Controllers
Josh Bongard (University of Vermont)

Digital Enzymes: Agents of Reaction Inside Robotic Controllers for the Foraging Problem
Manuel Lozano (University of Granada)

Bioinformatics, Computational, Systems, and Synthetic Biology (page 75)

A Novel Probabilistic Encoding for EAs Applied to Biclustering of Microarray Data
Michaël Marcozzi (University of Namur), Federico Divina (Pablo de Olavide University), Wim Vanhoof (University of Namur), Jesus Aguilar-Ruiz (Pablo de Olavide University)

A Genetic Algorithm to Enhance Transmembrane Helices Topology Prediction Using Compositional Index
Nizar Zaki (UAE University), Salah Bouktif (UAE University), Sanja Molnar (UAE University)

Digital Entertainment Technologies and Arts (page 90)

Interactively Evolving Harmonies through Functional Scaffolding
Amy Hoover (University of Central Florida), Paul Szerlip (University of Central Florida), Kenneth Stanley (University of Central Florida)

Interactive Evolution for the Procedural Generation of Tracks in a High-End Racing Game
Luigi Cardamone (Politecnico di Milano), Daniele Loiacono (Politecnico di Milano), Pier Luca Lanzi (Politecnico di Milano)

Evolutionary Combinatorial Optimization and Metaheuristics (page 86)

A Cooperative Tree-based Hybrid GA-B&B Approach for Solving Challenging Permutation-based Problems
Malika Mehdi (University of Luxembourg & INRIA Lille), Jean-Claude Charr (INRIA Lille Nord-Europe - University of Lille), Nouredine Melab (INRIA Lille Nord-Europe - University of Lille), EL-Ghazali Talbi (INRIA Lille Nord-Europe - University of Lille), Pascal Bouvry (University of Luxembourg)

An Efficient Hierarchical Parallel Genetic Algorithm for Graph Coloring Problem
Reza Abbasian (University of Regina), Malek Mouhoub (University of Regina)

Evolving Optimal agendas for Package Deal Negotiation
Shaheen Fatima (Loughborough University), Ahmed Kattan (Loughborough University)

Estimation of Distribution Algorithms (page 80)

Advanced Neighborhoods and Problem Difficulty Measures
Mark Hauschild (University of Missouri-St. Louis), Martin Pelikan (University of Missouri-St. Louis)

Hierarchical Allelic Pairwise Independent Functions
David Iclănzan (Sapientia Hungaryan University of Transylvania)

Evolutionary Multiobjective Optimization (page 83)

Improved S-CDAS using Crossover Controlling the Number of Crossed Genes for Many-objective Optimization
Hiroyuki Sato (The University of Electro-Communications), Hernan Aguirre (Shinshu University), Kiyoshi Tanaka (Shinshu University)

Many-Objective Directed Evolutionary Line Search
Evan Hughes (Cranfield University)

Convergence of Hypervolume-Based Archiving Algorithms I: Effectiveness
Karl Bringmann (Max-Planck-Institut Informatik), Tobias Friedrich (Max-Planck-Institut Informatik)

Evolution Strategies and Evolutionary Programming (page 89)

Mirrored Sampling in Evolution Strategies With Weighted Recombination
Dimo Brockhoff (Ecole Polytechnique), Anne Auger (INRIA Saclay - Ile-de-France), Nikolaus Hansen (INRIA Saclay - Ile-de-France)

Local-Meta-Model CMA-ES for Partially Separable Functions
Zyed Bouzarkouna (IFP Energies nouvelles), Anne Auger (INRIA), Didier Yu Ding (IFP Energies nouvelles)

Genetic Algorithms (page 71)

Pairwise and Problem-Specific Distance Metrics in the Linkage Tree Genetic Algorithm
Martin Pelikan (University of Missouri in St. Louis), Mark Hauschild (University of Missouri in St. Louis), Dirk Thierens (University of Utrecht)

How Crossover Helps in Pseudo-Boolean Optimization
Timo Kötzing (Max-Planck-Institute for Informatics), Dirk Sudholt (University of Birmingham), Madeleine Theile (Technische Universität Berlin)

Genetics Based Machine Learning (page 87)

XCS Cannot Learn All Boolean Functions
Charalambos Ioannides (University of Bristol), Kerstin Eder (University of Bristol), Geoff Barrett (Broadcom)

Evolving Spiking Networks with Variable Memristors
Gerard Howard (University of the West of England), Ella Gale (University of the West of England), Larry Bull (University of the West of England), Ben Costello (University of the West of England), Andrew Adamatzky (University of the West of England)

Modelling the Initialisation Stage of the ALKR Representation for Discrete Domains and GABIL Encoding
Maria Franco (University of Nottingham), Natalio Krasnogor (University of Nottingham), Jaume Bacardit (University of Nottingham)

Genetic Programming (page 88)

Rethinking Multilevel Selection in Genetic Programming
Shelly Wu (Memorial University of Newfoundland), Wolfgang Banzhaf (Memorial University of Newfoundland)

Reassembling Operator Equalisation - A Secret Revealed
Sara Silva (INESC-ID Lisboa)

Generative and Developmental Systems (page 81)

Enhancing ES-HyperNEAT to Evolve More Complex Regular Neural Networks
Sebastian Risi (University of Central Florida), Kenneth Stanley (University of Central Florida)

On the Relationships between Synaptic Plasticity and Generative Systems
Paul Tonelli (ISIR, Université Pierre et Marie Curie-Paris 6, CNRS UMR 7222), Jean-Baptiste Mouret (ISIR, Université Pierre et Marie Curie-Paris 6, CNRS UMR 7222)

Real World Applications (page 93)

Application of Evolutionary Algorithms in Detecting SMS Spam at Access Layer
M. Rafique (Center of Excellence in Information Assurance, King Saud University),
Nasser Alrayes (Center of Excellence in Information Assurance, King Saud University),
Muhammad Khan (Center of Excellence in Information Assurance, King Saud University)

RankDE: Learning a Ranking Function for Information Retrieval using Differential Evolution
Danushka Bollegala (The University of Tokyo), Nasimul Noman (The University of Tokyo), Hitoshi Iba (The University of Tokyo)

GPU-Accelerated High-Accuracy Molecular Docking using Guided Differential Evolution
Martin Simonsen (Bioinformatics Research Centre - Aarhus University), Christian Pedersen (Bioinformatics Research Centre - Aarhus University), Mikael Christensen (Molegro ApS), René Thomsen (Molegro ApS)

Search-Based Software Engineering (page 95)

Searching for Invariants using Genetic Programming and Mutation Testing
Sam Ratcliffe (University of York), David White (University of York), John Clark (University of York)

Using Multi-objective Metaheuristics to Solve the Software Project Scheduling Problem
Francisco Chicano (University of Malaga), Francisco Luna (University of Malaga), Antonio J. Nebro (University of Malaga), Enrique Alba (University of Malaga)

Finding Short Counterexamples in Promela Models Using Estimation of Distribution Algorithms
Jan Staunton (University of York), John Clark (University of York)

Self-* Search (page 91)

Policy Matrix Evolution for Generation of Heuristics
Ender Ozcan (University of Nottingham), Andrew Parkes (University of Nottingham)

Automatic Configuration of State-of-the-art Multi-objective Optimizers Using the TPLS+PLS Framework
Jérémie Dubois-Lacoste (IRIDIA, Université Libre de Bruxelles), Manuel López-Ibáñez (IRIDIA, Université Libre de Bruxelles), Thomas Stützle (IRIDIA, Université Libre de Bruxelles)

Theory (page 65)

An Analysis on Recombination in Multi-Objective Evolutionary Optimization
Chao Qian (Nanjing University), Yang Yu (Nanjing University), Zhihua Zhou (Nanjing University)

The Effects of Selection on Noisy Fitness Optimization
Sergiu Goschin (Rutgers The State University of New Jersey), Michael Littman (Rutgers The State University of New Jersey), David Ackley (The University of New Mexico)

Keynote: Steen Rasmussen (University of Southern Denmark & Santa Fe Institute)

Assembling Living Materials and Engineering Life-like Technologies

Thursday July 14 – 9:00am – 10:20am

Von Neumann, the inventor of the modern computer, realized that if life is a physical process, it should be possible to implement life in other media than biochemistry. In the 1950s, he was one of the first to propose the possibility of implementing genuine living processes in computers and robots. This perspective, while still controversial, is rapidly gaining momentum in many science and engineering communities. Below, we summarize our recent activities to create artificial life from scratch in physicochemical systems. We also outline the nature of the grand science and engineering challenges faced as we seek to realize Von Neumann's vision: Integration of information processing and material production from the nano- to the macroscale in technical systems.

About the Speaker

Currently Professor in Physics and Director for the Center for Fundamental Living Technology (FLinT), University of Southern Denmark; External Research Professor, the Santa Fe Institute, USA; Principle Investigator (PI) of the European Union (EC) sponsored Matrix for Chemical IT (MATCHIT) project and Co-PI for the EC sponsored projects: Electronic Chemical Cell (ECCell) and Coordination of Biological & Chemical IT Research Activities (COBRA). Further, he was the founder of the Center: Initiative for Science, Society, and Policy (ISSP), Denmark (2009-).

During his 20 years in New Mexico, USA (1988-2007, Alien of Extraordinary Abilities) he was the Team Leader for the Self-Organizing Systems (SOS) team at Los Alamos National Laboratory (LANL). He was PI for the Los Alamos Protocell Assembly (LDRD-DR) project and the Astrobiology program (origins of life) at LANL developing experimental and computational protocells and Cell-Like Entities, with USAF as a co-sponsor. Further, he was the Co-Director on the EC sponsored Programmable Artificial Cell Evolution (PACE) project and a Guest Professor at University of Copenhagen (2004-5).

He is a founding Science Board member for the European Center for Living Technology (ECLT) in Venice, Italy (2004-) and heads the Science Board for ProjectZero, in Sønderborg, Denmark. In the 90s he co-directed the Urban Security Initiative at LANL, developing an integrated simulation framework for urban systems as well as web-based disaster mitigation tools, which were implemented in Cerro Grande Wildfire where 20.000 people were evacuated. He was part of the original Los Alamos team on Critical Infrastructure Protection, now implemented by the US Department of Homeland Security. In the early 90s he co-developed the Transportation Simulation System (TRANSIMS) implemented by the USA Department of Transportation. He was one of the founders of the Artificial Life field in the late 1980s.

Professor Rasmussen has published more than 80 peer reviewed papers and many internal technical reports, given more than 180 invited presentations outside of home institutions, has co-organized eight international and several national conferences, and he has more than 100 media interviews. He organized the first international protocell conferences, at Los Alamos, the Santa Fe Institute (US) and in Dortmund (Germany) and edited the first book on the topic. Many communications (>100) about his work inside and outside of the scientific establishment have appeared on television in newspapers, periodicals, and books.

Since 2003 Professor Rasmussen has brought in about $34M (170M DDK) in research grants (PI: $17.6M and Co-PI: $16.4M) to his host institutions. He has extensive experience in international program development and research leadership and he is currently responsible for the day-to-day activities of about 25 people within FLinT.

Keynote: Rebecca Schulman (University of California, Berkeley)

Beyond Biology: Designing a New Mechanism for Self-Replication and Evolution at the Nanoscale

Friday July 15 – 9:00am – 10:20am

As biology demonstrates, evolutionary algorithms are an extraordinarily powerful way to design complex nanoscale systems. While we can harness the biological apparatus for replicating and selecting DNA sequences to evolve enzymes and to some extent, organisms, we would like to build replication machinery that would allow us to evolve designs for a much wider variety of materials and systems. Here we describe work that uses techniques from the new field of structural DNA nanotechnology to modularly design nanoscale components that together can be assembled into a system for self-replicating a new form of chemical information or genome, and thus for evolving a new type of chemical sequence.

About the Speaker

Rebecca Schulman's work focuses on complex, adaptive self-assembly processes and building simple, synthetic mimics of biological processes. Dr. Schulman studied computer science and mathematics at MIT, where her research focused on artificial intelligence. After several years writing search engines and natural language processing software in Silicon Valley, she returned to academia. Dr. Schulman worked with Erik Winfree at the California Institute of Technology, where she received her PhD in computation and neural systems in 2007. Dr. Schulman is currently a Miller research fellow in the physics department at U.C. Berkeley where she works in Jan Liphardt's laboratory. In August, she will join Johns Hopkins University's chemical and biomolecular engineering department as an assistant professor.

The 8th Annual (2011) "Humies" Awards for Human-Competitive Results

Oral presentations: **Thursday 14 July, 12:20 – 14:40, Lansdowne**
Awards presentation: **8:30-10:20, Lansdowne and Pembroke**

Prizes Totaling $10,000 to be awarded

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

Humie finalists will give short oral presentations about human-competitive results that they have produced by any form of genetic and evolutionary computation (e.g., genetic algorithms, genetic programming, evolution strategies, evolutionary programming, learning classifier systems, grammatical evolution, etc.).

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.

Evolutionary Computation in Practice

The Evolutionary Computation in Practice (ECP) track at GECCO 2011 is a three days event lasting 14th to 16th July 2011. Our invited speakers come from various industry sectors as well as from academia. The talks are all strongly practical oriented.

Purposes

Evolutionary Computation in Practice has several purposes:

- serve as a place for industrial and government attendees to talk and learn of new EC approaches that they can use
- provide top-level presentations of techniques across industries and organizations
- help students learn how to get employment in EC
- provide a forum in which practitioners of real-world systems can describe their approaches in a non-technical way
- provide descriptions of the way that practitioners have created and run successful EC projects

ECP: Evolutionary Computation in Practice

The ECP track is dedicated to the discussion of issues related to practical applications of Evolutionary Computation. Members from industry, governmental agencies, and other public sectors present and discuss how EC-related technologies are being used to solve real-world problems. Bridging academic training and real-world usage is also addressed.

Themes

- Real-world application success story
- Real-world application lessons learned
- Academic case study in real-world applications
- Expectations of academic training from industry

Domains

- Biomedical
- Design
- Energy and Resources
- Finance
- Government and Military
- Academic training for real-world applications
- Computer Graphics and Gaming

Organizers

Jörn Mehnen, Cranfield University, UK
Thomas Bartz-Beielstein, University of Applied Sciences, Cologne, Germany
David Davis, VGO Associates, USA -

ECP Session Schedule

ECP1 - Ask the Experts: EC questions from the audience	July 14	10:40AM - 12:20PM	Clanwilliam Room
ECP2 - Managing an EC project for success	July 14	2:40PM - 4:20PM	Leinster Room
ECP3 - EC in Design and Optimization	July 15	10:40AM - 12:20PM	Clanwilliam Room
ECP4 - EC in Statistics and EA consultancy	July 15	2:40PM - 4:20PM	Leinster Room
ECP5 - Getting a Job: What to do and what not to do	July 16	10:40AM - 12:20PM	Connaught 2 Room

The GECCO Industrial Challenge

The foreign exchange (FX) market is a financial market for trading currencies to enable international trade and investment. Goal of the GECCO 2011 Industrial Challenge is to find profitable trading strategies for automatic foreign exchange trading. A trading strategy is a function that generates a trading signal based on exchange rate time series data. Trading strategies are scored by cost-corrected profitability and risk. This scoring is based on a representative set of real-world exchange rate time series.

The challenge is organized in two rounds. In the first round, participants submit the sum of their scores reached on three test data sets supplied. They also submit their executable software together with short report describing their approach. In the second and final round, the ten best submissions of the first round will be ranked by their scores computed on new test data sets collected after the submission date, for the same currency pairs as used in the first round. The winner of the challenge will be the participant with the highest score in the final round.

Highlights of the GECCO 2011 Industrial Challenge include:

- Interesting Problem Domain: The FX market, with its complex patterns and behavior, offers a fascinating test case for innovative optimization methods.
- Real-world Data: Multiple real intraday FX return time series are provided for training and testing trading strategies.
- Realistic Quality Measurement: Trading strategies are scored using a simple but realistic trading simulator that takes trading costs and risk into account.
- Fair Submission Assessment: Winners are determined in a second round by simulated trading based on new FX return data sets, rendering accidental overfitting or cheating impossible.

Organizing Committee and Sponsors

Thomas Bartz-Beielstein, Cologne University of Applied Sciences
Christian von Strachwitz, Quaesta Capital GmbH
Oliver Flasch, Cologne University of Applied Sciences
Wolfgang Kantschik, DIP Dortmund Intelligence Project GmbH
Wolfgang Konen, Cologne University of Applied Sciences
Pier Luca Lanzi, Politecnico di Milano
Jorn Mehnen, Cranfield University

GECCO-2011 Competitions

This year the program includes five competitions:

- Demolition Derby
- Evolutionary Art
- GPUs for Genetic and Evolutionary Computation
- Simulated Car Racing Championship
- Visualizing Evolution Competition

Demolition Derby

Organizers

- Martin V. Butz, University of Würzburg, Germany
- Matthias J. Linhardt, University of Würzburg, Germany
- Daniele Loiacono, Politecnico di Milano, Italy
- Luigi Cardamone, Politecnico di Milano, Italy
- Pier Luca Lanzi, Politecnico di Milano, Italy

The Demolition Derby 2011 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.

GPUs for Genetic and Evolutionary Computation

Organizers

- Simon Harding, IDSIA, Switzerland

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.

Evolutionary Art

Organizers

- Christian Gagné, Université Laval
- Alain Lioret, Université Paris VIII
- Penousal Machado, Universidade de Coimbra

This competition invites conference participants to demonstrate that genetic and evolutionary computation can be applied to create impressive and provocative works of art. The competition will identify the best work, be it an image, a sculpture, a music score, a video, an interactive online experience, or a system that exhibits some form of independent creativity.

Simulated Car Racing Championship

Organizers

- Daniele Loiacono, Politecnico di Milano, Italy
- Luigi Cardamone, Politecnico di Milano, Italy
- Martin V. Butz, University of Würzburg, Germany
- Pier Luca Lanzi, Politecnico di Milano, Italy

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 engine RPMs, the current gear, wheel speeds, 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).

Visualizing Evolution Competition

Organizers

- Nicholas Sinnott-Armstrong, Dartmouth Medical School
- Jason Moore, Dartmouth Medical School

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.

GECCO-2011 Workshop Presentations

Evolutionary Computation Techniques for Constraint Handling

Explorations on Template-Directed Genetic Repair using Ancient Ancestors and Other Templates
Donagh Hatton (National University of Ireland)
Diarmuid P. O'Donoghue (National University of Ireland)

Case Study: Constraint Handling in Evolutionary Optimization of Catalytic Materials
Martin Holena (Academy of Sciences of the Czech Republic)
David Linke (Leibniz Institute for Catalysis)
Lukáš Bajer (Academy of Sciences of the Czech Republic)

A Memetic Algorithm for Two-dimensional Multi-Objective Bin-packing with Constraints
Antonio Fernandez (University of Almeria)
Consolación Gil (University of Almeria)
Antonio Lopez Marquez (University of Almeria)
Raul Baños (University of Almeria)
Maria Gil Montoya (University of Almeria)
Maria Parra (University of Almeria)

Combining PSO and Local Search to Solve Scheduling Problems
Xue-Feng Zhang (Kyushu University)
Miyuki Koshimura (Kyushu University)
Hiroshi Fujita (Kyushu University)
Ryuzo Hasegawa (Kyushu University)

Fourteenth International Workshop on Learning Classifier Systems

Voting Based Learning Classifier System for Multi-Label Classification
Kaveh Ahmadi-Abhari (Shiraz University)
Ali Hamzeh (Shiraz University)
Sattar Hashemi (Shiraz University)

PCA for Improving the Performance of XCSR in Classification of High-dimensional Problems
Mohammad Behdad (University of Western Australia)
Tim French (University of Western Australia)
Luigi Barone (University of Western Australia)
Mohammed Bennamoun (University of Western Australia)

Random Artificial Incorporation of Noise in a Learning Classifier System Environment
Ryan J. Urbanowicz (Dartmouth College)
Nicholas A. Sinnott-Armstrong (Dartmouth College)
Jason H. Moore (Dartmouth College)

Automatically Defined Functions for Learning Classifier Systems
Muhammad Iqbal (Victoria University of Wellington)
Mengjie Zhang (Victoria University of Wellington)
Will Browne (Victoria University of Wellington)

XCSF with Local Deletion: Preventing Detrimental Forgetting
Martin V. Butz (University of Würzburg)
Olivier Sigaud (Université Pierre et Marie Curie - Paris 6)

Grid Data Mining by Means of Learning Classifier Systems and Distributed Model Induction
Manuel Santos (University of Minho)
Wesley Mathew (University of Minho)
Henrique Santos (University of Minho)

Computational Intelligence on Consumer Games and Graphics Hardware (CIGPU)

Evolving CUDA PTX Programs by Quantum Inspired Linear Genetic Programming
Leandro Cupertino (Pontifical Catholic University of Rio de Janeiro)
Cleomar Silva (Pontifical Catholic University of Rio de Janeiro)
Douglas Dias (Pontifical Catholic University of Rio de Janeiro)
Marco Aurélio Pacheco (Pontifical Catholic University of Rio de Janeiro)
Cristiana Bentes (State University of Rio de Janeiro)

Acceleration of Genetic Algorithms for Sudoku Solution on Many-Core Processors
Yuji Sato (Hosei University)
Naohiro Hasegawa (Hosei University)
Mikiko Sato (TUAT)

Debugging CUDA
William B. Langdon (University College London)

Performing with CUDA
William B. Langdon (University College London)

Acceleration of Grammatical Evolution Using Graphics Processing Units
Petr Pospichal (Brno University of Technology)
Eoin Murphy (University College Dublin)
Michael O'Neill (University College Dublin)
Josef Schwarz (Brno University of Technology)
Jiri Jaros (Brno University of Technology)

Bitwise Operations for GPU Implementation of Genetic Algorithms
Martín Pedemonte (Universidad de la República Montevideo)
Enrique Alba (Universidad de Málaga)
Francisco Luna (Universidad de Málaga)

Identifying Similarities in TMBL Programs with Alignment to Quicken Their Compilation for GPUs
Tony E. Lewis (University of London)
George D. Magoulas (University of London)

TMBL Kernels for CUDA GPUs Compile Faster Using PTX
Tony E. Lewis (University of London)
George D. Magoulas (University of London)

Implementing Cartesian Genetic Programming Classifiers on Graphics Processing Units Using GPU.NET
Simon Harding (IDSIA, Switzerland & Memorial University Canada)
Wolfgang Banzhaf (Memorial University)

Medical Applications of Genetic and Evolutionary Computation (MedGEC)

Multi-Reward Policies for Medical Applications: Anthrax Attacks and Smart Wheelchairs
Harold Soh (Imperial College London)
Yiannis Demiris (Imperial College London)

Memetic Evolutionary Multi-Objective Neural Network Classifier to Predict Graft Survival in Liver Transplant Patients
Manuel Cruz-Ramírez (University of Córdoba)
Juan Carlos Fernández Caballero (University of Córdoba)
Francisco Fernández-Navarro (University of Córdoba)
Javier Briceño (Hospital Reina Sofía)
Manuel de la Mata (Hospital Reina Sofía)
César Hervás-Martínez (University of Córdoba)

Automatic Hippocampus Localization in Histological Images using PSO-Based Deformable Models
Roberto Ugolotti (University of Parma)
Pablo Mesejo (University of Parma)
Stefano Cagnoni (University of Parma)
Mario Giacobini (University of Torino)
Ferdinando Di Cunto (University of Torino)

An Adaptive Binary PSO to Learn Bayesian Classifier for Prognostic Modeling of Metabolic Syndrome
Satchidananda Dehuri (Fakir Mohan University)
Rahul Roy (KIIT University)
Sung-Bae Cho (Yonsei University)

Identification of Cancer Diagnosis Estimation Models Using Evolutionary Algorithms - A Case Study for Breast Cancer,
Melanoma, and Cancer in the Respiratory System
Stephan M. Winkler (Upper Austria University of Applied Sciences)
Michael Affenzeller (Upper Austria University of Applied Sciences)
Witold Jacak (Upper Austria University of Applied Sciences)
Herbert Stekel (General Hospital Linz)

On the Performance of Evolutionary Algorithms in Biomedical Keyword Clustering
Viktoria Dorfer (Upper Austria University of Applied Sciences)
Stephan M. Winkler (Upper Austria University of Applied Sciences)
Thomas Kern (Upper Austria University of Applied Sciences)
Sophie A. Blank (Upper Austria University of Applied Sciences)
Gerald Petz (Upper Austria University of Applied Sciences)
Patrizia Faschang (Upper Austria University of Applied Sciences)

Evolutionary Computation and Multi-Agent Systems and Simulation (ECoMASS) Fifth Annual Workshop

Road Traffic Optimisation Using an Evolutionary Game
Syed Md. Galib (Swinburne University of Technology)
Irene Moser (Swinburne University of Technology)

A Social Behaviour Evolution Approach for Evolutionary Optimisation
Mikdam Turkey (University of Essex)
Riccardo Poli (University of Essex)

An Agent-Based Model of the Effects of a Primate Social Structure on the Speed of Natural Selection
Gideon M. Gluckman (University of Bath)
Joanna J. Bryson (University of Bath)

Sociotechnical Simulation and Evolutionary Algorithm Optimization for Routing Siren Vehicles in a Water Distribution Contamination Event
M. Ehsan Shafiee (Texas A&M University)
Emily M. Zechman (Texas A&M University)

Evolution for Modeling - A Genetic Programming Framework for SeSAm
Robert Junges (Örebro University)
Franziska Klügl (Örebro University)

Estimating Functional Agent-Based Models: An Application to Bid Shading in Online Markets Format
Wei Guo (University of Maryland)
Wolfgang Jank (University of Maryland)
William Rand (University of Maryland)

1st Workshop on Evolutionary Computation for Designing Generic Algorithms

Towards the Automatic Design of Decision Tree Induction Algorithms
Rodrigo C. Barros (University of São Paulo)
André C. P. L. F. de Carvalho (University of São Paulo)
Marcio P. Basgalupp (Universidade Federal de São Paulo)
Alex A. Freitas (University of Kent)

Self-Configuring Crossover
Brian W. Goldman (Missouri University of Science and Technology)
Daniel R. Tauritz (Missouri University of Science and Technology)

Automatically Designing Selection Heuristics
John Woodward (The University of Nottingham, China)
Jerry Swan (The University of Nottingham)

Instance-Based Parameter Tuning for Evolutionary AI Planning
Mátyás Brendel (Université Paris-Sud)
Marc Schoenauer (INRIA Saclay)

Bio-Inspired Solutions for Wireless Sensor Networks (GECCO BIS-WSN 2011)

Robot Routing in Sparse Wireless Sensor Networks with Continuous Ant Colony Optimization
Giovanni Comarela (Universidade Federal de Minas Gerais)
Kênia Gonçalves (Universidade Federal de Minas Gerais)
Gisele L. Pappa (Universidade Federal de Minas Gerais)
Jussara Almeida (Universidade Federal de Minas Gerais)
Virgílio Almeida (Universidade Federal de Minas Gerais)

A Cooperative Coevolutionary Algorithm for the Design of Wireless Sensor Networks
André Siqueira Ruela (Universidade Federal de Ouro)
André L. L. Aquino (Universidade Federal de Alagoas)
Frederico G. Guimarães (Universidade Federal de Minas Gerais)

Implementing a Model of Japanese Tree Frogs' Calling Behavior in Sensor Networks: A Study of Possible Improvements
Hugo Hernández (Universitat Politècnica de Catalunya)
Christian Blum (Universitat Politècnica de Catalunya)

3rd Symbolic Regression and Modeling Workshop for GECCO 2011

Invited Talk: On the Integration of Symbolic Regression into High Throughput Research Workflows
Guido Smits (Dow Benelux B.V., Netherlands)

Separating the Wheat from the Chaff: On Feature Selection and Feature Importance in Regression Random Forests and Symbolic Regression
Sean Stijven (University of Antwerp)
Wouter Minnebo (University of Antwerp)
Katya Vladislavleva (University of Antwerp)

Overfitting Detection and Adaptive Covariant Parsimony Pressure for Symbolic Regression
Gabriel Kronberger (Upper Austria University of Applied Sciences)
Michael Kommenda (Upper Austria University of Applied Sciences)
Michael Affenzeller (Upper Austria University of Applied Sciences)

A Symbolic Regression Approach to Manage Femtocell Coverage Using Grammatical Genetic Programming
Erik Hemberg (University College Dublin)
Lester Ho (Bell Laboratories)
Michael O'Neill (University College Dublin)
Holger Claussen (Bell Laboratories)

Symbolic Regression Using Alpha, Beta Operators and Estimation of Distribution Algorithms: Preliminary Results
Luis M. Torres-Treviño (Universidad Autónoma de Nuevo León)

Automatic Pyrolysis Mass Loss Modeling from Thermo-Gravimetric Analysis Data Using Genetic Programming
Kenneth Holladay (Southwest Research Institute)
J. Marshall Sharp (Southwest Research Institute)
Marc Janssens (Southwest Research Institute)

Optimization by Building and Using Probabilistic Models (OBUPM-2011)

The Roles of Local Search, Model Building and Optimal Mixing in Evolutionary Algorithms from a BBO Perspective
Peter A. N. Bosman (Centrum Wiskunde & Informatica)
Dirk Thierens (Utrecht University)

Second Order Heuristics in ACGP
Cezary Z. Janikow (University of Missouri - St. Louis)
John Aleshunas (University of Missouri - St. Louis)
Mark W. Hauschild (University of Missouri - St. Louis)

Estimation of Distribution Algorithms: From Available Implementations to Potential Developments
Roberto Santana (Universidad Politécnica de Madrid)

Scaling Behaviours of Landscapes, Parameters and Algorithms

Covariance-based Parameters Adaptation in Differential Evolution
Valentino Santucci (University of Perugia)
Alfredo Milani (University of Perugia)

Using Landscape Measures for the Online Tuning of Heterogeneous Distributed GAs
Carolina Salto (Universidad Nacional de la Pampa)
Enrique Alba (Universidad de Málaga)
Francisco Luna (Universidad de Málaga)

Are Evolutionary Algorithm Competitions Characterizing Landscapes Appropriately?
Pilar Caamaño (Universidade da Coruña)
Jose A. Becerra (Universidade da Coruña)
Francisco Bellas (Universidade da Coruña)
Richard J. Duro (Universidade da Coruña)

Tuning Parameters across Mixed Dimensional Instances: A Performance Scalability Study of Sep-G-CMA-ES
Tianjun Liao (IRIDIA, CoDE, Université Libre de Bruxelles)
Marco A. Montes de Oca (IRIDIA, CoDE, Université Libre de Bruxelles)
Thomas Stützle (IRIDIA, CoDE, Université Libre de Bruxelles)

Evaluating Optimization Algorithms: Bounds on the Performance of Optimizers on Unseen Problems
David Corne (Heriot-Watt University)
Alan Reynolds (Heriot-Watt University)

GreenIT Evolutionary Computation

Open Source Tool for Energy Saving and Efficient System Management
Consolación Gil (Universidad de Almería)
Pedro Sánchez (Universidad de Almería)
Francisco G. Montoya (Universidad de Almería)
Antonio L. Márquez (Universidad de Almería)

An Efficient Routing Protocol for Green Communications in Vehicular Ad-hoc Networks
Jamal Toutouh (University of Málaga)
Enrique Alba (University of Málaga)

Optimizing Architectural and Structural Aspects of Buildings towards Higher Energy Efficiency
Álvaro Fialho (LIX, École Polytechnique)
Youssef Hamadi (Microsoft Research, Cambridge & École Polytechnique)
Marc Schoenauer (INRIA Saclay & Microsoft Research, France)

Load Balancing for Sustainable ICT
Alexandru-Adrian Tantar (University of Luxembourg)
Emilia Tantar (University of Luxembourg)
Pascal Bouvry (University of Luxembourg)

Graduate Students Workshop

Evolving Board-Game Players with Genetic Programming
Amit Benbassat (Ben-Gurion University of the Negev)
Moshe Sipper (Ben-Gurion University of the Negev)

Extracting Adaptation Strategies for E-Learning Programs with XCS
Anke Endler (University of Würzburg)
Martin V. Butz (University of Würzburg)
Günter Daniel Rey (University of Würzburg)

Investigating a New Paradigm for Designing Evolutionary Optimisation Algorithms Using Social Behaviour Evolution
Mikdam Turkey (University of Essex)
Riccardo Poli (University of Essex)

A Multiobjective Optimization Algorithm for Discovering Driving Strategies
Erik Dovgan (Jožef Stefan Institute)
Matjaž Gams (Jožef Stefan Institute)
Bogdan Filipič (Jožef Stefan Institute)

Cardiac Myocyte Model Parameter Sensitivity Analysis and Model Transformation Using a Genetic Algorithm
Armen R. Kherlopian (Weill Cornell Medical College)
Francis A. Ortega (Weill Cornell Medical College)
David J. Christini (Weill Cornell Medical College)

Finite State Machine Induction using Genetic Algorithm based on Testing and Model Checking
Fedor Tsarev (St. Petersburg State University of Information Technologies, Mechanics and Optics)
Kirill Egorov (St. Petersburg State University of Information Technologies, Mechanics and Optics)

Generation of Tests for Programming Challenge Tasks Using Evolution Algorithms
Maxim Buzdalov (St. Petersburg State University of Information Technologies, Mechanics and Optics)

Discrete Dynamics of Cellular Machines: Specification and Interpretation
Stefano Nichele (Norwegian University of Science and Technology)

Swarm Intelligence Guided by Multi-Objective Mathematical Programming Techniques
Saúl Zapotecas Martínez (CINVESTAV-IPN)
Carlos A. Coello Coello (CINVESTAV-IPN)

Genetic Algorithm for Induction of Finite Automata with Continuous and Discrete Output Actions
Anton Alexandrov (St. Petersburg State University of Info Technologies, Mechanics and Optics)
Alexey Sergushichev (St. Petersburg State University of Info Technologies, Mechanics and Optics)
Sergey Kazakov (St. Petersburg State University of Info Technologies, Mechanics and Optics)
Fedor Tsarev (St. Petersburg State University of Info Technologies, Mechanics and Optics)

Examining Grammars and Grammatical Evolution in Dynamic Environments
Eoin Murphy (University College Dublin)

Genotype-Phenotype Mapping in Dynamic Environments with Grammatical Evolution
David Fagan (University College Dublin)

Design Knowledge Extraction in Multi-objective Optimization Problems
Sunith Bandaru (Indian Institute of Technology Kanpur)
Kalyanmoy Deb (Indian Institute of Technology Kanpur)

MuGA - Multiset Genetic Algorithm
António Manso (Instituto Politécnico de Tomar & Universidade de Lisboa)
Luís Correia (Universidade de Lisboa)

Estimation of Distribution Algorithms based on Copula Functions
Rogelio Salinas-Gutiérrez (Center for Research in Mathematics)
Arturo Hernández-Aguirre (Center for Research in Mathematics)
Enrique R. Villa-Diharce (Center for Research in Mathematics)

Size-Based Tournaments for Node Selection
Thomas Helmuth (University of Massachusetts)
Lee Spector (Hampshire College)
Brian Martin (Hampshire College)

Late Breaking Abstracts Workshop

Collaborative Intelligence in Living Systems: Algorithmic Implications of Evo-devo Debates
Zann Gill (NASA Ames Reserch Center)

A Multi-objective Niching Co-evolutionary Algorithm (MNCA) for Identifying Diverse Sets of Non-dominated Solutions
Emily M. Zechman (Texas A&M University)
Marcio H. Giacomoni (Texas A&M University)
M. Shafiee (Texas A&M University)

Probabilistically Interpolated Rational Hypercube Landscape Evolutionary Algorithm
David Andrew Cape (Cape Canaveral)
Daniel R. Tauritz (Missouri University of Science and Technology)

Pricing Transmission Rights using Ant Colony Optimization
Sameer Kumar Singh (University of Manitoba)
Ruppa K. Thulasiram (University of Manitoba)
Parimala Thulasiraman (University of Manitoba)

A Simple Strategy to Maintain Diversity and Reduce Crowding in Particle Swarm Optimization
Stephen Chen (York University)
James Montgomery (Swinburne University)

Automatic Synthesis of MEMS Devices Using Self-Adaptive Hybrid Metaheuristics
Cem Celal Tutum (Technical University of Denmark)
Zhun Fan (Technical University of Denmark)

Privacy-Preserving Approach to Bayesian Network Structure Learning from Distributed Data
Olivier Regnier-Coudert (Robert Gordon University)
John McCall (Robert Gordon University)

Online Adaptation of Locomotion with Evolutionary Algorithms: A Transferability-based Approach
Sylvain Koos (Université Pierre et Marie Curie - Paris 6)
Jean-Baptiste Mouret (Université Pierre et Marie Curie - Paris 6)

Fitness Function Evaluation for MA Trading Strategies based on Genetic Algorithms
José Pinto (Instituto Superior Técnico)
Rui Ferreira Neves (Instituto Superior Técnico)
Nuno Horta (Instituto Superior Técnico)

Bayesian Networks Learning for Strategies in Artificial Life
Lisa Jing Yan (York University)
Nick Cercone (York University)

Acceleration Experiment of Genetic Computations for Sudoku Solution on Multi-Core Processors
Mikiko Sato (Tokyo University of Agriculture and Technology)
Yuji Sato (Hosei University)
Mitaro Namiki (Tokyo University of Agriculture and Technology)

Improving Energy Efficiency Based on Behavioral Model in a Swarm of Cooperative Foraging Robots
Jong-Hyun Lee (Sungkyunkwan University)
Chang Wook Ahn (Sungkyunkwan University)

Optimal OpAmp Sizing based on a Fuzzy-Genetic Kernel
Pedro Sousa (Instituto de Telecomunicações, Lisboa)
Carla Duarte (Instituto de Telecomunicações, Lisboa)
Manuel Barros (Instituto de Telecomunicações, Lisboa)
Jorge Guilherme (Instituto de Telecomunicações, Lisboa)
Nuno Horta (Instituto de Telecomunicações, Lisboa)

How Many Dimensions in Co-Optimization?
Wojciech Jaskowski (Poznan University of Technology)
Krzysztof Krawiec (Poznan University of Technology)

Machine Learning for Drug Design, Molecular Machines and Evolvable Artificial Cells
Filippo Caschera (University of Southern Denmark)
Martin Hanczyc (University of Southern Denmark)
Steen Rasmussen (University of Southern Denmark)

Genetic Algorithm with Genetic Engineering Technology for Multi-objective Dynamic Job Shop Scheduling Problems
Todor Dimitrov (Fraunhofer Institute of Optronics, System Technologies and Image Exploitation)
Michael Baumann (Fraunhofer Institute of Optronics, System Technologies and Image Exploitation)

Towards the Efficient Evolution of Particle-Based Computation in Cellular Automata
David Iclănzan (Sapientia Hungarian University of Transylvania)
Fülöp Péter István (Eötvös Loránd University)
Camelia Chira (Babes-Bolyai University Koglniceanu no.1)
Anca Gog (Babes-Bolyai University Koglniceanu no.1)

PSO-GPU: Accelerating Particle Swarm Optimization in CUDA-Based Graphics Processing Units
Daniel Leal Souza (Centro Universitário do Estado do Pará, Universidade Federal do Pará)
Tiago Carvalho Martins (Universidade Federal do Pará)
Victor Alexandrovich Dmitriev (Universidade Federal do Pará)
Glauber Duarte Monteiro (Centro Universitário do Estado do Pará, Universidade Federal do Pará)
Otávio Noura Teixeira (Centro Universitário do Estado do Pará)

Thursday 14 July 10:40 – 12:20

GA1: Adaptation
Room: Lansdowne
Session Chair: A.E. Eiben (Free University Amsterdam)

10:40-11:05 **On the Log-Normal Self-Adaptation of the Mutation Rate in Binary Search Spaces**
Johannes Kruisselbrink, Rui Li, Edgar Reehuis, Jeroen Eggermont, Thomas Baeck

This paper discusses the adoption of self-adaptation for Evolutionary Algorithms operating in binary spaces using a direct encoding of the mutation rate. In particular, it focuses on the log-normal update rule for adapting the mutation rate, incorporated in a (mu, lambda)-strategy. Although it is well known that in using such update rules, a lower boundary is required to keep the mutation rate from collapsing to zero, the naive approach of enforcing a fixed lower boundary has undesirable side-effects. This paper studies the dynamics of the fixed lower boundary approach in depth and proposes a simple alternative for dealing with the lower boundary issue.

11:05-11:30 **A parameter-less Genetic Algorithm with customized Crossover and Mutation operators**
Farhad Nadi, Ahamad Khader

Genetic algorithm is one of the well-known population based meta-heuristics. The reasonable performance of the algorithm on a wide variety of problems as well as its simplicity made this algorithm a first choice in lots of cases. However, the algorithm has some weaknesses such as the existence of some parameters that need to be carefully set before the run. The capability of the parameters to change the balance between exploration and exploitation make them crucial. Exploration and exploitation are the bases of every evolutionary algorithm. Conducting a balance between these elements is crucial for the success of any evolutionary algorithm. In this research a GA is proposed on which the crossover and mutation rate are removed. A probability vector holds the probability of the alleles for every locus within the individual. The probability is with regards to the contribution of the allele on either increasing or decreasing the fitness of the chromosome. The probability of an allele will increase if the fitness of the chromosome increases by a change or vise versa. The experiments conducted on a wide range of multi-modal and epistatic problems show good performance of the proposed method in comparison to other algorithms in literature.

11:30-11:55 **Adaptive Evolutionary Algorithm Based on Population Dynamics for Dynamic Environments**
Maury Gouvêa Jr., Aluizio Araujo

In dynamic environments, the absence of diversity may degrade the performance of evolutionary algorithms (EAs). In a previous article, it was created a new adaptive method, diversity-reference adaptive control (DRAC), to control population diversity based on a reference diversity. The DRAC method aims to track an appropriate diversity level to solve complex problems. The control strategy tackles the evolutionary process as a control problem, in which the process output is the population diversity and the process input is one or more EA adjustable parameters. In that first version of DRAC, the evolutionary process is treated as a black box, thus, the updating of the control variables is made as a function of the error between the population diversity and the reference-model diversity. The DRAC approach does not consider sensitivity analysis. In the version now put forward a population dynamics model is used to describe the evolutionary process and to allow the control variables to be up-dated.

11:55-12:20 **Idealized Dynamic Population Sizing for Uniformly Scaled Problems**
Fernando Lobo

This paper explores an idealized dynamic population sizing strategy for solving additive decomposable problems of uniform scale. The method is designed on top of the foundations of existing population sizing theory for this class of problems, and is carefully compared with an optimal fixed population sized genetic algorithm. The resulting strategy should be close to a lower bound in terms of what can be achieved, performance-wise, by self-adjusting population sizing algorithms for this class of problems.

GP1: Optimisation and Selection
Room: Pembroke
Session Chair: Raja Muhammad Atif Azad (University of Limerick)

10:40-11:05 **A Genetic Programming Based Hyper-heuristic Approach for Combinatorial Optimisation**
Su Nguyen, Mengjie Zhang, Mark Johnston

Genetic programming based hyper-heuristics (GPHH) have become popular over the last few years. Most of these proposed GPHH methods have focused on heuristic generation. This study investigates a new application of genetic programming (GP) in the field of hyper-heuristics and proposes a method called GPAM, which employs GP to evolve adaptive mechanisms (AM) to solve hard optimisation problems. The advantage of this method over other heuristic selection methods is the ability of evolved adaptive mechanisms to contain complicated combinations of heuristics and utilise problem solving states for heuristic selection. The method is tested on three problem domains and the results show that GPAM is very competitive when compared with existing hyper-heuristics. An analysis is also provided to gain more understanding of the proposed method.

11:05-11:30 **Geometric Nelder-Mead Algorithm on the Space of Genetic Programs**
Alberto Moraglio, Sara Silva

The Nelder-Mead Algorithm (NMA) is an almost half-century old method for numerical optimization, and it is a close relative of Particle Swarm Optimization (PSO) and Differential Evolution (DE). In recent work, PSO, DE and NMA have been generalized using a formal geometric framework that treats solution representations in a uniform way. These formal algorithms can be used as templates to derive rigorously specific PSO, DE and NMA for both continuous and combinatorial spaces retaining the same geometric interpretation of the search dynamics of the original algorithms across representations. In previous work, a geometric NMA has been derived for the binary string representation and permutation representation. Furthermore, PSO and DE have already been derived for the space of genetic programs. In this paper, we continue this line of research and derive formally a specific NMA for the space of genetic programs. The result is a Nelder-Mead Algorithm searching the space of genetic programs by acting directly on their tree representation. We present initial experimental results for the new algorithm. The challenge tackled in the present work compared with earlier work is that the pair NMA and genetic programs is the most complex considered so far.

11:30-11:55 **Variance based Selection To Improve Test Set Performance in Genetic Programming**
R. Muhammad Atif Azad, Conor Ryan

This paper proposes to improve the performance of Genetic Programming (GP) over unseen data by minimizing the variance of the output values of evolving models along with reducing error on the training data. Variance is a well-understood, simple and inexpensive statistical measure; it is easy to integrate into a GP implementation and can be computed over arbitrary input values even when the target output is not known. Moreover, we propose a simple variance based selection scheme to decide between two models (individuals). The scheme is simple because, although it uses bi-objective criteria to differentiate between two competing models, it does not rely on a multi-objective optimisation algorithm. In fact, standard multi-objective algorithms can also employ this scheme to identify good trade-offs such as those located around the knee of the Pareto Front. The results indicate that, despite some limitations, these proposals significantly improve the performance of GP over a selection of high dimensional (multi-variate) problems from the domain of symbolic regression. This improvement is manifested by superior results over test sets in three out of four problems, and by the fact that performance over the test sets does not degrade as often witnessed with standard GP;

11:55-12:20 **Genetic Programming with a Norm-referenced Fitness Function**
Geng Li, Xiaojun Zeng

In GP, the role of fitness function is very similar to an examination. The fitness function is a criterion-referenced test because the raw fitness value is used as testing score directly. One problem of criterion-referenced test is the possibility for a mis-match between question setter's expectation and the exam taker's level. This mismatch, once occurred, leads to the inability to differentiate the relative ranking of exam takers. On the other hand, the primary goal of a norm-referenced test is to show whether the test taker did better or worse than other people who took the test. As a result, norm-referenced test does not have the mismatch problem and it is a better fit to the task of establishing relative ranking. In this paper, we apply the idea of norm-referenced test in the context of GP by developing a new fitness function which determines the fitness not only based on raw fitness value, but also takes into account present population's performance. Experiments performed show that, norm-referenced fitness function developed is capable of improving the overall performance of GP system.

ESEP1: Evolution Strategies and Evolutionary Programming (Session 1)
Room: Ulster
Session Chair: Dirk V. Arnold (Dalhousie University)

10:40-11:05 **Noisy Optimization: A Theoretical Strategy Comparison of ES, EGS, SPSA & IF on the Noisy Sphere**
Steffen Finck, Hans-Georg Beyer, Alexander Melkozerov

This paper presents a performance comparison of 4 direct search strategies in continuous search spaces using the noisy sphere as test function. While the results of the Evolution Strategy (ES), Evolutionary Gradient Search (EGS), Simultaneous Perturbation Stochastic Approximation (SPSA) considered are already known from literature, Implicit Filtering (IF) as the fourth strategy is firstly analyzed in this paper. After a short review of ES, EGS, and SPSA, the derivation of the quality gain formula of IF is sketched. Using the results, a comparison of the strategies is performed that worked out the similarities and differences of the strategies.

11:05-11:30 **When Parameter Tuning Actually is Parameter Control**
Simon Wessing, Mike Preuss, Günter Rudolph

In this paper, we show that sequential parameter optimization (SPO), a method that was designed for (offline) parameter tuning, can be successfully used as a controller for multistart approaches of evolutionary algorithms (EA). We demonstrate this by replacing the restart heuristic of the IPOP-CMA-ES with the SPO algorithm. Experiments on the BBOB 2010 test cases suggest that the performance is at least competitive while the approach provides more options, e.g. setting more than one parameter at once. Essentially, we argue that SPO is a generalization of the IPOP heuristic and that the distinction between tuning and control is---although often useful---an artificial one.

11:30-11:55 **Exploratory Landscape Analysis**
Olaf Mersmann, Bernd Bischl, Heike Trautmann, Mike Preuss, Claus Weihs, Günter Rudolph

Exploratory Landscape Analysis (ELA) subsumes a number of techniques employed to obtain knowledge about the properties of an unknown optimization problem, especially insofar as these properties are important for the performance of optimization algorithms. Where in a first attempt, one could rely on high-level properties designed by experts, we approach the problem from a different angle here, namely by using relatively cheap low-level computer generated features. Interestingly, very few features are needed to separate the BBOB problem groups and also for relating a problem to high-level, expert designed features, paving the way for automatic algorithm selection.

11:55-12:20 **Niching Foundations: Basin Identification on Fixed-Property Generated Landscapes**
Mike Preuss, Catalin Stoean, Ruxandra Stoean

We investigate the effect of two suggested problem properties, basin size contrast and global to local optima contrast, on the performance of different basin identification methods, namely nearest-better clustering, detect-multimodal, and Jarvis-Patrick clustering, individually, or in combinations. Problem instances are generated and validated according to predefined property values and obtained result data is modeled in order to detect similarities that may be interpreted as effects of the stated properties. We also give recommendations concerning usage of basin identification methods in different situations.

EMO1: Diversity and Algorithmic Developments
Room: Munster
Session Chair: Evan J. Hughes (Cranfield University)

10:40-11:05 **Maximizing Population Diversity in Single-Objective Optimization**
Tamara Ulrich, Lothar Thiele

Typically, optimization attempts to find a solution which minimizes the given objective function. But often, it might also be useful to obtain a set of structurally very diverse solutions which all have acceptable objective values. With such a set, a decision maker would be given a choice of solutions to select from. In addition, he can learn about the optimization problem at hand by inspecting the diverse close-to-optimal solutions. This paper proposes NOAH, an evolutionary algorithm which solves a mixed multi-objective problem: Determine a maximally diverse set of solutions whose objective values are below a provided objective barrier. It does so by iteratively switching between objective value and set-diversity optimization while automatically adapting a constraint on the objective value until it reaches the

barrier. Tests on an nk-Landscapes problem and a 3-Sat problem as well as on a more realistic bridge construction problem show that the algorithm is able to produce high quality solutions with a significantly higher structural diversity than standard evolutionary algorithms.

11:05-11:30 **A Many-Objective Test Problem for Visually Examining Diversity Maintenance Behavior in a Decision Space**
Hisao Ishibuchi, Naoya Akedo, Yusuke Nojima

Recently distance minimization problems in a two-dimensional decision space have been utilized as many-objective test problems to visually examine the behavior of evolutionary multi-objective optimization (EMO) algorithms. Such a test problem is usually defined by a single polygon where the distance from a solution to each vertex is minimized in the decision space. We can easily generate different test problems from different polygons. We can also easily generate test problems with multiple equivalent Pareto optimal regions using multiple polygons of the same shape and the same size. Whereas these test problems have a number of advantages, they have no clear relevance to real-world situations since they are artificially generated unrealistic test problems. In this paper, we generate a distance minimization problem from a real-world map. Our test problem has four objectives, which are to minimize the distances to the nearest elementary school, junior high school, railway station, and convenience store. Using our test problem, we examine the behavior of well-known and frequently-used EMO algorithms in terms of their diversity maintenance ability in the two-dimensional decision space.

11:30-11:55 **Indicator-Based Differential Evolution Using Exclusive Hypervolume Approximation And Parallelization for Multi-core Processors**
Kiyoharu Tagawa, Hidehito Shimizu, Hiroyuki Nakamura

11:55-12:20 **Adaptive Multi-objective Differential Evolution with Stochastic Coding Strategy**
jing-hui zhong, Jun ZHANG

SS1: Self-* Search (Session 1)
Room: Leinster
Session Chair: Sebastien Verel (university of Nice Sophia Antipolis)

10:40-11:05 **GA-FreeCell: Evolving Solvers for the Game of FreeCell**
Achiya Elyasaf, Ami Hauptman, Moshe Sipper

11:05-11:30 **Self-Adaptive Mutation in the Differential Evolution**
Rodrigo César Pedrosa Silva, Rodolfo Lopes, Frederico Guimaraes

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11:30-11:55 **Towards the Development of Self-Ant Systems**
Jorge Tavares, Francisco Pereira

We propose a computational framework for the self-generation of components used by an Ant Colony Optimization algorithm. The approach relies on Strongly Typed Genetic Programming to automatically seek for effective update pheromone strategies. Best evolved strategies are then inserted in an Ant Colony Algorithm used to find good quality solutions for the Quadratic Assignment Problem. Results reveal that evolved update rules are competitive with human designed variants and can be effectively reused on different instances of the same problem. Moreover, we investigate the possibility of evolving general strategies that can be used across different optimization problems.

11:55-12:20 **DAMS: Distributed Adaptive Metaheuristic Selection**
Bilel Derbel, Sebastien Verel

ACO-SI1: Ant Colony Optimization and Swarm Intelligence (Session 1)
Room: Connaught Suite 1
Session Chair: Mohammad Majid al-Rifiae (Goldsmiths, University of London)

10:40-11:05 **A performance study on synchronous and asynchronous updates in particle swarm optimization**
Juan Rada-Vilela, Mengjie Zhang, Winston Seah

This work provides a further study on the difference between synchronous and asynchronous updates in Particle Swarm Optimization with different neighborhood sizes ranging from local best to global best. Ten well-known functions are used as benchmarks on both variants. Statistical tests performed on the results provide strong evidence to claim that synchronous updates yield in general better results with similar or even faster speed of convergence than its asynchronous counterpart, contrary to observations and conclusions of previous studies based solely on descriptive statistics.

11:05-11:30 **Particle Swarm Optimisation with Gradually Increasing Directed Neighbourhoods**
Hongliang Liu, Enda Howley, Jim Duggan

Particle swarm optimisation (PSO) is an intelligent random search algorithm, and the key to success is to effectively balance between the exploration of the solution space in the early stages and the exploitation of the solution space in the late stages. This paper presents a new dynamic topology called "gradually increasing directed neighbourhoods (GIDN)" that provides an effective way to balance between exploration and exploitation in the entire iteration process. In our model, each particle begins with a small number of connections and there are many small isolated swarms that improve the exploration ability. At each iteration, we gradually add a number of new connections between particles, which improves the ability of exploitation gradually. Furthermore, these connections among particles are created randomly and have directions. We formalise this topology using random graph representations. Experiments are conducted on 31 benchmark test functions to validate our proposed topology. The results show that the PSO with GIDN performs much better than a number of the state of the art algorithms on almost all of the 31 functions.

11:30-11:55 **An investigation into the merger of Stochastic Diffusion Search and Particle Swarm Optimisation**
Mohammad Majid al-Rifaie, Mark Bishop, Tim Blackwell

This study reports early research aimed at applying the powerful resource allocation mechanism deployed in Stochastic Diffusion Search (SDS) to the Particle Swarm Optimiser (PSO) metaheuristic, effectively merging the two swarm intelligence algorithms. The results reported herein suggest that the hybrid algorithm, exploiting information sharing between particles, has the potential to improve the optimisation capability of conventional PSOs.

11:55-12:20 **Detection of Continuous, Smooth and Thin Edges in Noisy Images Using Constrained Particle Swarm Optimisation**
Mahdi Setayesh, Mengjie Zhang, Mark Johnston

Detecting continuous edges is a hard problem especially in noisy images. We propose an algorithm based on particle swarm optimisation (PSO) to detect continuous and smooth edges in such images. A constrained PSO-based algorithm with a new penalised objective function and two constraints is proposed to overcome noise and reduce broken edges. The new algorithm is examined and compared with a modified version of the Canny algorithm, the robust rank order (RRO)-based algorithm, and an existing PSO-based algorithm on two sets of images with different types and levels of noise. The results suggest that the new algorithm detect edges more accurately than these three algorithms and the detected edges are smoother than those detected by the previous PSO algorithm and thinner than those detected by RRO.

RWA1: Networks
Room: Connaught Suite 2
Session Chair: Zorana Bankovic (Technical University of Madrid)

10:40-11:05 **Large Network Analysis for Fisheries Conservation using Coevolutionary Genetic Algorithms**
Garnett Wilson, Simon Harding, Orland Hoeber, Rodolphe Devillers, Wolfgang Banzhaf

Traditionally, a genetic algorithm is used to analyze networks by maximizing the modularity (Q) measure to create a favorable community division of a network. A coevolutionary algorithm is used here to not only find the appropriate community division for a network, but to find interesting networks containing substantial changes in data within a very large network space. The network is one of the largest, if not the largest, analyzed by evolutionary computation techniques to date and is created using a real world data set consisting of fisheries catch data in the north Atlantic Ocean off the coast of Canada. This work examines the quantitative performance of two types of coevolutionary algorithms against both a standard GA that uses a natural (but not necessarily optimal) division of the data set into

communities, and simulated annealing. The goal for all search algorithms was to automatically find anomalies (differences in catch) within the data. To measure practical usefulness of the system, a fisheries expert analyzed the best networks located by the search algorithms using an existing visualization software prototype. The expert indicated that a refined version of coevolutionary GA known as PAMDGA was found to most reliably locate subnetworks containing anomalies of biological relevance.

11:05-11:30 **A Non-dominated Neighbor Immune Algorithm for Community Detection in Networks**
Gong Maoguo, Tian Hou

The study of complex networks has received an enormous amount of attention from the scientific community in recent years. In this paper, we propose a multi-objective approach, named NNIA-Net, to discover communities in networks by employing Non-dominated Neighbor Immune Algorithm (NNIA). Our algorithm optimizes two objectives to find communities in networks—groups of vertices within which connections are dense, but between which connections are sparser. The method can produce a series of solutions which represent various divisions to the networks at different hierarchical levels. The number of subdivisions is automatically determined by the non-dominated individuals resulting from our algorithm. We demonstrate that our algorithm is highly efficient at discovering quality community structure in both synthetic and real-world network data. And also in this paper, a new initialization method is proposed to improve the traditional initialization method by about 30% in running time.

11:30-11:55 **Evolutionary Optimization of Layouts for High Density Free Space Optical Network Links**
Steffen Limmer, Dietmar Fey, Ulrich Lohmann, Jürgen Jahns

Electrical chip- and board-level connections are becoming more and more a bottleneck in computation. A solution to that problem could be optical connections, which allow a higher bandwidth. The usage of free space optics can avoid the problem of crosstalk and geometrical signal path crossings in systems with a high density of interconnections. The choice of appropriate design parameters, allowing the realization of such interconnections, is a complicated task. We present an evolutionary algorithm that is able to find these parameters. We describe the parallel execution of that algorithm and present optimization results.

11:55-12:20 **Improving Reputation Systems for Wireless Sensor Networks using Genetic Algorithms**
Zorana Bankovic, David Fraga, Juan Carlos Vallejo, Jose Manuel Moya

We propose to couple reputation systems for wireless sensor networks with a genetic algorithm in order to improve their time of response to adversarial activities. The reputation of each node is assigned by an unsupervised genetic algorithm trained for detecting outliers in the data. The response of the system consists in assigning low reputation values to the compromised nodes rendering them isolated from the network. The genetic algorithm uses the feature extraction process that does not capture the properties of the attacks, but rather relies on the existing temporal and spatial redundancy in sensor networks and tries to detect temporal and spatial inconsistencies in the sequences of sensed values and the routing paths used to forward these values to the base station. This solution offers many benefits: scalable solution, fast response to adversarial activities, ability to detect unknown attacks, high adaptability, and high ability in detecting and confining attacks. Comparing to the standard clustering algorithms, the benefit of this one is that it is not necessary to assign the number of clusters from the start. The solution is also robust to both parameter changes and the presence of large amounts of malicious data in the training and testing datasets.

ECOM1: Scheduling, Timetabling, and Constraint Satisfaction
Room: Elgin
Session Chair: Dan Qaurooni (Amirkabir University of Technology)

10:40-11:05 **A Memetic Algorithm for Course Timetabling**
Dan Qaurooni

Course timetabling consists in scheduling a sequence of lectures in a way that satisfies various constraints. In this paper, we develop and study the performance of a memetic algorithm that is designed to solve the course timetabling problem. Our aim here is twofold: to develop a competitive algorithm, and to investigate, more generally, the applicability of evolutionary algorithms to timetabling. To this end, the algorithm is first introduced and tested using a benchmark set. The obtained results are then compared with other algorithms in the literature, signifying the strong and weak points of our algorithm. More comprehensive analyses are performed in relation with another evolutionary

algorithm that uses strictly group-based operators. Empirical results and analyses, ultimately, lead us to question the exclusive use of group-based operators in solving timetabling problems.

11:05-11:30 **Tabu Search to Solve the Synchronized and Integrated Two-Level Lot Sizing and Scheduling Problem**
Claudio Toledo, Márcio Arantes, Paulo França

This paper proposes a tabu search approach to solve the Synchronized and Integrated Two-Level Lot Sizing and Scheduling Problem (SITLSP). It is a real-world problem, often found in soft drink companies, where the production process has two integrated levels with decisions concerning raw material storage and soft drink bottling. Lot sizing and scheduling of raw materials in tanks and products in bottling lines must be simultaneously determined. Real data provided by a soft drink company is used to make comparisons with a previous genetic algorithm. Computational results have demonstrated that tabu search outperformed genetic algorithm in all instances

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11:30-11:55 **Metaheuristic for Parallel Machines Scheduling with Resource-assignable Sequence Dependent Setup Times**
Luís Henrique Bicalho, André Gustavo dos Santos, José Elias Claudio Arroyo

In this paper, we describe and show the results of the combination of two metaheuristics to solve an unrelated parallel machines scheduling problem in which the setup times depend not only on the machine and job sequence, but also on the amount of resource assigned. This problem has been proposed recently on the literature and since then a couple of metaheuristics have been used to address it. The one proposed here, called GTS, consists of two phases: initially, some solutions are generated by the GRASP metaheuristic; subsequently, the Tabu Search (TS) is applied in the best solution found by GRASP. The numerical experiments show that the GTS heuristic was able to improve the results in 70% (251 out of 360) of the larger instances available in the literature.

11:55-12:20 **Heuristic Techniques for Variable and Value Ordering in CSPs**
Malek Mouhoub, Bahareh Jashmi

SBSE1: Search-Based Software Engineering (Session 1)
Room: O'Connell
Session Chair: Simon Poulding (University of York)

10:40-11:05 **Transition Coverage Testing for Simulink/Stateflow Models Using Messy Genetic Algorithms**
Mark Harman, Jungsup Oh, Shin Yoo

This paper introduces a messy GA for transition coverage of Simulink StateFlow models. We introduce a tool that implements our approach and evaluate it on three benchmark embedded system Simulink models. Our messy GA is able to achieve statistically significantly better coverage when compared to both random search and to a commercial tool for Simulink StateFlow model Testing.

11:05-11:30 **Search-based software testing and test data generation for a dynamic programming language**
Stefan Mairhofer, Robert Feldt, Richard Torkar

Manually creating test cases is time consuming and error prone. Search-based software testing can help automate this process and thus reduce time and effort and increase quality by automatically generating relevant test cases. Previous research has mainly focused on static programming languages and simple test data inputs such as numbers. This is not practical for dynamic programming languages that are increasingly used by software developers. Here we present an approach for search-based software testing for dynamically typed programming languages that can generate test scenarios and both simple and more complex test data. The approach is implemented as a tool, RuTeG, in and for the dynamic programming language Ruby. It combines an evolutionary search for test cases that give structural code coverage with a learning component to restrict the space of possible types of inputs. The latter is called for in dynamic languages since we cannot always know statically which types of objects are valid inputs. Experiments on 14 cases taken from real-world Ruby projects show that RuTeG achieves full or higher statement coverage on more cases and does so faster than randomly generated test cases.

11:30-11:55 **Establishing Integration Test Orders of Classes with Several Coupling Measures**
Wesley Assunção, Thelma Colanzi, Aurora Pozo, Silvia Vergilio

During the inter-class test, a common problem, named Class Integration and Test Order (CITO) problem, involves the determination of a test class order that minimizes stub creation effort, and consequently test costs. The approach based on Multi-Objective Evolutionary Algorithms (MOEAs) has achieved promising results because it allows the use of different factors/measures that can affect the stubbing process. Many times these factors are in conflict and usually there is no a single solution for the problem. Existing works on MOEAs present some limitations. The approach was evaluated with only two coupling measures, based on the number of attributes and methods of the stubs to be created, and only one evolutionary algorithm, NSGA-II. However, other MOEAs can be explored and also other measures. Considering this fact, this paper investigates the performance of two MOEAs: NSGA-II and SPEA2, for the CITO problem with four coupling measures (objectives) related to: attributes, methods, number of distinct return types and distinct parameter types. An experimental study was performed with four systems developed in Java. The results point out that the MOEAs can be efficiently used to solve this problem with several objectives, achieving solutions with balanced compromise between the measures, and of minimal effort to test.

11:55-12:20 **A Multi-Objective Evolutionary Algorithm to Obtain Test Cases With Variable Lengths**
Thaise Yano, Eliane Martins, Fabiano De Sousa

In this paper a new multi-objective implementation of the generalized extremal optimization (GEO) algorithm, named M-GEOvsl, is presented. It was developed primarily to be used as a test case generator to find transition paths from extended finite state machines (EFSM), taking into account not only the transition to be covered but also the minimization of the test length. M-GEOvsl has the capability to deal with strings that have a dynamic number of elements, making it possible to generate solutions with different lengths. The steps of the algorithm are described for a general multi-objective problem in which the solution length is a element to be optimized. Experiments were performed to generate test case from EFSM benchmark models using M-GEOvsl and the approach was compared with a related work.

ECP1 - Ask the Experts: EC questions from the audience
Room: Clanwilliam
Session Chair: Jorn Mehnen (Cranfield University)

Thursday 14 July 14:40 – 16:20

GA2: Applications
Room: Lansdowne
Session Chair: Evert Haasdijk (VU University Amsterdam)

14:40-15:05 **A Multiobjective Genetic Algorithm for Automatic Orthogonal Graph Drawing**
Bernadete Mendonça Neta, Gustavo Araújo, Frederico Guimarães, Renato Mesquita

We present a multiobjective hybrid technique for automatic orthogonal graph drawing. The new methodology combines the classical approach to automatic orthogonal graph drawings, the topology-shape-metric approach, and a multiobjective genetic algorithm based on the NSGA-II method. In the topology-shape-metric method, a xed planar embedding is obtained in the planarization step and submitted to the orthogonalization and compaction steps, in this order. In the hybrid approach, a greater number of planar embeddings is explored by varying the order of edges insertion that forms the planar embedding in the planarization step. The problem is then formulated as a multiobjective permutationbased combinatorial optimization problem, considering the minimization of the number of crossings, the number of bends and the area of the drawing. Solutions on the estimated Pareto front represent di erent drawings, that can be stored and selected by the user in real-time. We illustrate a possible multicriteria decision making based on fuzzy decision. The results show that the hybrid methodology using NSGA-II is able to nd good and diverse solutions, when compared to the traditional topology-shape-metric method.

15:05-15:30 **Stochastic Algorithms Assessment using Performance Profiles**
Lino Costa, Isabel Espírito Santo, Pedro Oliveira

Optimization with stochastic algorithms has become a relevant approach, specially, in problems with complex search spaces. Due to the stochastic nature of these algorithms, the assessment and comparison is not straightforward. Several performance measures have been proposed to overcome this difficulty. In this work, the use of performance profiles and an analysis integrating a trade-off between accuracy and precision are carried out for the comparison of two stochastic algorithms. Traditionally, performance profiles are used to compare deterministic algorithms performance. This methodology is applied in the comparison of two stochastic algorithms - genetic algorithms and simulated annealing. The results highlight the advantages and drawbacks of the proposed assessment.

15:30-15:55 **Locating Seismic-Sense Stations Through Genetic Algorithm**
Josafath Espinosa Ramos, Roberto Vázquez

Recent studies warn of a possible major earthquake off the coast of State of Guerrero, Mexico, so that, it turns important to alert the population as long as possible and avoid a great disaster. This requires the construction of seismic sense stations at strategical locations to detect earthquakes and issue a timely warning. For this particular research, the implementation of a genetic algorithm was chosen to determine the optimal location of seismic sensing stations in State of Guerrero. The number of earthquakes detected by the network's stations will be used as a reference point with respect to the currently installed seismic alert system (SAS) and will justify the use of genetic algorithms as a designing tool prior to the construction of other networks' stations in other states of Mexico. SAS stations and each solution proposed by genetic algorithm underwent a procedure in which it is simulated the occurrence of earthquakes obtained from the Mexico's National Seismological Service (SSN) database, to determinate its efficiency in terms of time to warn Mexico City.

15:55-16:20 **Adaptive and Hybrid Genetic Approaches for Estimating the Camera Motion from Image Point Correspondences**
Francisco Vasconcelos, Carlos Antunes, João Barreto

Rigid motion estimation from image point correspondences is an overconstrained problem that can be solved by minimizing an adequate cost function. Given the unreliable nature of image point correspondences, they must be divided into two categories: inliers and outliers. Finding the correct camera motion and discarding the outliers is a coupled problem usually solved by a random search of the solution space. This article proposes adaptive and hybrid genetic approaches to improve the efficiency of this search. We build on top of the GASAC algorithm that has been recently presented for solving problems in geometric computer vision. GASAC is modified to address the specific issues of camera motion estimation such as outlier ratios above 50% due to wide-baseline image acquisition and an adequate choice of a fitness function. In order to avoid local minima, we propose three adaptive strategies: varying the mutation probability, resampling the lowest ranked individuals, and using a hybrid approach that combines GASAC with

simulated annealing. Results are validated on publicly available benchmark images, and it is shown that the proposed genetic approaches outperform the standard RANSAC search used among computer vision practitioners.

GP2: Classification
Room: Pembroke
Session Chair: Leonardo Trujillo (Instituto Tecnológico de Tijuana)

14:40-15:05 **Evolving Ensembles in Multi-objective Genetic Programming for Classification with Unbalanced Data**
Urvesh Bhowan, Mengjie Zhang, Mark Johnston

Machine learning algorithms can suffer a performance bias when data sets are unbalanced. This paper proposes a Multi-objective Genetic Programming approach using negative correlation learning to evolve an accurate and diverse ensemble of non-dominated solutions where members vote on class membership. We also compare two popular Pareto-based fitness schemes on the classification tasks. Our results show that the evolved ensembles can achieve high accuracy on both classes using six unbalanced binary data sets, and that this performance is often better than many of its individual members.

15:05-15:30 **A Gaussian Groundplan Projection Area Model for Evolving Probabilistic Classifiers**
Theodoros Theodoridis

In this paper, an investigation of evolvable probabilistic classifiers is conducted, along with a thorough comparison between a classical Gaussian distance model, and the induction of Gaussian-to-circle projection model. The newly introduced model refers to a distance fitness measure, based on the projection of Gaussian distributions with geometric circles. The projection architecture aims to model and classify physical aggressive behaviours, by using biomechanical primitives. The primitives are being used to model the dynamics of the aggressive activities, by evolving biomechanical classifiers, which can discriminate between three behaviours and six actions. Both evolutionary models have shown strong discrimination performances on recognising the individual actions of each behaviour. From the comparison, the proposed model outperformed the classical one with three ensemble programs.

15:30-15:55 **Drawing Boundaries: Using Individual Evolved Class Boundaries for Binary Classification Problems**
Jeannie Fitzgerald, Conor Ryan

This paper describes a technique which can be used with Genetic Programming (GP) to remove implicit bias from binary classification tasks. Arbitrarily chosen class boundaries can introduce bias, but if individuals can choose their own boundaries, tailored to their function set, then their outputs are automatically scaled into a usable range.

Our system calculates the Evolved Class Boundary (ECB) for each individual in every generation, with the twin aims of reducing training times and improving test fitness. The method is tested on three benchmark binary classification data sets from the medical domain.

The results obtained suggest that the strategy can improve training, validation and test fitness, and can also result in smaller individuals as well as reduced training times. Our approach is compared with a standard benchmark GP system, as well as with over twenty other systems from the literature, many of which use highly tuned, non-EC methods, and is shown to yield superior results in many cases.

15:55-16:20 **Predicting problem difficulty for genetic programming applied to data classification**
Leonardo Trujillo, Yuliana Martínez, Edgar Galván-López, Pierrick Legrand

During the development of applied systems, an important problem that must be addressed is that of choosing the correct tools for a given domain or scenario. This general task has been addressed by the genetic programming (GP) community by attempting to determine, ormeasure, the intrinsic difficulty of a problem for canonical GP search. In this paper, we present an approach to predict the performance of GP applied to data classification, one of the most common problems of computer science in general. The novelty of our proposal is to use both statistical and data complexity descriptors of the problem, and from these to estimate the expected performance of a GP classifier. We derive two types of predictive models: linear regressionmodels and symbolic regressionmodels evolvedwith GP. The experimental results show that both approaches provide good estimates of classifier performance, using synthetic and real-world problems to validate our approach. In conclusion, we show that it is possible to accurately predict the expected performance of a GP classifier using a set of descriptors that characterize the problem data.

GA3: Philosophy/Theory
Room: Ulster
Session Chair: Thomas Jansen (University College Cork)

14:40-15:05 **On the Deleterious Effects of a priori Objectives on Evolution and Representation**
Brian Woolley, Kenneth Stanley

Evolutionary algorithms are often evaluated by measuring and comparing their ability to consistently reach objectives chosen a priori by researchers. Yet recent results from experiments without explicit a priori objectives, such as in Picbreeder and with the novelty search algorithm, raise the question of whether the very act of setting an objective is exacting a subtle price. Nature provides another hint that the reigning objective-based paradigm may be obfuscating evolutionary computation's true potential; after all, many of the greatest discoveries of natural evolution, such as flight and human-level intelligence, were not set as a priori objectives at the beginning of the search. The dangerous question is whether such triumphs only result because they were not objectives. To examine this question, this paper takes the unusual experimental approach of attempting to re-evolve images that were already once evolved on Picbreeder. In effect, images that were originally discovered serendipitously become a priori objectives for a new experiment with the same algorithm. Therefore, the resulting failure to reproduce the very same results cannot be blamed on the evolutionary algorithm, setting the stage for a contemplation of the price we pay for evaluating our algorithms only for their ability to achieve preconceived objectives.

15:05-15:30 **Critical Factors in the Performance of Novelty Search**
Steijn Kistemaker, Shimon Whiteson

Novelty search is a recently proposed method for evolutionary computation designed to avoid the problem of deception, in which the fitness function guides the search process away from global optima. Novelty search replaces fitness-based selection with novelty-based selection, where novelty is measured by comparing an individual's behavior to that of the current population and an archive of past novel individuals. Though there is substantial evidence that novelty search can overcome the problem of deception, the critical factors in its performance remain poorly understood. This paper helps to bridge this gap by analyzing how the behavior function, which maps each genotype to a behavior, affects performance. We propose the notion of descendant fitness probability (DFP), which describes how likely a genotype's descendants are to have a certain fitness, and formulate two hypotheses about when changes to the behavior function will improve novelty search's performance, based on the effect of those changes on behavior and DFP. Experiments in both artificial and deceptive maze domains provide substantial empirical support for these hypotheses.

15:30-15:55 **Mutation Rates of the (1+1)-EA on Bounded Pseudo-Boolean Functions**
Andrew Sutton, Darrell Whitley, Adele Howe

When the epistasis of the fitness function is bounded by a constant, we show that the expected fitness of an offspring of the (1+1)-EA can be efficiently computed for any point. Moreover, we show that, for any point, it is always possible to efficiently retrieve the "best" mutation rate at that point in the sense that the expected fitness of the resulting offspring is maximized.

On linear functions, it has been shown that a mutation rate of 1/n is provably optimal. On functions where epistasis is bounded by a constant k, we show that for sufficiently high fitness, the commonly used mutation rate of 1/n is also best, at least in terms of maximizing the expected fitness of the offspring. However, we find for certain ranges of the fitness function, a better mutation rate can be considerably higher, and can be found by solving for the real roots of a degree-k polynomial whose coefficients contain the nonzero Walsh coefficients of the fitness function. Simulation results on maximum k-satisfiability problems and NK-landscapes show that this expectation-maximized mutation rate can cause significant gains early in search.

15:55-16:20 **Black-Box Complexities of Combinatorial Problems**
Benjamin Doerr, Timo Kötzing, Johannes Lengler, Carola Winzen

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DETA1: Games
Room: Munster
Session Chair: Mike Preuss (TU Dortmund)

14:40-15:05 **Learning N-tuple Networks for Othello by Coevolutionary Gradient Search**
Krzysztof Krawiec, Marcin Szubert

We propose Coevolutionary Gradient Search, a blueprint for a family of iterative learning algorithms that combine elements of local search and population-based search. The approach is applied to learning Othello strategies represented as n -tuple networks, using different search operators and modes of learning We focus on the interplay between the continuous, directed, gradient-based search in the space of weights, and fitness-driven, combinatorial, coevolutionary search in the space of entire n -tuple networks. In an extensive experiment, we assess both the objective and relative performance of algorithms, concluding that the hybridization of search techniques improves the convergence. The best algorithms not only learn faster than constituent methods alone, but also produce top ranked strategies in the online Othello League.

15:05-15:30 **Evolving Patch-based Terrains for use in Video Games**
William Raffe, Fabio Zambetta, Xiaodong Li

Procedurally generating content for video games is gaining interest as an approach to mitigate rising development costs and meet users' expectations for a broader range of experiences. This paper explores the use of evolutionary algorithms to aid in the content generation process, especially the creation of three-dimensional terrain. We outline a prototype for the generation of in-game terrain by compiling smaller height-map patches that have been extracted from sample maps. Evolutionary algorithms are applied to this generation process by using crossover and mutation to evolve the layout of the patches. This paper demonstrates the benefits of an interactive two-level parent selection mechanism as well as how to seamlessly stitch patches of terrain together. This unique patch-based terrain model enhances control over the evolution process, allowing for terrain to be refined more intuitively to meet the user's expectations.

15:30-15:55 **Human-Assisted Neuroevolution through Shaping, Advice and Examples**
Igor Karpov, Vinod Valsalam, Risto Miikkulainen

Many different methods for combining human expertise with machine learning in general, and evolutionary computation in particular, are possible. Which of these methods work best, and do they outperform human design and machine design alone? In order to answer this question, a human-subject experiment for comparing human-assisted machine learning methods was conducted. Three different approaches, i.e. advice, shaping, and demonstration, were employed to assist a powerful machine learning technique (neuroevolution) on a collection of agent training tasks, and contrasted with both a completely manual approach (scripting) and a completely hands-off one (neuroevolution alone). The results show that, (1) human-assisted evolution outperforms a manual scripting approach, (2) unassisted evolution performs consistently well across domains, and (3) different methods of assisting neuroevolution outperform unassisted evolution on different tasks. If done right, human-assisted neuroevolution can therefore be a powerful technique for constructing intelligent agents.

15:55-16:20 **Evolving Neural Networks for Geometric Game-tree Pruning**
Jason Gauci, Kenneth Stanley

Abstract Game-tree search is the engine behind many computer game opponents. Traditional game-tree search algorithms decide which move to make based on simulating actions, evaluating future board states, and then applying the evaluations to estimate optimal play by all players. Yet the limiting factor of such algorithms is that the search space increases exponentially with the number of actions taken (i.e. the depth of the search). More recent research in game-tree search has revealed that even more important than evaluating future board states is effective pruning of the search space. Accordingly, this paper discusses Geometric Game-Tree Pruning (GGTP), a novel evolutionary method that learns to prune game trees based on geometric properties of the game board. The experiment compares Cake, a minimax-based game-tree search algorithm, with HyperNEAT-Cake, the original Cake algorithm combined with an indirectly encoded, evolved GGTP algorithm. The results show that HyperNEAT-Cake wins significantly more games than regular Cake playing against itself.

ECP2 - Managing an EC project for success
Room: Leinster
Session Chair: David Davis (VGO Associates)

ACO-SI2: Ant Colony Optimization and Swarm Intelligence (Session 2)
Room: Connaught Suite 1
Session Chair: Stephen Y. Chen (York University)

14:40-15:05 **Selection Strategies for Initial Positions and Initial Velocities in Multi-optima Particle Swarms**
Stephen Chen, James Montgomery

Standard particle swarm optimization cannot guarantee convergence to the global optimum in multi-modal search spaces, so multiple swarms can be useful. The multiple swarms all need initial positions and initial velocities for their particles. Several simple strategies to select initial positions and initial velocities are presented. A series of experiments isolates the effects of these selected initial positions and velocities compared to random initial positions and velocities. A first set of experiments shows how locust swarms benefit from "scouting" for initial positions and the use of initial velocities that "launch away" from the previous optimum. A second set of experiments show that the performance of WoSP (Waves of Swarm Particles) can be improved by using new search strategies to select the initial positions and initial velocities for the particles in its sub-swarms.

15:05-15:30 **Diversity Preservation Using Excited Particle Swarm Optimisation**
Shannon Pace, Clinton Woodward

15:30-15:55 **A Multi-objective Particle Swarm Optimizer Based on Decomposition**
Saúl Zapotecas Martínez, Carlos Coello Coello

The simplicity and success of particle swarm optimization (PSO) algorithms, has motivated researchers to extend the use of these techniques to the multi-objective optimization field. This paper presents a multi-objective particle swarm optimization (MOPSO) algorithm based on a decomposition approach, which is intended for solving continuous and unconstrained multi-objective optimization problems (MOPs). The proposed decomposition-based multi-objective particle swarm optimizer (dMOPSO), updates the position of each particle using a set of solutions considered as the global best according to the decomposition approach. dMOPSO is mainly characterized by the use of a memory reinitialization process which aims to provide diversity to the swarm. Our proposed approach is compared with respect to two decomposition-based multi-objective evolutionary algorithms (MOEAs) which are representative of the state-of-the-art in the area. Our results indicate that our proposed approach is competitive and it outperforms the two MOEAs with respect to which it was compared in most of the test problems adopted.

15:55-16:20 **Hybrid Particle Swarm Optimisation Based on History Information Sharing**
Wenlong Fu, Mark Johnston, Mengjie Zhang

Particle Swarm Optimisation (PSO) is an intelligent search method based on swarm intelligence and has been widely used in many fields. However it is also easily trapped in local optima. In order to find a global optimum, some evolutionary search operators used in multi-agent genetic algorithms are integrated into a novel hybrid PSO, with the expectation of effectively escaping from local optima. Particles share their history information and then update their positions using the latest and best history information. Some benchmark high-dimensional functions (from 20 to 10000 dimensions) are used to test the performance of the hybrid algorithms. The results demonstrate that the algorithm can solve high-dimensional nonlinear optimisation problems and that the number of function evaluations required to do so increases with function dimension at a sublinear rate.

RWA2: Finance & Linear Genetic Programming
Room: Connaught Suite 2

14:40-15:05 **An Evolutionary Approach to Design Dilation-Erosion Perceptrons for Stock Market Indices Forecasting**
Ricardo Araujo

In this work we present an evolutionary learning process using the covariance matrix adaptation evolutionary strategy (CMAES) to design the dilation-erosion perceptron (DEP) for stock market indices forecasting. Also, we have included an automatic phase fix procedure (APFP) into proposed learning process to eliminate time phase distortions observed in some forecasting problems. The main advantage of the DEP model designed by our learning process, apart from its higher forecasting performance, is do not request any methodology to overcome the nondifferentiability of morphological operators needed into classical gradient-based learning process of the DEP model. Besides, we present

an experimental analysis using two stock market indices, where five well-known performance metrics and an evaluation function are used to assess forecasting performance.

15:05-15:30 **Enhanced Rule Extraction and Classification Mechanism of Genetic Network Programming for Stock Trading Signal Generation**
Shingo Mabu, Kotaro Hirasawa

Evolutionary computation generally aims to create the optimal individual which represents optimal action rules when it is applied to agent systems. On the other hand, Genetic Network Programming (GNP) with rule accumulation extracts a large number of rules throughout the generations and stores them in rule pools. So, the concept of its individual evolution is different from general evolutionary computation. Concretely, the individuals of GNP with rule accumulation are regarded as evolving rule generators and the generated rules in the rule pools are regarded as solutions. In this paper, GNP with rule accumulation is enhanced in terms of its rule extraction and classification abilities for generating stock trading signals considering up and down trends and occurrence frequency of specific buying/selling timing. A large number of buying and selling rules are extracted by the individuals evolved in the training period. Then, a unique classification mechanism is used to appropriately judge whether the current stock market situation is buying/selling timing or not based on the extracted rules. In the testing simulations, the stock trading is carried out using the extracted rules and it is confirmed that the rule-based trading model shows higher profits than the conventional individual-based trading model.

15:30-15:55 **Stock Trading using Linear Genetic Programming with Multiple Time Frames**
Garnett Wilson, Derek Leblanc, Wolfgang Banzhaf

A number of researchers have attempted to take successful GP prediction systems, and make them even better through the use of filters. We investigate the use of a linear genetic programming (LGP) system that combines GP recommendations provided over multiple intraday time frames to produce one trading action. Four combinations of time frames stretching further into the past are examined. Two different decision mechanisms for evaluating the overall signal given the GP recommendations over all time frames are also examined, one based on majority vote and another based on temporal proximity to the buying decision. Results indicated that majority vote outperformed emphasis on proximity of time frames to the current trading decision. Analyses also indicated that longer time frame combinations were more conservative and outperformed shorter combinations for both overall upward and downward price trends.

15:55-16:20 **Scaling up a Hybrid Genetic/Linear Programming Algorithm**
Martin Serpell, Jim Smith, Alistair Clark, Andrea Staggemeier

This paper looks at the real world problem of statistical disclosure control. National Statistics Agencies are required to publish detailed statistics and simultaneously guarantee the confidentiality of the contributors. When published statistical tables contain magnitude data such as turnover or health statistics the preferred method is to suppress the values of cells which may reveal confidential information. However suppressing these `primary' cells alone will not guarantee protection due the presence of margin (row/column) totals and therefore other `secondary' cells must also be suppressed. A previously developed algorithm that hybridizes linear programming with a genetic algorithm has been shown to protect tables with up to 40,000 however Statistical Agencies are often required to protect tables with over 100,000 cells. This algorithms performance highly depended on the choice of mutation operator so firstly this dependency was removed. As the algorithm is unable to protect larger tables due to the time it takes for its fitness function (a linear program) to execute. A series of reformulations have been applied that significantly reduced its execution time which in turn greatly extend the capabilities of the algorithm to the point that it can now protect tables with up to one million cells.

ALIFE1: Robotics
Room: Elgin
Session Chair: Giovanni Squillero (ALIFE Chair)

14:40-15:05 **An Algorithm for Distributed On-line, On-board Evolutionary Robotics**
Giorgos Karafotias, Evert Haasdijk, A.E. Eiben

This paper presents part of an endeavor towards robots and robot collectives that can adapt their controllers autonomously and self-sufficiently and so independently learn to cope with situations unforeseen by their designers.

We introduce the Embodied Distributed Evolutionary Algorithm (EDEA) for on-line, on-board adaptation of robot controllers. We experimentally evaluate EDEA using a number of well-known tasks in the evolutionary robotics field to determine whether it is a viable implementation of on-line, on-board evolution. We compare it to the encapsulated mu+1 algorithm in terms of (the stability of) task performance and the sensitivity to parameter settings. Experiments show that EDEA provides an effective method for on-line, on-board adaptation of robot controllers. Compared to mu+1, in terms of performance there is no clear winner, but in terms of sensitivity to parameter settings and stability of performance EDEA is significantly better than mu+1.

15:05-15:30 **Agent Fitness Functions for Evolving Coordinated Sensor Networks**
Christian Roth, Matt Knudson, Kagan Tumer

15:30-15:55 **Racing to Improve On-line, On-board Evolutionary Robotics**
Evert Haasdijk, Arif Atta-ul-Qayyum, A.E. Eiben

In evolutionary robotics, robot controllers are often evolved in a separate development phase preceding actual deployment -- we call this off-line evolution. In on-line evolutionary robotics, by contrast, robot controllers adapt through evolution while the robots perform their proper tasks, not in a separate preliminary phase. In this case, individual robots can contain their own self-sufficient evolutionary algorithm (the encapsulated approach) where individuals are typically evaluated by means of a time sharing scheme: an individual is given the run of the robot for some amount of time and fitness corresponds to the robot's task performance in that period.

Racing was originally introduced as a model selection procedure that quickly discards clearly inferior models. We propose and experimentally validate racing as a technique to cut short the evaluation of poor individuals before the regular evaluation period expires. This allows an increase of the number of individuals evaluated per time unit, but it also increases the robot's actual performance by virtue of abandoning controllers that perform inadequately. Our experiments show that racing can improve the performance of robots that adapt their controllers by means of an on-line evolutionary algorithm significantly.

15:55-16:20 **Coupled Inverted Pendulums: A Benchmark for Evolving Decentral Controllers in Modular Robotics**
Heiko Hamann, Thomas Schmickl, Karl Crailsheim

The new field of self-reconfiguring modular robotics (i.e., decentrally controlled 'super-robots' based on autonomous, interacting robot modules with variable morphologies) calls for new paradigms of designing robot controllers. One option is the approach of evolutionary robotics. The challenge is to achieve high evaluation numbers with the available resources which may even affect the feasibility of the approach. Simulations are applied at least in a preliminary stage of research to lower these costs. However, even simulations are computationally expensive which gets even more burdensome once comprehensive studies and comparisons between different controller designs and approaches have to be done. Hence, a benchmark with low computational cost is needed that still contains the typical challenges of decentral control, is comparable, and easily manageable. We propose such a benchmark and report an empirical study of its characteristics including the transition from the single-robot setting to the multi-robot setting, typical local optima, and properties of adaptive walks through the fitness landscape.

SBSE2: Search-Based Software Engineering (Session 2)
Room: O'Connell
Session Chair: Shin Yoo (University College London)

14:40-15:05 **Multiobjective Simulation Optimisation in Software Project Management**
Daniel Rodriguez

Background: Traditionally, simulation has been used by project managers in optimising decision making. However, current simulation packages only include simulation optimisation which considers a single objective.

Aim: This paper aims to describe an approach that consists of using multiobjective optimisation techniques via simulation in order to help software project managers find the best values for initial team size and schedule estimates for a given project so that cost, time and productivity are optimised.

Method: Using a System Dynamics (SD) simulation model of a software project, the sensitivity of the output variables regarding productivity, cost and schedule using different initial team size and schedule estimations is determined. The

generated data is combined with a well-known multiobjective optimisation algorithm, called NSGA-II, to find optimal solutions for the output variables, i.e., development time, cost and productivity.

Results: The NSGA-II algorithm was able to quickly converge to a set of optimal solutions (Pareto front) composed of multiple and conflicting variables from a medium size software project simulation model.

Conclusions: Multiobjective optimisation and SD simulation modeling are complementary techniques that can generate the Pareto front needed by project managers for decision making. Furthermore, visual representations of such solutions in two or three dimensions are intuitive and can help project managers in their decision making process.

15:05-15:30 **QoS-Based Service Optimization using Differential Evolution**
Florin Pop, Denis Pallez, Marcel Cremene, Andrea Tettamanzi, Mihai Suciu, Mircea Vaida

The aim of our research is to find an efficient solution to the services QoS optimization problem. This NP-hard problem is well known in the service-oriented computing field: given a business workflow that includes a set of abstract services and a set of concrete service implementations for each abstract service, the goal is to find the optimal combination of concrete services. The majority of recent proposals indicate the Genetic Algorithms (GA) as the best approach for complex workflows. But this problem usually needs to be solved at runtime, a task for which GA may be too slow. We propose a new approach, based on Differential Evolution (DE), that converges faster and it is more scalable and robust than the existing solutions based on Genetic Algorithms.

15:30-15:55 **Evolving Relationships between Social Networks and Stakeholder Involvement in Software Projects**
Soo Ling Lim, Peter Bentley

Software projects often fail because stakeholder communication and involvement are inadequate. This paper proposes a novel approach to understand project social networks and their corresponding stakeholder involvement. The method uses five types of model social network, which represent various types of stake-holder activity in a project. It exploits evolutionary computation to correlate the social network of a real software project against each model. Experiments show that the real project most resembles the “rational” model where more highly connected stakeholders are more involved in the project.

Thursday 14 July 16:50 – 18:55

EDA1: Estimation of Distribution Algorithms (Session 1)
Room: Lansdowne
Session Chair: Peter A.N. Bosman (Centre for Mathematics and Computer Science)

16:50-17:15 **The essence of Real-valued Characteristic Function for Pairwise Relation in Linkage Learning for EDAs**
Jui-Ting Lee, Kai-Chun Fan, Tian-Li Yu

Existing EDAs learn linkages starting from pairwise interactions. The characteristic function which indicates the relations among variables is binary. In other words, the characteristic function indicates that there exist or not interactions among variables. Empirically, it can occur that two variables should be sometimes related but sometimes not. This paper introduces a real-valued characteristic function to illustrate this property of fuzziness. We examine all the possible binary models and real-valued models on a test problem. The results show that the optimal real-valued model is better than all the binary models. This paper also proposes a crossover method which is able to utilize the real-valued information. Experiments show that the proposed crossover could reduce the number of function evaluations up to four times. Moreover, this paper proposes an effective method to find a threshold for entropy based interaction-detection metric, and the found threshold can be utilized to provide real-valued models. Experiments show that the proposed crossover with the threshold-finding method works well.

17:15-17:40 **Parameter-less Local Optimizer with Linkage Identification for Deterministic Order-k Decomposable Problems**
Petr Pošík, Stanislav Vaníček

A simple parameter-less local optimizer able to solve deterministic problems with building blocks of bounded order is proposed in this article. The algorithm is able to learn and use linkage information during the run. The algorithm is algorithmically simple, easy to implement and with the exception of termination condition, it is completely parameter-free - there is thus no need to tune the population size and other parameters to the problem at hand. An empirical comparison on 3 decomposable functions, each with uniformly scaled building blocks of size 5 and 8, was carried out. The algorithm exhibits quadratic scaling with the problem dimensionality, but the comparison with the extended compact genetic algorithm and Bayesian optimization algorithm shows that it needs lower or comparable number of fitness function evaluations on the majority of functions for the tested problem dimensionalities. The results also suggest that the efficiency of the local optimizer compared to both the estimation-of-distribution algorithms should be better for problems sizes under at least a few hundreds of bits.

17:40-18:05 **Dependence Trees with Copula Selection for Continuous EDAs**
Rogelio Salinas-Gutierrez, Arturo Hernandez-Aguirre, Enrique Villa-Diharce

In this paper a new Estimation of Distribution Algorithm (EDA) is presented. The proposed algorithm employs a dependency tree as graphical model and bivariate copula functions for modeling relationships between pairwise variables. By selecting copula functions it is possible to build a very flexible joint distribution as probabilistic model. The experimental results show that the proposed algorithm has a better performance than EDAs based on Gaussian assumptions.

18:05-18:30 **Regularized k-order Markov Models in EDAs**
Roberto Santana, Hossein Karshenas, Concha Bielza, Pedro Larrañaga

k-order Markov models have been introduced to estimation of distribution algorithms (EDAs) to solve a particular class of optimization problems in which each variable depends on its previous k variables in a given, fixed order. In this paper we investigate the use of regularization as a way to approximate k-order Markov models when k is increased. The introduced regularized models are used to balance the complexity and accuracy of the k-order Markov models in the context of EDAs. We investigate the behavior of the EDAs in several instances of the hydrophobic-polar (HP) protein problem, a simplified protein folding model. Our preliminary results show that EDAs that use regularized approximations of the k-order Markov models offer a good compromise between complexity and efficiency, and could be an appropriate choice when the number of variables is increased.

18:30-18:55 **Use of Infeasible Individuals in Probabilistic Model Building Genetic Network Programming**
Xianneng Li, Shingo Mabu, Kotaro Hirasawa

Classical EDAs generally use truncation selection to emphasize to estimate the distribution of the feasible (good) individuals while ignoring the infeasible (bad) ones. However, various research in EAs reported that the infeasible individuals may affect and help the problem solving. This paper proposed a new method to use the infeasible individuals by studying the sub-structures rather than the entire individual structures to solve Reinforcement Learning (RL) problems, which generally factorize their entire solutions to the sequences of state-action pairs. This work was studied in a recent graph-based EDA named Probabilistic Model Building Genetic Network Programming (PMBGNP) which can solve RL problems successfully. The effectiveness of this work is verified in a real-world RL problem, i.e., robot control, comparing with some other related work.

GDS1: Generative and Developmental Systems (Session 1)
Room: Pembroke
Session Chair: Jeff Clune (Cornell University)

16:50-17:15 **Evolving Complete Robots with CPPN-NEAT: The Utility of Recurrent Connections**
Joshua Auerbach, Josh Bongard

17:15-17:40 **Constraining Connectivity to Encourage Modularity in HyperNEAT**
Phillip Verbancsics, Kenneth Stanley

A challenging goal of generative and developmental systems (GDS) is to effectively evolve neural networks as complex and capable as those found in nature. Two key properties of neural structures in nature are regularity and modularity. While HyperNEAT has proven capable of generating neural network connectivity patterns with regularities, its ability to evolve modularity remains in question. This paper investigates how altering the traditional approach to determining whether connections are expressed in HyperNEAT influences modularity. In particular, an extension is introduced called a Link Expression Output (HyperNEAT-LEO) that allows HyperNEAT to evolve the pattern of weights independently from the pattern of connection expression. Because HyperNEAT evolves such patterns as functions of geometry, important general topographic principles for organizing connectivity can be seeded into the initial population. For example, a key topographic concept in nature that encourages modularity is locality, that is, components of a module are located near each other. As experiments in this paper show, by seeding HyperNEAT with a bias towards local connectivity implemented through the LEO, modular structures arise naturally. Thus this paper provides an important clue to how an indirect encoding of network structure can be encouraged to evolve modularity.

17:40-18:05 **SMCGP2: Self Modifying Cartesian Genetic Programming in Two Dimensions**
Simon Harding, Julian Miller, Wolfgang Banzhaf

Self Modifying Cartesian Genetic Programming is a general purpose, graph-based, developmental form of Cartesian Genetic Programming. Using a combination of computational functions and special functions that can modify the phenotype at runtime, it has been employed to find general solutions to certain Boolean circuits and mathematical problems. In the present work, a new version, of SMCGP is proposed and demonstrated. Compared to the original SMCGP both the representation and the function set have been simplified. However, the new representation is also two-dimensional and it allows evolution and development to have more ways to solve a given problem. Under most situations we show that the new method makes the evolution of solutions to even parity and binary addition faster than with previous version of SMCGP.

18:05-18:30 **Using Feedback in a Regulatory Network Computational Device**
Rui Lopes

18:30-18:55 **On the Correlations Between Developmental Diversity and Genomic Composition**
Gunnar Tufte, Stefano Nichele

PS1: Parallel Evolutionary Systems (Session 1)
Room: Ulster
Session Chair: Pierre Collet (LIL-ULCO)

16:50-17:15 **ACO with Tabu Search on a GPU for Solving QAPs using Move-Cost Adjusted Thread Assignment**
Shigeyoshi Tsutsui, Noriyuki Fujimoto

17:15-17:40 **GPU-based Asynchronous Particle Swarm Optimization**
Luca Mussi, Youssef Nashed, Stefano Cagnoni

17:40-18:05 **Collaborative Multi-Swarm PSO for Task Matching using Graphics Processing Units**
Steven Solomon, Parimala Thulasiraman, Ruppa Thulasiram

18:05-18:30 **Parallel Divide-and-Evolve: Experiments with OpenMP on a Multicore Machine**
Caner Candan, Johann Dréo, Pierre Savéant, Vincent Vidal

Multicore machines are becoming a standard way to speed up the system performance. After having instantiated the evolutionary metaheuristic DAEX with the forward search YAHSP planner, we investigate on the global parallelism approach, which exploits the inherent parallelism of the individual evaluation. This paper describes a parallel shared-memory release of the DAEYAHSP planning system using the OpenMP directive-based API. The parallelization scheme applies at a high level abstraction and thus can be used by any evolutionary algorithm implemented with the Evolving Objects framework. The proof of concept is made on a 48-core machine with two planning tasks extracted from the last international planning competition. Experiments show significant speedups along the number of cores and along the size of the population. This preliminary work opens an avenue for parallelizing any evolutionary algorithm developed with EO.

18:30-18:55 **Effect of Topology on Diversity of Spatially-Structured Evolutionary Algorithms**
Matteo De Felice, Sandro Meloni, Stefano Panzieri

The aim of this work is an investigation on the effects of networks topology to spatially-structured evolutionary algorithms' dynamics. We applied the algorithm on a multi-modal optimization problem and we focused our study on convergence time and diversity of the solutions. Using as algorithms' underlying structure different networks models we studied the relationship between algorithm dynamic, i.e. convergence time, first hitting time and number of distinct optima found during the evolution, and networks' characteristics. A comparison with a panmictic evolutionary algorithm is made to study the effects of the introduction of a structure in the mating dynamics of the algorithm, resulting in an enhancement of diversity and containing the convergence time and first hitting time overhead. The results on a multi-modal combinatorial optimization problem show that the underlying network characteristics clearly influences algorithm dynamics and diversity of the solutions found.

EMO2: Applications I
Room: Munster
Session Chair: Irina Harris (University of Cardiff)

16:50-17:15 **Differential Evolution for RFID Antenna Design: A Comparison with Ant Colony Optimisation**
James Montgomery, Marcus Randall, Andrew Lewis

Differential evolution (DE) has been traditionally applied to solving benchmark continuous optimisation functions. To enable it to solve a combinatorially oriented design problem, such as the construction of effective radio frequency identification antennas, requires the development of a suitable encoding of the discrete decision variables in a continuous space. This study introduces an encoding that allows the algorithm to construct antennas of varying complexity and length. The DE algorithm developed is a multiobjective approach that maximises antenna efficiency and minimises resonant frequency. Its results are compared with those generated by a family of ant colony optimisation (ACO) metaheuristics that have formed the standard in this area. Results indicate that DE can work well on this problem and that the proposed solution encoding is suitable. On small antenna grid sizes (hence, smaller solution spaces) DE performs well in comparison to ACO, while as the solution space increases its relative performance decreases. However, as the ACO employs a local search operator that the DE currently does not, there is scope for further improvement to the DE approach.

17:15-17:40 **Using Pareto-Optimality for Solving Multi-Objective Unequal Area Facility Layout Problems**
Kazi Shah Nawaz Ripon, Kashif Nizam Khan, Kyrre Glette, Mats Hovin, Jim Torresen

A lot of optimal and heuristic algorithms for solving facility layout problem (FLP) have been developed in the past few decades. The majority of these approaches adopt a problem formulation known as the quadratic assignment problem (QAP) that is particularly suitable for equal area facilities. Unequal area FLP comprises a class of extremely difficult and widely applicable optimization problems arising in many diverse areas to meet the requirements for real-world applications. Unfortunately, most of these approaches are based on a single objective. While, the real-world FLPs are multi-objective by nature. Only very recently have meta-heuristics been designed and used in multi-objective FLP. They most often use the weighted sum method to combine the different objectives and thus, inherit the well-known problems of this method. As of now, there is no formal approach published for the unequal area multi-objective FLP to consider several objectives simultaneously. This paper presents an evolutionary approach for solving multi-objective unequal area FLP using multi-objective genetic algorithm that presents the layout as a set of Pareto-optimal solutions optimizing multiple objectives simultaneously. The experimental results show that the proposed approach performs well in dealing with multi-objective unequal area FLPs which better reflects the real-world scenario.

17:40-18:05 **Robust Design of a Re-entry Unmanned Space Vehicle by Multi-fidelity Evolution Control**
Edmondo Minisci, Massimiliano Vasile

The paper addresses the preliminary robust design of a small-medium scale re-entry unmanned space vehicle by means of a hybrid optimisation technique, where an evolutionary multi-objective algorithm is coupled with a direct transcription method for optimal control problems. Uncertainties on the aerodynamic forces and the vehicle mass are taken into account, and a Monte-Carlo sampling procedure is used to compute relevant statistical characteristics of the performance. Then the hybrid algorithm searches for geometries that minimise the mean value of the maximum heat flux, the mean value of the maximum achievable distance, and the variance of the maximum heat flux: the evolutionary part handles the shape parameters of the vehicle and the uncertain functions, while the direct transcription method generates the optimal control profiles for the re-entry trajectories of each individual of the population. During the optimisation process, artificial neural networks are used to approximate the aerodynamic forces required by the optimal control solver. The artificial neural networks are trained and updated by means of a multi-fidelity approach, where a low-fidelity analytical model is initially used to train the neural networks, and through the evolution a mix of analytical and computational fluid dynamic high-fidelity computations are used to update it.

18:05-18:30 **An Evolutionary Bi-Objective Approach to the Capacitated Facility Location Problem with Cost and CO_2 Emissions**
Irina Harris, Christine Mumford, Mohamed Naim

It is strategically important to design efficient and environmentally friendly distribution networks. In this paper we propose a new methodology for solving the capacitated facility location problem (CFLP) based on combining an evolutionary multi-objective algorithm with Lagrangian Relaxation for modelling large problem instances where financial costs and CO_2 emissions are considered simultaneously. Two levels of decision making are required: 1) which facilities to open from a set of potential sites, and 2) which customers to assign to which open facilities without violating their capacity. We choose SEAMO2 (Simple Evolutionary Multi-objective Optimization 2) as our multi-objective evolutionary algorithm to determine which facilities to open, because of its fast execution speed. For the allocation of customers to open facilities we use a Lagrangian Relaxation technique. We test our approach on large problem instances with realistic qualities, and validate solution quality by comparison with extreme solutions obtained using CPLEX.

18:30-18:55 **Investigating Relevant Aspects of MOEAs for Protein Structures Prediction**
Christiane Brasil, Alexandre Delbem, Daniel Bonetti

Several computational models have been developed in the context of the Protein Structure Prediction (PSP) problem. These methods involve a combinatorial problem and can be solved using optimizing algorithms in order to search for a global minimum energy. Genetic Algorithms (GAs) have produced relevant results in this area. Several energies in the protein are known to be directly responsible for the stabilization of their structures. These energies can represent each objective of multiobjective evolutionary algorithms. Many techniques, as the NSGA-II, are used to deal with the multi-objective approach for proteins, however they are not adequate for the PSP problem. New strategies have been sought with multiple criteria. In this context, this paper introduces the application of multiobjective evolutionary algorithm on tables algorithm to the PSP problem. In order to evaluate this approach, we compare it with the well-known NSGA-II

algorithm. The new approach investigated for PSP can generate protein structures with energies significantly smaller than those generated by the NSGA-II.

THEORY1: Best Paper Nominees
Room: Leinster
Session Chair: Per Kristian Lehre (DTU Informatics)

16:50-17:15 **Exact Computation of the Expectation Curves of the Bit-Flip Mutation using Landscapes Theory**
Francisco Chicano, Enrique Alba

Bit-flip mutation is a common operation when a genetic algorithm is applied to solve a binary problem. We use in this paper some results of landscapes' theory and Krawtchouk polynomials to exactly compute the expected value for the fitness of a mutated solution. We prove that this expectation is a polynomial in p, the probability of flipping a single bit. We analyze these polynomials and propose some applications of the obtained theoretical results.

17:15-17:40 **Unbiased Black Box Search Algorithms**
Jonathan Rowe, Michael Vose

We formalize the concept of an \emph{unbiased} black box algorithm, which generalises the idea previously introduced by Lehre and Witt. Our formalization of bias relates to the symmetry group of the problem class under consideration, establishing a connection with previous work on No Free Lunch. Our definition is motivated and justified by a series of results, including the outcome that given a biased algorithm, there exists a corresponding unbiased algorithm with the same expected behaviour (over the problem class) and equal or better worst-case performance. For the case of evolutionary algorithms, it is already known how to construct unbiased mutation and crossover operators, and we summarise those results.

17:40-18:05 **Too Fast Unbiased Black-Box Algorithms**
Benjamin Doerr, Timo Kötzing, Carola Winzen

Unbiased black-box complexity was recently introduced (Lehre and Witt, GECCO 2010) as a refined complexity model for randomized search heuristics. For several problems, this notion avoids the unrealistically low complexity results given by the classical model of Droste, Jansen and Wegener (Theor. Comput. Sci. 2006).

In this work, we show that for two natural problems the unbiased black-box complexity remains artificially small. For the classical jump-k test function class and for the well-known partition problem, we give mutation-only unbiased black-box algorithms having complexity O(n log n). Since the first problem usually needs Theta(n^k) time to be optimized and the second is even NP-complete, these black-box complexities seem not to indicate the true difficulty of the two problems for randomized search heuristics.

18:05-18:30 **An Analysis on Recombination in Multi-Objective Evolutionary Optimization**
Chao qian, Yang Yu, Zhi-Hua Zhou

18:30-18:55 **The Effects of Selection on Noisy Fitness Optimization**
Sergiu Goschin, Michael Littman, David Ackley

This paper examines how the choice of the selection mechanism in an evolutionary algorithm impacts the objective function it optimizes, specifically when the fitness function is noisy. We provide formal results showing that, in an abstract infinite-population model, proportional selection optimizes expected fitness, truncation selection optimizes order statistics, and tournament selection can oscillate. The ``winner'' in a population depends on the choice of selection rule, especially when fitness distributions differ between individuals resulting in variable risk. These findings are further developed through empirical results on a novel stochastic optimization problem called ``Die4'', which, while simple, extends existing benchmark problems by admitting a variety of interpretations of optimality.

BIO1: Bioinformatics, Computational, Systems, and Synthetic Biology (Session 1)
Room: Connaught Suite 1
Session Chair: William Bush (Vanderbilt University)

16:50-17:15 **Analysing Structure in Complex Networks Using Quality Functions Evolved by Genetic Programming**
Fergal Reid, Neil Hurley

17:15-17:40 **Evolving Random Boolean Networks with Genetic Algorithms for Regulatory Networks Reconstruction**
Mariana Mendoza, Ana Lucia Bazzan

The discovery of genetic regulatory networks' structure is of great interest for biologists and geneticists due to its pivotal role in organisms' metabolism. In the present paper we aim to investigate the inference power of genetic regulatory networks modeled as random boolean networks without the use of any prior biological information. The solutions space is explored by means of genetic algorithms and the methods's main goal is to find a consistent network given the target data, obtained from biological experiments. We show that this approach succeeds in reconstructing a model with satisfactory level of accuracy, representing an useful tool to guide biologist towards the most probable interactions between the target genes.

17:40-18:05 **The Power of Quantitative Grammatical Evolution Neural Networks to Detect Gene-Gene Interactions**
Nicholas Hardison, Alison Motsinger-Reif

Applying grammatical evolution to evolve neural networks (GENN) has been increasing used in genetic epidemiology to detect gene-gene or gene-environment interactions, also known as epistasis, in high dimensional data. GENN approaches have previously been shown to be highly successful in a range of simulated and real case-control studies, and has recently been applied to quantitative traits. In the current study, we evaluate the potential of an application of GENN to quantitative traits (QTGENN) to a range of simulated genetic models. We demonstrate the power of the approach, and compare this power to more traditional logistic regression analysis approaches. We find that the QTGENN approach has relatively high power to detect both single-locus models as well as several completely epistatic two-locus models, and favorable compare to the regression methods.

18:05-18:30 **Automated Modeling of Stochastic Reactions with Large Measurement Time-Gaps**
Michael Schmidt, Hod Lipson

Many systems, particularly in biology and chemistry, involve the interaction of discrete quantities, such as individual elements or molecules. When the total number of elements in the system is low, the impact of individual reactions becomes non-negligible and modeling requires the simulation of exact sequences of reactions. In this paper, we introduce an algorithm that can infer an exact stochastic reaction model based on sparse measurements of an evolving system of discrete quantities. The algorithm is based on simulating a candidate model to maximize the likelihood of the data. When the likelihood is too small to provide a search gradient, the algorithm uses the distance of the data to the model's estimated distribution. Results show that this method infers stochastic models reliably with both short time gaps between measurements of the system, and long time gaps where the system state has evolved qualitatively far between each measurement. Furthermore, the proposed metric outperforms optimizing on likelihood or distance components alone. Traits measured on the search novelty, age, and bloat suggest that this algorithm scales well to increasingly complex systems.

18:30-18:55 **Evolutionary-Based Iterative Local Search Algorithm for the Shortest Common Supersequence Problem**
Jiri Kubalik

RWA3: Algorithms
Room: Connaught Suite 2
Session Chair: Andrea G. B. Tettamanzi (Università degli Studi di Milano)

16:50-17:15 **Hyperheuristic Encoding Schemes for Multi-Objective Guillotine Cutting Problems**
Jesica de Armas, Gara Miranda, Coromoto León

Most research on Strip Packing and Cutting Stock problems are focused on single-objective formulations of the problems. However, in this work we deal with more general and practical variants of the problems, which not only seeks to optimise the usage of the raw material, but also the overall production process. The problems target the cutting of a large rectangle in a set of smaller rectangles using orthogonal guillotine cuts. Common approaches are

based in the minimisation of the strip length required to cut the whole set of demanded pieces (for strip problems) and in the maximisation of the total profit obtained from the available surface (for cutting stock problems). In this work we also deal with an extra objective which seeks to minimise the number of cuts involved in the cutting process, thus maximising the efficiency of the global production process. In order to obtain solutions to these problems, we have applied some of the most-known multi-objective evolutionary algorithms, since they have shown promising behaviours when tackling multi-objective real-world problems. We have designed and implemented hyperheuristic-based encodings as an alternative to combine heuristics in such a way that a heuristic's strengths make up for the drawbacks of another.

17:15-17:40 **Coevolving Collection Plans for UAS Constellations**
Daniel Stouch, Ernest Zeidman, William Callahan, Kirk McGraw, Marc Richards

We are developing a tool called SPARTEN (Spatially Produced Airspace Routes from Tactical Evolved Networks) that generates coordinated mission plans for constellations of unmanned aerial vehicles by allowing the mission planner to specify which objectives are important to them for each mission. Using an evolutionary algorithm-based, multi-objective optimization technique, we consider factors such as area of analysis coverage, restricted operating zones, maximum ground control station range, adverse weather effects, military terrain value, airspace collision avoidance, path linearity, named area of analysis emphasis, and sensor performance. By employing novel visualization techniques using geographic information systems to represent their effectiveness, we help the user “look under the hood” of the algorithms and understand the viability and effectiveness of the mission plans to identify coverage gaps and other inefficiencies. In this paper, we present our overall approach to the application of multi-objective evolutionary algorithms to the air mission planning domain, with a focus on the visualization components.

17:40-18:05 **An Efficient Evolutionary Algorithm for Solving Incrementally Structured Problems**
Jason Ansel, Maciej Pacula, Saman Amarasinghe, Una-May O'Reilly

Many real world problems have a structure where small problem instances are embedded within large problem instances, or where solution quality for large problem instances is loosely correlated to that of small problem instances. This structure can be exploited because smaller problem instances typically have smaller search spaces and are cheaper to evaluate. We present an evolutionary algorithm, INCREA, which is designed to incrementally solve a large, noisy, computationally expensive problem by deriving its initial population through recursively running itself on problem instances of smaller sizes. The INCREA algorithm also expands and shrinks its population each generation and cuts off work that doesn't appear to promise a fruitful result. For further efficiency, it addresses noisy solution quality efficiently by focusing on resolving it for small, potentially reusable solutions which have a much lower cost of evaluation. We compare INCREA to a general purpose evolutionary algorithm and find that in most cases INCREA arrives and the same solution in significantly less time.

18:05-18:30 **A Genetic Algorithm for the Freight Consolidation Problem with One-dimensional Container Loading**
Zizhen Zhang, Hu Qin, Andrew Lim

In today’s global free market, third-party logistics providers (3PLs) are becoming increasingly important. This paper studies a problem faced by a 3PL operating a warehouse in Shanghai, China, under contract with a major company for children’s clothing based in the United States. The problem involves the allocation of textile parcel shipments at the warehouse to shipping routes with different destination ports, where the shipments are destined for different retail stores. The shipments must be loaded into containers of varying sizes and costs, and the objective is to find an allocation that minimizes the total container transportation and parcel delivery costs. We formulate the problem into an integer linear programming model, and also propose a genetic algorithm approach to solve the problem practically. A demonstration of a good solution to this problem was a decisive factor in the awarding of the contract to the 3PL in question.

18:30-18:55 **Coastal Current Prediction using CMA Evolution Strategies**
Andrea Tettamanzi, Christel Dartigues-Pallez, Célia da Costa Pereira, Denis Pallez, Philippe Gourbesville

We propose a data-driven evolutionary approach to the modeling of marine currents in the Bay of Monaco. The CMA evolution strategy is used to optimize the parameters of a predictive model that may be used as a surrogate of expensive and time-consuming finite-element simulations. The models obtained are reasonably accurate and easy to interpret.

ECOM2: Graph and Knapsack Problems
Room: Elgin
Session Chair: Ruben Ruiz-Torrubiano (Universidad Autonoma Madrid)

16:50-17:15 **Population-based and Learning-based Metaheuristic Algorithms for the Graph Coloring Problem**
David Chalupa

In this paper, two new metaheuristic algorithms for the graph coloring problem are introduced. The first one is a multiagent evolutionary algorithm (MEA), using a multiagent system designed to manage multiple agents representing tabu search procedures. The second one is a pseudo-reactive tabu search (PRTS), introducing a new on-line learning strategy to balance its own parameter settings. While both algorithms empirically outperform basic tabu search algorithm TabuCol on the well-established DIMACS instances, they achieve this by using different strategies. While MEA is more complex, population-based method suitable for benchmarking experiments, PRTS is a simpler, more automated learning-based local search technique.

17:15-17:40 **Genetic Approaches for Graph Partitioning: A Survey**
Jin Kim, Inwook Hwang, Yong-Hyuk Kim, Byung-Ro Moon

The graph partitioning problem occurs in numerous applications such as circuit placement, matrix factorization, load balancing, and community detection. For this problem, genetic algorithm is a representative approach with competitive performance, and many related papers have been published. Although there are a number of surveys on graph partitioning, none of them deals with genetic algorithms in much detail. In this survey, we discuss a number of problem-specific issues in applying genetic algorithms to the graph partitioning problem; the issues include encoding, crossover, normalization, and balancing.

17:40-18:05 **A Hybrid Heuristic Approach for Solving the Generalized Traveling Salesman Problem**
Petrica Pop, Serban Iordache

The generalized traveling salesman problem (GTSP) is an NP-hard problem that extends the classical traveling salesman problem by partitioning the nodes into clusters and looking for a minimum Hamiltonian tour visiting exactly one node from each cluster. In this paper, we combine the consultant-guided search technique with a local-global approach in order to solve efficiently the generalized traveling salesman problem. We use candidate lists in order to reduce the search space and we introduce efficient variants of 2-opt and 3-opt local search in order to improve the solutions. The resulting algorithm is applied to Euclidean GTSP instances derived from the TSPLIB library. The experimental results show that our algorithm is able to compete with the best existing algorithms in terms of solution quality and running time.

18:05-18:30 **The TransRAR Crossover Operator for Genetic Algorithms with Set Encoding**
Ruben Ruiz-Torrubiano, Alberto Suarez

This work introduces a new crossover operator specially designed to be used in genetic algorithms (GAs) that encode candidate solutions as sets of fixed cardinality. The Transmitting Random Assortment Recombination (TransRAR) operator proceeds by taking elements from a multiset, which is built by the union of the parent chromosomes allowing repeated elements. If an element that is present in both parents is drawn, it is accepted with probability 1. Elements that belong to only one of the parents are accepted with a probability p, smaller than 1. The performance of this novel crossover operator is assessed in experiments on synthetic and in real-world problems. In these problems, GAs that employ this type of crossover outperform those that use alternative operators for sets, such as Random Assortment Recombination (RAR), Random Respectful Recombination (R^3) or Random Transmitting Recombination (RTR). Furthermore, TransRAR can be implemented very efficiently and is faster than RAR, its closest competitor in terms of overall performance.

18:30-18:55 **A Hybrid Evolutionary Metaheuristics (HEMH) Applied On 0/1 Multi-objective Knapsack Problems**
Ahmed Kafafy, Ahmed Bounekkar, Stéphane Bonnevay

GBML1: Genetics Based Machine Learning (Session 1)
Room: O'Connell
Session Chair: Martin Butz (gbml chair)

16:50-17:15 **Fleet Estimation for Defence Logistics Using Learning Classifier Systems**
Kamran Shafi, Axel Bender, Hussein Abbass

Predicting optimal size and mix of future transportation fleets for defence logistics is of paramount importance. It allows military strategists to efficiently and cost effectively plan for the capabilities that the defence force may require in future. However, this prediction task faces the classical challenge of uncertain future owing to a changing environment and adaptive adversaries. In addition, optimising the mix of a large heterogeneous transport fleet is inherently a complex problem. Heuristic-based optimisation techniques are often applied that provide approximate solutions to support decision making process for such complex problems. One shortcoming of the heuristic based methods is that they act as black boxes and do not provide any insight into the relationships between the future scenarios and the corresponding solutions. In this paper, we employ an evolutionary rule-based approach to overcome this problem. A Learning Classifier System (LCS) is used to learn interpretable patterns of future scenarios and associate them with the best performing heuristics under given conditions. The performance of heuristics is judged under multiple objectives. This is achieved by introducing two new reward functions that assign credits to classifiers based on the multi objective performance of predicted heuristics. Results show that LCS can generalise well to relate scenario characteristics with Pareto optimal heuristics.

17:15-17:40 **Interaction Detection for Hybrid Decomposable Problems**
Hadi Sharifi, Amin Nikanjam, Adel Torkaman Rahmani

In this paper, we present a perturbation-based linkage identification algorithm that employs a novel metric to detect linkages. The proposed metric is a combination of linearity and multiplicatively relationship. The proposed method is called Interaction Detection for Hybrid Decomposable Problems (IDHDP) algorithm. Our algorithm can be applied to the additive and multiplicative decomposable problems and problems that have both kind of decomposability, i.e. hybrid decomposability. By using IDHDP, an interaction matrix is computed that represents the degree of interaction between pairs of loci. To extract linkage groups from the interaction matrix, a local threshold is calculated for each variable by the two-means algorithm. We apply IDHDP to problems with different type of decomposability. A comparison with an existing algorithm showed the efficiency of IDHDP. Next we apply IDHDP to a quasi-decomposable problem and a comparison with LIEM revealed that IDHDP can obtain more accurate linkage groups.

17:40-18:05 **Towards Final Rule Set Reduction in XCS: A Fuzzy Representation Approach**
Farzaneh Shoeleh, Ali Hamzeh, Sattar Hashemi

18:05-18:30 **Flexible Learning of k-Dependence Bayesian Network Classifiers**
Arcadio Rubio García, José Gámez Martín

In this paper we present an extension to the classical k-dependence Bayesian network classifier algorithm.

The original method intends to work for the whole continuum of Bayesian classifiers, from naïve Bayes to unrestricted networks. In our experience, it performs well for low values of k. However, the algorithm tends to degrade in more complex spaces, as it greedily tries to add k dependencies to all feature nodes of the resulting net.

We try to overcome this limitation by seeking for optimal values of k on a feature per feature basis. At the same time, we look for the best feature ordering. That is, we try to estimate the joint probability distribution of optimal feature orderings and individual number of dependencies. We feel that this preserves the essence of the original algorithm, while providing notable performance improvements.

18:30-18:55 **PSO Aided k-Means Clustering: Introducing Connectivity in k-Means**
Mihaela Breaban, Henri Luchian

Friday 15 July 10:40 – 12:20

GA4: Linkage (Best Paper Nominees)
Room: Lansdowne
Session Chair: Jim Smith (University of the West of England)

10:40-11:05 **Analysis of Epistasis Correlation on NK Landscapes with Nearest-Neighbor Interactions**
Martin Pelikan

Epistasis correlation is a measure that estimates the strength of interactions between problem variables. This paper presents an empirical study of epistasis correlation on a large number of random problem instances of NK landscapes with nearest neighbor interactions. The results are analyzed with respect to the performance of hybrid variants of two evolutionary algorithms: (1) the genetic algorithm with uniform crossover and (2) the hierarchical Bayesian optimization algorithm.

11:05-11:30 **A Surrogate-assisted Linkage Inference Approach in Genetic Algorithms**
Tomasz Oliwa, Khaled Rasheed

Linkage in terms of genetic algorithms is a measure of interdependence of groups of genes. When linkage exists, the fitness contribution for one gene depends on the allele setting of another. Our approach, a surrogate-assisted linkage inference genetic algorithm (SALIGA), is able to detect linkage for real-valued alleles. It uses a perturbation-based method with the aid of fitness surrogates and clustering techniques. Experimental results of linkage inference on several synthetic fitness functions are provided. The results demonstrate that SALIGA is able to reliably infer linkage and will correctly group the genes of an individual according to their linkage group membership,while using fewer fitness evaluations through a surrogate model. In addition, our results are augmented with a discussion regarding linkage detection through feature selection.

11:30-11:55 **Pairwise and Problem-Specific Distance Metrics in the Linkage Tree Genetic Algorithm**
Martin Pelikan, Mark Hauschild, Dirk Thierens

The linkage tree genetic algorithm (LTGA) identifies linkages between problem variables using an agglomerative hierarchical clustering algorithm and linkage trees. This enables LTGA to solve many decomposable problems that are difficult with more conventional genetic algorithms. The goal of this paper is two-fold: (1) Present a thorough empirical evaluation of LTGA on a large set of problem instances of additively decomposable problems and (2) speed up the clustering algorithm used to build the linkage trees in LTGA by using a pairwise and a problem-specific metric.

11:55-12:20 **How Crossover Helps in Pseudo-Boolean Optimization**
Timo Kötzing, Dirk Sudholt, Madeleine Theile

Understanding the impact of crossover on performance is a major problem in the theory of genetic algorithms (GAs). We present new insight on working principles of crossover by analyzing the performance of crossover-based GAs on the simple functions ONEMAX and Jump.

First, we assess the potential speedup by crossover when combined with a fitness-invariant bit shuffling operator that simulates a lineage of independent evolution on a function of unitation. Theoretical and empirical results show drastic speedups for both functions.

Second, we consider a simple GA without shuffling and investigate the interplay of mutation and crossover on Jump. If the crossover probability is small, subsequent mutations create sufficient diversity, even for very small populations. Contrarily, with high crossover probabilities crossover tends to lose diversity more quickly than mutation can create it. This has a drastic impact on the performance on Jump. We complement our theoretical findings by Monte Carlo simulations on the population diversity.

GP3: Representations
Room: Pembroke
Session Chair: Anthony Brabazon (University College Dublin)

10:40-11:05 **Examining the Landscape of Semantic Similarity based Mutation**
Quang Uy Nguyen, Xuan Hoai Nguyen, Michael O'Neill

This paper examines how the semantic locality of a search operator affects the fitness landscape of Genetic Programming (GP). We compare the fitness landscapes of GP search when standard subtree mutation and a recently proposed semantic-based mutation, Semantic Similarity-based Mutation (SSM), are used. The comparison is based on two well-studied fitness landscape measures, namely, the autocorrelation function and information content. The experiments were conducted on a family of symbolic regression problems with increasing degrees of difficulty. The results show that SSM helps to significantly smooth out the fitness landscape of GP compared to standard subtree mutation. This gives an explanation for the better performance of SSM over standard subtree mutation operator.

11:05-11:30 **Mutation as a Diversity Enhancing Mechanism in Genetic Programming**
David Jackson

In various evolutionary computing algorithms, mutation operators are employed as a means of preserving diversity of populations. In genetic programming (GP), by contrast, mutation tends to be viewed as offering little benefit, to the extent that it is often not implemented in GP systems. We investigate the role of mutation in GP, and attempt to answer questions regarding its effectiveness as a means for enhancing diversity, and the consequent effects of any such diversity promotion on the solution finding performance of the algorithm. We find that mutation can be beneficial for GP, but subject to the proviso that it be tailored to enhance particular forms of diversity.

11:30-11:55 **Semantically Embedded Genetic Programming: Automated Design of Abstract Program Representations**
Krzysztof Krawiec

We propose an alternative program representation that relies on automatic design of semantic-based embeddings of genetic programs into discrete multidimensional spaces. The embedding imposes a well-structured hypercube topology on the search space, endows it with a semantic-aware neighbourhood, and enables convenient search using Cartesian coordinates. The embedding algorithm consists in locality-driven optimization and operates in abstraction from a specific fitness function, improving locality of all possible fitness landscapes simultaneously. In experimental part, we validate the approach on the domain of symbolic regression and demonstrate on a large sample of problem instances that semantic embedding provides better search performance than the original program space. Moreover, we show also that semantic embedding of small programs can be effectively exploited in a compositional manner to search the space of large compound programs.

11:55-12:20 **A Comparison of GE and TAGE in Dynamic Environments**
Eoin Murphy, Michael O'Neill, Anthony Brabazon

The lack of study of genetic programming in dynamic environments is recognised as a known issue in the field of genetic programming. This study compares the performance of two forms of genetic programming, grammatical evolution and a variation of grammatical evolution which uses tree-adjunct grammars, on a series of dynamic problems. Mean best fitness plots for the two representations are analysed and compared.

GA5: Representations
Room: Ulster
Session Chair: Franz Rothlauf (University of Mainz)

10:40-11:05 **An Analysis of Multi-chromosome GAs on Deceptive Problems**
Menglin Li, Colm O'Riordan, Seamus Hill

This paper discusses a new approach to using GAs to solve deceptive fitness landscape by incorporating mechanisms to control the convergence direction instead of simply increasing the population diversity. Supported by experiments, the deceptive problem's solution space has been analysed. Based on this analysis, the authors discuss the diversity and convergence of genetic algorithms, and then explain why GAs can have difficulty in solving different kinds of deceptive problems. Two new multi-chromosome genetic algorithms have been designed to accelerate the GA's searching speed in more complicated deceptive problems by looking for a balance between diversity and convergence. Five different

problems have been used in the testing. The results show that the lack of diversity is not the only reason that normal GAs have difficulty in solving deceptive problems but that convergence direction is also important.

11:05-11:30 **Index-based Genetic Algorithm for Continuous Optimization Problems**
Ni Chen, Jun ZHANG

Accelerating the convergence of Genetic Algorithms (GAs) is a significant and promising research direction of evolutionary computation. In this paper, a novel Index-based GA (termed IndexGA) is proposed for the acceleration of convergence by reducing the number of fitness evaluations (FEs) in the reproduction procedure, i.e. the process of crossover and mutation. The algorithm divides the solution space into multiple regions, each represented by a unique index. Individuals in the IndexGA are redefined as indexes instead of solutions. In the reproduction procedure, an evaluated region is never evaluated again, and the fitness is directly obtained from the memory. Moreover, to improve the fitness of the promising regions, the algorithm performs an orthogonal local search (OLS) operator on the best-so-far region in each generation. Numerical experiments have been conducted on 13 benchmark functions and an application problem of power electronic circuit (PEC) to investigate the performance of IndexGA. The results show that the index-based strategy and the OLS in IndexGA significantly enhance the performance of GAs in terms of both convergence rate and solution accuracy.

11:30-11:55 **Memory-based CHC Algorithms for Dynamic Environments**
Anabela Simões, Ernesto Costa

The CHC algorithm uses an elitist selection method that, combined with an incest prevention mechanism and a method to diverge the population whenever it converges, allows the maintenance of the population diversity. This algorithm was successfully used in the past for static optimization problems. The use of memory in Evolutionary Algorithms has been proved to be advantageous when dealing with dynamic optimization problems. In this paper we investigate the use of three different explicit memory strategies included in the CHC algorithm. These strategies - direct, immigrant and associative - combined with the CHC algorithm are used to solve different instances of the dynamic Traveling Salesman Problem in cyclic, noisy and random environments. The experimental results, statistically validated, show the efficiency, robustness and adaptability of the memory-based CHC algorithms solving different dynamic traveling salesman problems.

11:55-12:20 **ESDL: A Simple Description Language for Population-Based Evolutionary Computation**
Steve Dower, Clinton Woodward

A large proportion of publications in the field of evolutionary computation describe algorithm specialisation and experimentation. Algorithms are variously described using text, tables, flowcharts, functions or pseudocode. However, ambiguity that can limit the efficiency of communication is common. Evolutionary System Definition Language (ESDL) is a conceptual model and language for describing evolutionary systems efficiently and with reduced ambiguity, including systems with multiple populations and adaptive parameters. ESDL can be machine-interpreted to run systems without requiring a hand-coded implementation. The syntax is distinct from existing notations and easily recognisable. This paper describes the case for ESDL and provides an overview of ESDL and usage examples.

EMO3: Decision Making and Visualization
Room: Munster
Session Chair: Carlos A. Coello Coello (CINVESTAV-IPN)

10:40-11:05 **Evolving Policies for Multi-Reward Partially Observable Markov Decision Processes (MR-POMDPs)**
Harold Soh, Yiannis Demiris

Plans and decisions in many real-world scenarios are made under uncertainty and to satisfy multiple, possibly conflicting, objectives. In this work, we contribute the multi-reward partially-observable Markov decision process (MR-POMDP) as a general modelling framework. To solve MR-POMDPs, we present two hybrid (memetic) multi-objective evolutionary algorithms that generate non-dominated sets of policies (in the form of stochastic finite state controllers). Performance comparisons between the algorithms on multi-objective problems in robotics (with 2, 3 and 5 objectives), web-advertising (with 3, 4 and 5 objectives) and infectious disease control (with 3 objectives), revealed that memetic variants outperformed their original counterparts. We anticipate that the MR-POMDP along with multi-objective evolutionary solvers will prove useful in a variety of theoretical and real-world applications.

11:05-11:30 **Interactive MOEA/D for Multi-objective Decision Making**
Gong Maoguo, Fang Liu, Wei Zhang, Qingfu Zhang

In this paper, an interactive version of the decomposition based multiobjective evolutionary algorithm (iMOEA/D) is proposed for interaction between the decision maker (DM) and the algorithm. In MOEA/D, a multi-objective problem (MOP) can be decomposed into several single-objective sub-problems. Thus, the preference incorporation mechanism in our algorithm is implemented by selecting the preferred sub-problems rather than the preferred region in the objective space. At each interaction, iMOEA/D offers a set of current solutions and asks the DM to choose the most preferred one. Then, the search will be guided to the neighborhood of the selected. iMOEA/D is tested on some benchmark problems, and various utility functions are used to simulate the DM's responses. The experimental studies show that iMOEA/D can handle the preference information very well and successfully converge to the expected preferred regions.

11:30-11:55 **Interactive Evolutionary Algorithms for Multi-objective Optimization Problems with Interval Parameters Based on Preference Polyhedron**
Dui-wei Gong, Jing Sun

Multi-objective optimization (MOO) problems with interval parameters are very popular and important uncertain optimization problems in real-world applications. However, previous evolutionary optimization methods aim to find a set of well-converged and well-diversified Pareto-optimal solutions. We present a novel interactive evolutionary algorithm (IEA) incorporating an optimization-cum-decision-making procedure to obtain a most preferred solution that fits a decision-maker (DM)'s preferences. First, a preference polyhedron for an optimization problem with interval parameters is theorized. Then, an IEA for MOO problems with interval parameters based on the above preference polyhedron is proposed. The algorithm periodically provides part non-dominated solutions to a DM, and a preference polyhedron, based on which evolutionary individuals are ranked, is constructed taking the worst solution as vertex. Finally, our method is applied to two bi-objective optimization problems with interval parameters, and the experimental results confirm the advantages of our method.

11:55-12:20 **Visualizing 4D Approximation Sets of Multiobjective Optimizers with Prosections**
Tea Tusar, Bogdan Filipic

SS2: Self-* Search (Session 2)
Room: Leinster
Session Chair: Andrew J Parkes (University of Nottingham, UK)

10:40-11:05 **Generalized Adaptive Pursuit Algorithm for Genetic Pareto local search algorithms**
Madalina Drugan, Dirk Thierens

Genetic Pareto local search (GPLS) are Pareto local search algorithms that restart the local search from solutions generated with genetic operators. The performance of GPLSs is sensitive to the choice of parameters for the genetic operators. We design adaptive algorithms for GPLSs that select on-line genetic operators to restart the local search. We call them adaptive GPLS (aGPLS). The standard adaptative pursuit technique (AP) shows preference for a single operator a relatively long time and it is incapable of simultaneously exploiting multiple operators. We generalize AP by allowing any target distribution for operator selection probabilities. We call this the generalized adaptive pursuit algorithm (GAPA). We propose and experimentally test two instances of GAPA. Assuming that there are sets of useful operators, the multi-operator AP pursuits more than one operator. The multi-layer AP scales up the pursuit algorithm by optimizing a smaller number of operators. We show that the probability matching and multi-armed bandit strategies, with particular settings, can be integrated in the GAPA framework and used with the proposed GAPA instances. Experimentally, we show on bi-objective Quadratic assignment problem (bQAP) instances with a large number of facilities and high correlation that aGPLSs are the most performant GPLS algorithms tested.

11:05-11:30 **Policy Learning in Resource-Constrained Optimization**
Richard Allmendinger, Joshua Knowles

11:30-11:55 **The Road to VEGAS: Guiding the Search over Neutral Networks**
Marie-Eleonore Marmion, Clarisse Dhaenens, Arnaud Liefooghe, Sebastien Verel, laetitia jourdan

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11:55-12:20 **Adaptive Iterated Local Search for Cross-domain Optimisation**
Edmund Burke, Gabriela Ochoa, James Walker, Michel Gendreau

We propose two adaptive variants of a multiple neighborhood iterated local search algorithm. Iterated local search is a simple yet powerful algorithm. Its search strategy consists of applying small perturbations on local optima and restarting local search from the perturbed solution. The adaptive variants employ online learning techniques, also called adaptive operation selection, in order to select which perturbation to apply at each iteration step from a set of available move operators. Using a common software interface (the HyFlex framework) the proposed algorithms are tested across four hard combinatorial optimisation problems: permutation flow shop, 1D bin packing, maximum satisfiability, and personnel scheduling (including instance data from real-world industrial applications). Using the HyFlex framework, exactly the same high level search strategy can be applied to all the domains and instances. Our results confirm that the adaptive variants outperform a baseline iterated local search with uniformly at random selection of the move operators. Moreover, the best variant produced new best-known solutions on two instances of the personnel scheduling problem. We argue that the adaptive algorithms proposed are general yet powerful, and contribute to the goal of increasing the generality and applicability of heuristic search.

BIO2: Bioinformatics, Computational, Systems, and Synthetic Biology (Best Paper Nominees)
Room: Connaught Suite 1
Session Chair: Alex A. Freitas (University of Kent)

10:40-11:05 **Conotoxin Protein Classification Using Pairwise Comparison and Amino Acid Composition**
Nazar Zaki

Conotoxin classification could assist in the study of the structure-function relationship of ion-channels and receptors as well as identifying potential therapeutics in the treatment of a wide variety of diseases such as schizophrenia, chronic pain, cardiovascular and bladder dysfunction. In this study, we introduce a novel method (Toxin-AAM) for conotoxin superfamily classification. Toxin-AAM incorporates evolutionary information using a powerful means of pairwise sequence comparison and amino acid composition knowledge. The combination of the sequential model and the discrete model has made the Toxin-AAM method exceptional in classifying conotoxin superfamily, when compared to other state-of-the-art techniques.

11:05-11:30 **Affinity Propagation Enhanced by Estimation of Distribution Algorithms**
Roberto Santana, Concha Bielza, Pedro Larrañaga

Tumor classification based on gene expression data can be applied to set appropriate medical treatment according to the specific tumor characteristics. In this paper we propose the use of estimation of distribution algorithms (EDAs) to enhance the performance of affinity propagation (AP) in classification problems. AP is an efficient clustering algorithm based on message-passing methods and which automatically identifies exemplars of each cluster. We introduce an EDA-based procedure to compute the preferences used by the AP algorithm and analyze the effect of using different similarity measures in the classification accuracy. Our results show that AP performance can be notably improved by using the introduced approach. Furthermore, we present evidence that classification of new data is improved by employing previously identified exemplars with only minor decrease in classification accuracy.

11:30-11:55 **A Novel Probabilistic Encoding for EAs Applied to Biclustering of Microarray Data**
Michaël Marcozzi, Federico Divina, Wim Vanhoof, Jesus Aguilar-Ruiz

In this paper we propose a novel representation scheme, called probabilistic encoding. In this representation, each gene of an individual represents the probability that a certain trait of a given problem has to belong to the solution. This allows dealing with uncertainty that can be present in an optimization problem, and grant more exploration capability to an evolutionary algorithm. With this encoding, the search is not restricted to points of the search space. Instead, whole regions are searched, with the aim of individuating a promising region, i.e., a region that contains the optimal solution. This implies that a strategy for searching the individuated region has to be adopted. In this paper we incorporate the probabilistic encoding into a multi-objective and multi-modal evolutionary algorithm. The algorithm returns a promising region, which is then searched by using simulated annealing. We apply our proposal to the problem of discovering biclusters in microarray data. Results confirm the validity of our proposal.

11:55-12:20 **A Genetic Algorithm to Enhance Transmembrane Helices Topology Prediction Using Compositional Index**
Nizar Zaki, Salah Bouktif, Sanja Molnar

A transmembrane helix (TMH) topology prediction is becoming a central problem in bioinformatics because the structure of TM proteins is difficult to determine by experimental means. Therefore, methods that could predict the TMHs topologies computationally are highly desired. In this paper we introduce TMHindex, a method for detecting TMH segments solely by the amino acid sequence information. Each amino acid in a protein sequence is represented by a Compositional Index deduced from a combination of the difference in amino acid appearances in TMH and non-TMH segments in a training protein sequences and the amino acid composition information. Furthermore, genetic algorithm was employed to find the optimal threshold value to separate TMH segments from non-TMH segments. The method successfully predicted 376 out of the 378 TMH segments in 70 testing protein sequences. The level of the accuracy achieved using TMHindex in comparison to recent methods for predicting the topology of TM proteins is a strong argument in favor of our method.

RWA4: Optimization
Room: Connaught Suite 2
Session Chair: Martin Lukasiewycz (TU Munich)

10:40-11:05 **A Modular Framework for Meta-heuristic Optimization**
Martin Lukasiewycz, Michael Glaß, Felix Reimann, Jürgen Teich

This paper presents a modular framework for the meta-heuristic optimization of complex optimization tasks by decomposing them into subtasks that may be designed and developed separately. Since these subtasks are generally correlated, a separate optimization is prohibited and the framework has to be capable of optimizing the subtasks concurrently. For this purpose, a distinction of the genetic representation (genotype) and the representation of a solution of the optimization problem (phenotype) is imposed. A compositional genotype and appropriate operators enable the separate development and testing of the optimization of subtasks by a strict decoupling. The proposed concept is implemented in a open source reference framework written in Java. The architecture of this implementation is outlined and design decisions are discussed that enable a maximal decoupling and flexibility. A case study of a complex real-world optimization problem from the automotive domain is introduced. This case study requires the concurrent optimization of several heterogeneous aspects. Exemplary, it is shown how the proposed framework allows to efficiently optimize this complex problem by decomposing it into subtasks that are optimized concurrently.

11:05-11:30 **A Combination of Evolutionary Algorithm and Mathematical Programming for the 3D Thermal-Aware Floorplanning Problem**
David Cuesta, Jose Luis Risco, Jose Luis Ayala

Heat removal and power density distribution delivery have become two major reliability concerns in 3D stacked technology. Additionally, the placement of Through-Silicon-Vias (TSVs) for connecting different layers is one of the key issues in 3D technology. Although a few recent works have considered thermal-aware placement of cores in chip multi-processor architectures, the concepts of 3D and TSVs have not been conveniently incorporated. Therefore, new suitable exploration methods for the 3D thermal-aware floorplaning problem need to be developed. In this paper we analyze the benefits of two different exploration techniques for the floorplanning problem: Multi-Objective Genetic Algorithm (MOGA) and a Mixed Integer Linear Program (MILP). We present a novel algorithm that uses MILP to minimize aver-age temperature in the 3D chip, whereas uses MOGA to in-sert TSVs, connecting the layers while the total wire length is minimized. Our experiments with two different 3D chips show that our algorithm achieves 10% reduction in the maximum temperature and thermal gradient.

11:30-11:55 **Optimizing Ballast Design of Wave Energy Converters Using Evolutionary Algorithms**
Mitch Colby, Ehsan Nasroullahi

Wave energy converters promise to be a viable alternative to current electrical generation methods. However, these generators must become more efficient before wide-scale industrial use can become cost-effective. The efficiency of these devices is primarily dependent upon their geometric design, which is extremely complex and mathematically rigorous, making potential geometric designs difficult to evaluate, due to slow computation time and high computation cost. In this paper, we design the ballast geometry of a wave energy generator using evolutionary algorithms. The wave energy converter design developed by the evolutionary algorithm resulted in an 84% improvement in power output over a ballast-free wave energy converter. The results indicate that evolutionary algorithms can effectively guide the design of the ballasts of a wave energy generator. In order to complete the evolutionary algorithm, we generated a

neural network function approximator to predict wave energy converter power output with respect to key geometric design variables. We show that using a neural network approximator instead of traditional approaches such as AQWA simulations provides a realistic model while reducing computation time by over 99%, making it possible for us to apply population based search such as the evolutionary algorithm we used to find an optimal ballast configuration

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11:55-12:20 **A Direct Optimization Approach to the P300 Speller**
Roberto Santana, Santiago Muelas, Antonio Latorre, Jose Peña

The P300 component of the brain event-related-potential is one of the most used signals in brain computer interfaces (BCIs). One of the required steps for the application of the P300 paradigm is the identification of this component in the presence of stimuli. In this paper we propose a direct optimization approach to the P300 classification problem. A general formulation of the problem is introduced. Different classes of optimization algorithms are applied to solve the problem and the concepts of k-best and k-worst ensembles of solutions are introduced as a way to improve the accuracy of single solutions. The introduced approaches are able to achieve a classification rate over 80% on test data.

ALIFE 2: Digital Organisms
Room: Elgin
Session Chair: Giovanni Squillero (ALIFE Chair)

10:40-11:05 **The Evolution of Optimal Foraging Strategies in Populations of Digital Organisms**
Jacob Walker

Foraging strategies in uncertain environments is the subject of a great deal biological investigation, much of which is grounded in mathematical models. One theoretical prediction with wide empirical support is the ideal free distribution (IFD), where agents distribute themselves among patches of resources in proportion to their suitability. However, the IFD assumes that agents have perfect information of the environment. In nature, this assumption is often violated, yet the IFD is still observed. Insights into evolved mechanisms and behaviors that result in the IFD show how such efficient outcomes may emerge from such little information. In this study, we used the artificial life platform Avida to observe populations of digital organisms as they evolved to optimize resource intake in an environment with unpredictable resource distributions. We show that the ideal free distribution can emerge from simple foraging strategies that require minimal information. We demonstrate that this distribution is a result of choices made by the organisms, and not simply due to those in a more advantageous setting producing more offspring. Deviations from the IDF appear to be correlated with reduced information or foraging aggregation. We also investigate distributions with organisms of differing abilities, and demonstrate further correspondence with theoretical predictions.

11:05-11:30 **Evolving a Diversity of Creatures through Novelty Search and Local Competition**
Joel Lehman, Kenneth Stanley

An ambitious challenge in artificial life is to craft an evolutionary process that discovers a wide diversity of well-adapted virtual creatures within a single run. Unlike in nature, evolving creatures in virtual worlds tend to converge to a single morphology because selection therein greedily rewards the morphology that is easiest to exploit. However, novelty search, a technique that explicitly rewards diverging, can potentially mitigate such convergence. Thus in this paper an existing creature evolution platform is extended with multi-objective search that balances drives for both novelty and performance. However, there are different ways to combine performance-driven search and novelty search. The suggested approach is to provide evolution with both a novelty objective that encourages diverse morphologies and a local competition objective that rewards individuals outperforming those most similar in morphology. The results in an experiment evolving locomoting virtual creatures show that novelty search with local competition discovers more functional morphological diversity within a single run than models with global competition, which are more predisposed to converge. The conclusions are that novelty search with local competition may complement recent advances in evolving virtual creatures and may in general be a principled approach to combining novelty search with pressure to achieve.

11:30-11:55 **Rapid Host-Parasite Coevolution Drives the Production and Maintenance of Diversity in Digital Organisms**
Luis Zaman, Suhas Devangam, Charles Ofria

Accumulating evidence suggests evolution and ecology can happen on similar time scales. Coevolution between hosts and parasites is a practical example of interacting ecological and evolutionary dynamics. Antagonistic interactions have been shown theoretically and experimentally to increase host diversity, but the contribution of novel variation to diversity is not well understood. In laboratory or natural settings it is infeasible to prohibit novel mutations in communities while still allowing frequencies of extant organisms to change. We turn to digital organisms to investigate the effects of rapid evolution on host-parasite community diversity in the presence and absence of novel variation. We remove the source of variation in coevolved digital host-parasite communities and allow them to reach an equilibrium. We find that coevolved host-parasite communities are surprisingly stable in the absence of new variation. However, the communities at equilibrium are less diverse than those that continued to experience novel variation. In either case, hosts coevolving with parasites are significantly more diverse than hosts evolving alone. Harnessing an advantage of in silico evolution, we show that novel variation increases host diversity in communities with parasites farther than the trivial increase expected from new mutations.

11:55-12:20 **Modeling the Evolutionary Dynamics of Plasmids in Spatial Populations**
Brian Connelly, Luis Zaman, Philip McKinley, Charles Ofria

One of the processes by which microorganisms are able to rapidly adapt to changing conditions is horizontal gene transfer, whereby an organism incorporates additional genetic material from sources other than its parent. These genetic elements encode a wide variety of beneficial adaptations. Under certain conditions, many computational models capture the evolutionary dynamics of adaptive behaviors such as toxin production, quorum sensing, and biofilm formation, and have even provided new insights into otherwise unknown or misunderstood phenomena. However, such models rarely incorporate horizontal gene transfer, so they may be incapable of fully representing the vast repertoire of behaviors exhibited by natural populations. Although models of horizontal gene transfer exist, they rarely account for the spatial structure of populations, which is often critical to adaptive behaviors.

In this work we develop a spatial model to examine how conjugation, one mechanism of horizontal gene transfer, can be maintained. We investigate how both the costs of transfer and the benefits conferred affect evolutionary outcomes. Further, we examine how evolving rates of transmission allows this system to adapt to different environments. Through spatial models such as these, we can gain a greater understanding of the environments under which horizontally-acquired behaviors are evolved and are maintained.

GBML2: Genetics Based Machine Learning (Session 2)
Room: O'Connell
Session Chair: Jaume Bacardit (University of Nottingham)

10:40-11:05 **Learning Optimal Control Policies with XCSF: Generalization Capabilities and Further Improvement**
Didier Marin, Jérémie Decock, Lionel Rigoux, Olivier Sigaud

11:05-11:30 **Modularization of XCSF for Multiple Output Dimensions**
Martin Butz, Patrick Stalph

XCSF approximates function surfaces by evolving a suitable clustering of the input space, such that simple -- typically linear -- predictors are sufficient to approximate a single cluster. With an increasing number of distinct output dimensions, this task becomes increasingly difficult. We analyze the performance of a single XCSF instance and compare it to the performance of a multiple-instance XCSF, where each instance predicts one dimension of the output. We show that dependent on the problem at hand, the multiple-instance XCSF approach is highly advantageous. In particular, we show that the more local linearity structures differ, the more a modularized approximation by multiple XCSF instances pays off. In fact, if the relevant structures are orthogonal to each other, the problem complexity can increase exponentially in the number of orthogonally-structured output dimensions when a single XCSF is used. To relate these results also to current XCSF application options, we compare XCSF with a mutiple-instance XCSF on the problem of learning a compact model of the forward- and inverse-kinematics of an anthropomorphic robot arm in simulation.

11:30-11:55 **Accuracy Exponentiation in UCS and its Effect on Voting Margins**
Tim Kovacs, Narayanan Edakunni, Gavin Brown

11:55-12:20 **Semi-supervised Genetic Programming for Classification**
Filipe Arcanjo, Gisele Pappa, Paulo Bicalho, Wagner Meira Jr., Altigran da Silva

Learning from unlabeled data provides innumerable advantages to a wide range of applications where there is a huge amount of unlabeled data freely available. Semi-supervised learning, which builds models from a small set of labeled examples and a potential large set of unlabeled examples, is a paradigm that may effectively use those unlabeled data. Here we propose KGP, a semi-supervised transductive genetic programming algorithm for classification. Apart from being one of the first semi-supervised algorithms, it is transductive (instead of inductive), i.e., it requires only a training dataset with labeled and unlabeled examples, which should represent the complete data domain. The algorithm relies on the three main assumptions on which semi-supervised algorithms are built, and performs both global search on labeled instances and local search on unlabeled instances. Periodically, unlabeled examples are moved to the labeled set after a weighted voting process performed by a committee. Results on eight UCI datasets were compared with Self-Training and KNN, and showed KGP as a promising method for semi-supervised learning.

ECP3 - EC in Design and Optimization
Room: Clanwilliam
Session Chair: Jorn Mehnen (Cranfield University)

Friday 15 July 14:40 – 16:20

EDA2: Best Paper Nominees
Room: Lansdowne
Session Chair: John McCall (IDEAS Research Institute)

14:40-15:05 **A Preliminary Study on EDAs for Permutation Problems Based on Marginal-based Models**
Josu Ceberio, Alexander Mendiburu, Jose Antonio Lozano

Estimation of Distribution Algorithms are a class of evolutionary algorithms characterized by the use of probabilistic models. These algorithms have been applied successfully to a wide set of artificial and real-world problems, achieving competitive results in most scenarios. Nevertheless, there are some problems whose solutions can be naturally represented as a permutation, for which EDAs do not show promising behavior. Although some work has been done in this area, most of the approaches are adaptations of EDAs designed for binary or integer problems. In this paper, we present an EDA that learns probability distributions over permutations. Particularly, our approach is based on the use of k-order marginals. some preliminary experiments have been done to study how they perform in the quadratic assignment problem and flow shop scheduling.

15:05-15:30 **Optimal Mixing Evolutionary Algorithms**
Dirk Thierens, Peter Bosman

A key search mechanism in Evolutionary Algorithms is the mixing or juxtaposing of partial solutions present in the parent solutions. In this paper we look at the efficiency of mixing in genetic algorithms (GAs) and estimation-of-distribution algorithms (EDAs). We compute the mixing probabilities of two partial solutions and discuss the effect of the covariance build-up In GAs and EDas. We also propose two new Evolutionary Algorithms that maximize the juxtaposing of the partial solutions present in the parents: the Recombinative Optimal Mixing Evolutionary Algorithm (ROMEA) and the Gene-pool Optimal Mixing Evolutionary Algorithm (GOMEA).

15:30-15:55 **Advanced Neighborhoods and Problem Difficulty Measures**
Mark Hauschild, Martin Pelikan

While different measures of problem difficulty of fitness land- scapes have been proposed, recent studies have shown that many of the common ones do not closely correspond to the actual difficulty of problems when solved by evolutionary al- gorithms. One of the reasons for this is that most problem difficulty measures are based on neighborhood structures that are quite different from those used in most evolutionary algorithms. This paper examines several ways to increase the accuracy of problem difficulty measures by including linkage information in the measure to more accurately take into account the advanced neighborhoods explored by some evolutionary algorithms. The effects of these modifications of problem difficulty are examined in the context of several simple and advanced evolutionary algorithms. The results are then discussed and promising areas for future research are proposed.

15:55-16:20 **Hierarchical Allelic Pairwise Independent Functions**
David Iclănzan

Current multivariate EDAs rely on computationally efficient pairwise linkage detection mechanisms to identify higher order linkage blocks. Historical attempts to exemplify the potential disadvantage of this computational shortcut were scarcely successful. In this paper we introduce a new class of test functions to exemplify the inevitable weakness of the simplified linkage learning techniques. Specifically, we show that presently employed EDAs are not able to efficiently mix and decide between building-blocks with pairwise allelic independent components. We also show that EDAs can solve these nearly decomposable problems scalably and reliably, at the expense of exploring a vastly larger search space of multivariable linkage.

GDS2: Generative and Developmental Systems (Best Paper Nominees)
Room: Pembroke
Session Chair: Gregory S Hornby (UC Santa Cruz)

14:40-15:05 **Evolved Neurogenesis and Synaptogenesis for Robotic Control: the L-Brain model**
Michael Palmer

We have developed a novel method to “grow” neural networks according to an inherited set of production rules (the genotype), inspired by Lindenmayer systems. In the first phase, the neurons proliferate in three-dimensional space by cell division, and differentiate in function, according to the production rules. In the second phase, axons emerge from the neurons and seek out connection targets. A feed-forward neural network is thus produced. Part of each production rule is an arithmetic expression. Evaluation of the expression fills several LIFO stacks with values, to facilitate decisions during both phases of growth. We connect each network to a (fixed) robotic body with a set of input sensors and muscle actuators. The robot is placed in a physically simulated environment and controlled by its network for a certain time, receiving a fitness score according to its behavior (the phenotype). Mutations are introduced into offspring by making changes to their sets of production rules. This paper describes the “L-Brain” growth algorithm, and describes our first evolutionary experiments with it, which produced controllers for robotic “spiders” with the ability to gallop, and to follow a compass heading.

15:05-15:30 **A Novel Generative Encoding for Evolving Modular, Regular and Scalable Networks**
Marcin Suchorzewski, Jeff Clune

We introduce the Developmental Symbolic Encoding (DSE), a new generative encoding for evolving networks (e.g. neural or boolean). DSE combines elements of two generative encodings, Cellular Encoding and HyperNEAT, to evolve networks that are modular, regular, scale-free, and scalable. These network properties are important because they can enhance performance and evolvability. We test DSE's ability to generate scale-free and modular networks by explicitly rewarding these properties. We compare the networks DSE evolves to those of HyperNEAT. The results show that both encodings can produce scale-free networks, although DSE performs slightly, but significantly, better on this objective. DSE networks are far more modular than HyperNEAT networks. Both encodings produce regular networks. We further demonstrate that DSE genomes can grow networks to accommodate different numbers of inputs. We also show that DSE outperforms HyperNEAT on a pattern recognition problem, suggesting that its potential lay not just in the properties of the networks it produces, but also because competes with leading encodings at solving challenging problems. These preliminary results imply that DSE is an interesting new encoding worthy of additional study. The results also raise questions about which network properties are more likely to be produced by different types of generative encodings.

15:30-15:55 **On the Relationships between Synaptic Plasticity and Generative Systems**
Paul Tonelli, Jean-Baptiste Mouret

The present paper analyzes the mutual relationships between generative and developmental systems (GDS) and synaptic plasticity when evolving plastic artificial neural networks (ANN) in reward-based scenarios. We first introduce the concept of Transitive Learning Abilities (TLA), which reflects how well an evolved plastic NN can cope with learning scenarios not encountered during the evolution process. We subsequently report results of a set of experiments designed to check that (1) synaptic plasticity can help a GDS to fine-tune synaptic weights and (2) that with the investigated generative encoding (EvoNeuro), only a few learning scenarios are necessary to evolve a general learning system, which can adapt itself to reward-based scenarios not tested during the fitness evaluation.

15:55-16:20 **Enhancing ES-HyperNEAT to Evolve More Complex Regular Neural Networks**
Sebastian Risi, Kenneth Stanley

The recently-introduced evolvable-substrate HyperNEAT (ES-HyperNEAT) demonstrated that the placement and density of hidden nodes in a neural network can be determined based on implicit information in an infinite-resolution pattern of weights, thereby avoiding the need to evolve explicit placement. However, ES-HyperNEAT is computationally expensive because it must search the entire hypercube, and was shown only to match the performance of the original HyperNEAT in a simple benchmark problem. Iterated ES-HyperNEAT, introduced in this paper, helps to reduce computational costs by focusing the search on a sequence of two-dimensional cross-sections of the hypercube and therefore makes possible searching the hypercube at a finer resolution. A series of experiments and an analysis of the evolved networks shows for the first time that iterated ES-HyperNEAT not only matches but outperforms original HyperNEAT in more complex domains because ES-HyperNEAT can evolve networks with limited connectivity, elaborate on existing network structure, and compensate for movement of information within the hypercube.

GA6: Niching & Speciation
Room: Ulster
Session Chair: Maribel Garcia Arenas (University of Granada)

14:40-15:05 **Speciation in Evolutionary Algorithms: Adaptive Species Discovery**
Antonio Della Cioppa, Angelo Marcelli, Prisco Napoli

ThThe use of niching methods for solving real optimization problems is limited by the difficulty to obtain a proper setting of the speciation parameters without any a priori information about the fitness landscape. To avoid such a difficulty, we propose a novel method, called Adaptive Species Discovery, that removes the basic assumption of perfect discrimination among peaks underlying Fitness Sharing and, consequently, allows to overcome the drawbacks of the most performing sharing-based methods. This is achieved through an explicit mechanism able to discover the species in the population during the evolution. The method does not require any a priori knowledge, in that it makes no assumption about the location and the shape of the peaks, while it exploits information about the ruggedness of the fitness landscape, dynamically acquired at each generation. The proposed method has been evaluated on a set of standard functions largely adopted in the literature to assess the performance of niching methods. The experimental results show that our method has a better ability to discover and maintain all the peaks with respect to other methods proposed so far.

15:05-15:30 **Spacing Memetic Algorithms**
Daniel Porumbel, Jin-Kao Hao, Pascale Kuntz

We present the Spacing Memetic Algorithm (SMA), a formal evolutionary model devoted to a systematic control of spacing (distances) among individuals. SMA uses search space distance information to decide what individuals are acceptable in the population, what individuals need to be replaced and when to apply mutations. By ensuring a ``healthy'' spacing (and thus diversity), SMA substantially reduces the risk of premature convergence and helps the search process to continuously discover new high-quality search areas. Generally speaking, the number of distance calculations represents a limited computational overhead compared to the number of local search iterations. Most existing memetic algorithms can be ``upgraded'' to a spacing memetic algorithm, provided that a suitable distance measure can be specified. The impact of the main SMA components is assessed within several case studies on different problems

15:30-15:55 **Learning Individual Mating Preferences**
Lisa Guntly, Daniel Tauritz

Mate selection is a key step in evolutionary algorithms which traditionally has been panmictic and based solely on fitness. Various mate selection techniques have been published which show improved performance due to the introduction of mate restrictions or the use of genotypic/phenotypic features. However, those techniques typically suffer from two major shortcomings: (1) they are fixed for the entire evolutionary run, which is suboptimal because problem specific mate selection may be expected to outperform general purpose mate selection and because the best mate selection configuration may be dependent on the state of the evolutionary run, and (2) they require problem specific tuning in order to obtain good performance, which often is a time consuming manual process. This paper introduces two versions of Learning Individual Mating Preferences (LIMP), a novel mate selection technique in which characteristics of good mates are learned during the evolutionary process. Centralized LIMP (C-LIMP) learns at the population level, while Decentralized LIMP (D-LIMP) learns at the individual level. Results are presented showing D-LIMP to outperform a traditional genetic algorithm (TGA), the Variable Dissortative Mating Genetic Algorithm (VDMGA), and C-LIMP on the DTRAP and MAXSAT benchmark problems, while both LIMP techniques perform comparably to VDMGA on NK Landscapes.

15:55-16:20 **A Robust Dynamic Niching Genetic Clustering Approach for Image Segmentation**
Dongxia Chang, Yao Zhao

In this paper, a novel genetic clustering algorithm based on dynamic niching (DNGA) for image segmentation is proposed. It is an effective and robust approach to image segmentation on the basis of a total similarity function relating to the approximate density shape estimation. In the new algorithm, a dynamic identification of the niches is performed at each generation to automatically evolve the proper number of clusters and appropriate cluster centers of the data set. Moreover, a local search method is embeded in the evolutionary process which makes the dynamic niching method insensitive to the radius of the niche. Compared to existing methods, DNGA algorithm does not need to

pre-specify the number of segmentation. Several images are used to demonstrate its superiority. The experimental results show that DNGA algorithm has high performance, effectiveness and flexibility.

EMO4: Best Paper Nominees
Room: Munster
Session Chair: Oliver Schuetze (CINVESTAV-IPN)

14:40-15:05 **Convergence of Hypervolume-Based Archiving Algorithms I: Effectiveness**
Karl Bringmann, Tobias Friedrich

15:05-15:30 **Improved S-CDAS using Crossover Controlling the Number of Crossed Genes for Many-objective Optimization**
Hiroyuki Sato, Hernan Aguirre, Kiyoshi Tanaka

Self-controlling dominance area of solutions (S-CDAS) reclassifies solutions in each front obtained by non-domination sorting to realize fine-grained ranking of solutions and improve the search performance of multi-objective evolutionary algorithms (MOEAs) in many-objective optimization problems (MaOPs). In this work, we further improve search performance of S-CDAS in MaOPs by analyzing genetic diversity in many-objective problems and enhancing crossover operators. First, we analyze genetic diversity in the population and the contribution of the conventional genetic operators when we increase the number of objectives, showing that the genetic diversity in the population significantly increases and offspring created by conventional crossover come to be not selected as parents because the operator becomes too disruptive and its effectiveness decrease. To overcome this problem, we implement crossover controlling the number of crossed genes (CCG) in S-CDAS and verify its effectiveness. Through performance verification using many-objective knapsack problems with 4-10 objectives, we show that the search performance of S-CDAS noticeably improves when we restrict the number of crossed genes. Also, we show that the effectiveness of CCG operator becomes significant as we increase the number of objectives. Furthermore, we show that offspring created by CCG are selected as parents more often than conventional crossover.

15:30-15:55 **Many-Objective Directed Evolutionary Line Search**
Evan Hughes

Algorithms capable of performing efficient and controllable many objective optimisation are becoming more necessary as the complexity of optimisation problems to be solved increases. This paper describes a new algorithm that combines elements of traditional gradient based optimisation methods along with a powerful many-objective capable search process. The algorithm exploits the directed line search (such as Golden Section Search) procedures found in many single-objective gradient based algorithms in order to both explore and exploit features in the optimisation landscape. The target vector and aggregation methods used in the MSOPS algorithm have been employed to provide effective and controllable many-objective optimisation, especially suited to close interaction with a designer where it is often desired to target specific regions of the Pareto front. The Many Objective Directed Evolutionary Line Search (MODELS) algorithm is demonstrated on a constrained function with a concave Pareto front in up to 20 dimensions and is shown to outperform existing optimisers, some of which are known to perform well for many-objective problems.

15:55-16:20 **Set-based Multiobjective Fitness Landscapes: A Preliminary Study**
Sebastien Verel, Arnaud Liefooghe, Clarisse Dhaenens

Fitness landscape analysis aims to understand the geometry of a given optimization problem in order to design more efficient search algorithms. However, there is a very little knowledge on the landscape of multiobjective problems. In this work, following a recent proposal by Zitzler et al. (2010), we consider multiobjective optimization as a set problem. Then, we give a general definition of set-based multiobjective fitness landscapes. An experimental set-based fitness landscape analysis is conducted on the multiobjective NK-landscapes with objective correlation. The aim is to adapt and to enhance the comprehensive design of set-based multiobjective search approaches, motivated by an a priori analysis of the corresponding set problem properties.

ECP4 - EC in Statistics and EA consultancy
Room: Leinster
Session Chair: Thomas Bartz-Beielstein (Cologne University of Applied Sciences)

ACO-SI3: Ant Colony Optimization and Swarm Intelligence (Session 3)
Room: Connaught Suite 1
Session Chair: Mohammed El-Abd (American University of Kuwait)

14:40-15:05 **PSO Based Motion Deblurring for Single Image**
Chunhe Song, Hai Zhao, Wei Jing, Hongbo Zhu

This paper addresses the issue of non-uniform motion deblurring due to hand shake for a single photograph. The main difficulty of spatially variant motion deblurring is that the deconvolution algorithm can not directly be used to estimate blur kernel as the kernel of different pixels are different with each other. In this paper, after building up the motion model of the camera, we proposed to use PSO algorithm to optimize the weighed parameters of the corresponding poses. The main issue of using PSO for deblurring is that it is generally impossible to obtain the ground true of the observed blurred image, which is used as the input of the PSO algorithm. To solve this problem, firstly a novel image prediction method is proposed which combines a shock filter and a non-linear structure tensor with anisotropic diffusion. The main advantage of the proposed prediction method is that it can overcome the misleading of the rich texture in the image for the deblurring process. Secondly an alternatively optimizing procedure is used to gradually refine the motion kernel and the latent image. Experimental results show that our approach makes it possible to model and remove non-uniform motion blur without hardware support.

15:05-15:30 **Bonding as a Swarm: Applying Bee Nest-Site Selection Behaviour to Protein Docking**
Konrad Diwold, Daniel Himmelbach, Rene Meier, Carsten Baldauf, Martin Middendorf

Friend or Foe? For a protein, this question can usually be answered by identifying its interactions with a possible ligand of interest. The identification of protein binding sites and the prediction of protein-ligand complexes play a key role in the pharmaceutical drug design process as well as in many domains of life sciences. Computational approaches for protein-ligand docking (or molecular docking) have experienced an increased attention over the last years as they allow inexpensive and fast prediction of protein-ligand complexes. This paper introduces the principle of Bee Nest-Site Selection optimisation (BNSO) which solves optimisation problems by using the novel scheme that is inspired by the nest-site selection behaviour found in honeybees. Moreover, the first BNSO algorithm – called Bee-Nest – is proposed and is applied to the protein-docking problem. The performance of Bee-Nest is tested on 173 docking instances from the PDBbind core set and compared to the performance of three reference algorithms. The results show that Bee-Nest could find ligand poses with very good energy levels. Interestingly, the reference Particle Swarm Optimization (PSO) produces results that are qualitatively closer to wet-lab experimentally derived complexes but of worse energy than Bee-Nest. Our results clearly highlight the superior performance of Bee-Nest in semi-local (regional) optimization for the molecular docking problem, and suggests its usefulness in a hybrid strategy.

15:30-15:55 **A Honey Bees Mating Optimization Algorithm for the Open Vehicle Routing Problem**
Yannis Marinakis, Magdalene Marinaki

Honey Bees Mating Optimization algorithm is a relatively new nature inspired algorithm. In this paper, this nature inspired algorithm is used in a hybrid scheme with other metaheuristic algorithms for successfully solving the Open Vehicle Routing Problem. More precisely, the proposed algorithm for the solution of the Open Vehicle Routing Problem, the Honey Bees Mating Optimization (HBMOOVRP), combines a Honey Bees Mating Optimization (HBMO) algorithm and the Expanding Neighborhood Search (ENS) algorithm. Two set of benchmark instances is used in order to test the proposed algorithm. The results obtained for both sets are very satisfactory. More specifically, in the fourteen instances proposed by Christofides, the average quality is 0.35% when a hierarchical objective function is used, where, first, the number of vehicles is minimized and, afterwards, the total travel distance is minimized and the average quality is 0.42% when only the travel distance is minimized, while for the eight instances proposed by Li et al. when a hierarchical objective function is used the average quality is 0.21%.

15:55-16:20 **Opposition-based Artificial Bee Colony Algorithm**
Mohammed El-Abd

The Artificial Bee Colony (ABC) algorithm is a relatively new algorithm for function optimization. The algorithm is inspired by the foraging behavior of honeybees. In this work, the performance of ABC is enhanced by introducing the concept of opposition-based learning. This concept is introduced through the initialization step and through generation jumping. The performance of the proposed opposition- based ABC (OABC) is compared to the performance of ABC when applied to the Black-Box Optimization Benchmarking (BBOB) library introduced in the previous two GECCO conferences.

RWA5: Human Behavior & Evolutionary Strategies
Room: Connaught Suite 2
Session Chair: Thomas Baeck (Leiden University)

14:40-15:05 **Augmented Genetic Algorithms for Searching over Small Spaces based on Highly Quantized Fidelity Criteria**
Sean Lineaweaver, Gregory Wakefield

As suggested in the Blind Watchmaker, human selection can be a remarkable source of information for guiding a genetic algorithm when objective cost functions are unknown. Properly harnessing such input, however, requires an understanding of the "numbers" humans produce as well as the limitations humans face when performing extensive judgment tasks. The Interactive Augmented Genetic Algorithm (IAGA) modifies both the procedural and algorithmic components of Interactive Genetic Algorithms (IGAs) to better match the human selection process. Experimental results show that cochlear implant recipients are successful in using the IAGA to select processing parameters to improve their perception of music.

15:05-15:30 **Quantitative Modeling of Customer Perception from Service Data using Evolutionary Optimization**
Sunith Bandaru, Kalyanmoy Deb, Vineet Khare, Rahul Chougule

This paper proposes a novel method for using the service (field failure) data of consumer vehicles to estimate customer perception. To achieve this, relevant variables are extracted from the vehicle service data and provided as input to the proposed algorithm which then comes up with an optimized mathematical model for predicting the Customer Satisfaction Index or CSI. The methodology is then extended in a way that allows comparison of the CSIs of two or more vehicle models, thus providing a measure of the market's perceived quality of a vehicle model relative to another. Validation against the Consumer Reports data shows that customer experiences and their consequent response in surveys are indeed a reflection of the numbers the service data provides. However, it is argued that the proposed model is more generic than the Consumer Reports because – (1) it doesn't rely on consumer surveys and (2) it can be used to assess individual consumer level satisfaction.

15:30-15:55 **Using Evolutionary Learning Classifiers To Do Mobile Spam (SMS) Filtering**
Muhammad Junaid, Mudassar Farooq

In recent years, we have witnessed the dramatic increase in the volume of mobile SMS (Short Messaging Service) spam. The reason is that operators -- owing to fierce market competition -- have introduced packages that allow its customer to send unlimited SMS in less than \$1 a month. It not only degrades the service of cellular operators but also compromises security and privacy of users. In this paper, we analyze the SMS spam to identify novel features that distinguishes it from benign SMS (ham). The novelty of our approach is that we intercept the SMS at the access layer of a mobile phone -- in hexadecimal format -- and extract two features: (1) octet bigrams, and (2) frequency distribution of octets. Later, we provide these features to a number of evolutionary and non-evolutionary classifiers to identify the best classifier for our mobile spam filtering system. We evaluate the detection rate and false alarm rate of our system -- using different classifiers -- on the real world dataset. The results of our experiments show that sUpervised Classifier System (UCS), by operating on the the above-mentioned features' set, achieves more than 89\% detection rate and 0\% false alarm rate.

15:55-16:20 **Evolutionary Strategies for Identification and Validation of Material Model Parameters for Forming Simulations**
Thomas Bäck, Lutz Kessler, Ingo Heinle

Identification and validation of material models for forming simulations to match experimental data is a key requirement of complex forming applications in the automotive industry. Besides the fact that these models need more and relatively expensive material data input, a problem is still the reliable fit of all necessary parameters. For the steel grade DX54, an interaction of strain rate and yield locus has been identified, finally leading to different material model calibrations. An even better accuracy of feasibility studies is promoted by using advanced yield locus models for forming simulations. With a new set of specially designed experiments in combination with evolutionary strategies, inverse material parameter identification is realized through minimization of a nonlinear error function. This approach defines a new and powerful method for selection and validation of the adequate material model for industrial simulation.

ECOM3: Best Paper Nominees
Room: Elgin
Session Chair: Petrica Pop (North University of Baia Mare, Romania)

14:40-15:05 **Evolving Optimal agendas for Package Deal Negotiation**
Shaheen Fatima, Ahmed Kattan

This paper presents a hyper GA system to evolve optimal agendas for package deal negotiation. The proposed system uses a Surrogate Model based on Radial Basis Function Networks (RBFNs) to speed up the evolution. The negotiation scenario is as follows. There are two negotiators/agents (a and b) and m issues/items available for negotiation. But from these m$issues, the agents must choose g<m issues and negotiate on them. The g issues thus chosen form the agenda. The agenda is important because the outcome of negotiation depends on it. Furthermore, a and b will, in general, get different utilities/profits from different agendas. Thus, for competitive negotiation (i.e., negotiation where each agent wants to maximize its own utility), each agent wants to choose an agenda that maximizes its own profit. However, the problem of determining an agent's optimal agenda is complex, as it requires combinatorial search. To overcome this problem, we present a hyper GA system that uses a Surrogate Model based on Radial Basis Function Networks (RBFNs). The performance of the proposed method is evaluated experimentally. The results of these experiments demonstrate that the surrogate assisted algorithm, on average, performs better than standard GA and random search.

15:05-15:30 **A Cooperative Tree-based Hybrid GA-B&B Approach for Solving Challenging Permutation-based Problems**
Malika Mehdi, Jean-Claude Charr, Nouredine Melab, EL-Ghazali Talbi, Pascal Bouvry

The issue addressed in this paper is how to build low-level hybrid cooperative optimization methods that combine a Genetic Algorithm (GA) with a Branch-and-Bound algorithm (B&B). The key challenge is to provide a common solution and search space coding and associated transformation operators enabling an efficient cooperation between the two algorithms. The tree-based coding is traditionally used in exact optimization methods such as B&B. In this paper, we explore the original idea of using such coding in Genetic Algorithms. Following this idea, we propose a pioneering approach hybridizing a GA with a B&B algorithm. The information (solutions and search sub-spaces) exchanges between the two algorithms is performed at low-level and during the exploration process. From the implementation point of view, the common coding has facilitated the low-level coupling of two software frameworks: ParadisEO and BOB++ used to implement respectively the GA and the B&B algorithms. The proposed approach has been experimented on the 3D Quadratic Assignment problem (Q3AP). In order to support the CPU cost of the hybridization mechanism hierarchical parallel computing is used together with grid computing. The experiments demonstrate the efficiency and effectiveness of the approach. Indeed, a set of Q3AP benchmarks have been solved to optimality for the first time.

15:30-15:55 **An Efficient Hierarchical Parallel Genetic Algorithm for Graph Coloring Problem**
Reza Abbasian, Malek Mouhoub

Graph coloring problems (GCPs) are constraint optimization problems with various applications including scheduling, time tabling, and frequency allocation. The GCP consists in finding the minimum number of colors for coloring the graph vertices such that adjacent vertices have distinct colors. We propose a parallel approach based on Hierarchical Parallel Genetic Algorithms (HPGAs) to solve the GCP. We also propose a new extension to PGA, that is Genetic Modification (GM) operator designed for solving constraint optimization problems by taking advantage of the properties between variables and their relations. Our proposed GM for solving the GCP is based on a novel Variable Ordering Algorithm (VOA). In order to evaluate the performance of our new approach, we have conducted several experiments on GCP instances taken from the well known DIMACS website. The results show that the proposed approach has a high performance in time and quality of the solution returned in solving graph coloring instances taken from DIMACS website. The quality of the solution is measured here by comparing the returned solution with the optimal one.

15:55-16:20 **Partial Neighborshoods of the Traveling Salesman Problem**
Darrell Whitley, Gabriela Ochoa

The Traveling Salesman Problem (TSP) is known to display an elementary landscape under all k-opt move operators. Previous work has also shown that partial neighborhoods may exist that retain some properties characteristic of elementary landscapes. For a tour of n cities, we show that the 2-opt neighborhood can be decomposed into Floor(n/2-1) partial neighborhoods. While this paper focuses on the TSP, it also introduces a more formal treatment of partial neighborhoods which applies to all elementary landscapes. Tracking partial neighborhood averages in elementary

landscapes requires partitioning the cost matrix. After every move in the search space, the relevant partitions must be updated. However, just as the evaluation function allows a partial update for the TSP, there also exists a partial update for the cost matrix partitions. By only looking at a subset of the partial neighborhoods we can further reduce the cost of updating the cost matrix partitions.

GBML3: Genetics Based Machine Learning (Best Paper Nominees)
Room: O'Connell
Session Chair: Will Neil Browne (Victoria University of Wellington)

14:40-15:05 **Online, GA based Mixture of Experts : a Probabilistic Model of UCS**
Narayanan Edakunni, Gavin Brown, Tim Kovacs

15:05-15:30 **Evolving Spiking Networks with Variable Memristors**
Gerard Howard, Ella Gale, Larry Bull, Ben Costello, Andrew Adamatzky

This paper presents a spiking neuro-evolutionary system which implements memristors as neuromodulatory connections, i.e. whose weights can vary during a trial. The evolutionary design process exploits parameter self-adaptation and a constructionist approach, allowing the number of neurons, connection weights, and inter-neural connectivity pattern to be evolved for each network. Additionally, each memristor has its own conductance profile, which alters the neuromodulatory behaviour of the memristor and may be altered during the application of the GA. We demonstrate that this approach allows the evolutionary process to discover beneficial memristive behaviours at specific points in the networks. We evaluate our approach against two phenomenological real-world memristive implementations, a theoretical ``linear memristor'', and a system containing standard connections only. Performance is evaluated on a simulated robotic navigation task.

15:30-15:55 **XCS Cannot Learn All Boolean Functions**
Charalambos Ioannides, Kerstin Eder, Geoff Barrett

In this paper we applied the eXtended Classifier System (XCS) on a novel real world problem, namely digital Design Verification (DV). We witnessed the inadequacy of XCS on binary problems that contain high overlap between optimal rules especially when the focus is on population and not system level performance. The literature attempts to underplay the importance of the aforementioned weakness and in short, supports that a) XCS can potentially learn any binary function given enough resources are allocated (right parameters used) and b) the main metric deciding the learning difficulty of a binary function is the amount of classifiers required to represent it (i.e. |[O]|). With this work we experimentally refuted the aforementioned propositions and as a result of the work, we introduce new insights on the behavior of XCS when solving two-valued binary functions using a binary reward scheme (1000/0). We also introduce a new population metric (%[EPI]) that should necessarily be used to guide future research on improving XCS performance on the aforementioned problems.

15:55-16:20 **Modelling the Initialisation Stage of the ALKR Representation for Discrete Domains and GABIL Encoding**
Maria Franco, Natalio Krasnogor, Jaume Bacardit

Models in Genetic Based Machine Learning (GBML) systems are commonly used to gain understanding of how the system works and, as a consequence, adjust it better. In this paper we propose models for the probability of having a good initial population using the Attribute List Knowledge Representation (ALKR) for discrete inputs using the GABIL encoding. We base our work in the scheme and covering bound models previously proposed for XCS. The models are extended to (a) deal with the combination of ALKR+GABIL representation, (b) explicitly handle datasets with niche overlap and (c) model the impact of using covering and a default rule in the representation. The models are designed and evaluated within the framework of the BioHEL GBML system and are empirically evaluated using first boolean datasets and later also nominal datasets of higher cardinality. The models in this paper allow us to evaluate the challenges presented by problems with high cardinality (in terms of number of attributes and values of the attributes) as well as the benefits contributed by each of the components of BioHEL's representation and initialization operators.

Friday 15 July 16:50 – 18:30

GA7: Differential Evolution
Room: Lansdowne
Session Chair: Jim Smith (University of the West of England)

16:50-17:15 **Differential Evolution with Self Adaptive Local Search**
Nasimul Noman, Danushka Bollegala, Hitoshi Iba

The performance of a memetic algorithm (MA) largely depends on the synergy between its global and local search counterparts. The amount of global exploration and local exploitation to be carried out, for optimal performance, varies with problem type. Therefore, an algorithm should intelligently allocate its computational efforts between genetic search and local search. In this work we propose an adaptive local search method that adjusts the effort for local tuning of individuals, taking feedback from the search. We implemented an MA hybridizing this adaptive local search method with differential evolution algorithm. Experimenting with a standard benchmark suite it was found that the proposed MA can utilize its global and local search components adaptively. The proposed algorithm also exhibited very competitive performance with other existing algorithms.

17:15-17:40 **A New Differential Evolution Algorithm with Dynamic Population Partition and Local Restart**
Yuan-long Li, Jun ZHANG

This paper will introduce a new differential evolution (DE) algorithm called DE/cluster. DE/cluster applies a simple hierarchical clustering model to mine the distribution information of the DE population every K generations to make a dynamic partition of the population. One special cluster formed by the single-individual clusters will use a slower convergence mutation strategy to do the global search. The other clusters will use more greedy searching strategy to do the local search. As long as the subpopulations may be trapped by local minima, the "dead" state is defined for a cluster and clusters will be checked in every generation and the "dead" clusters will be restarted in the current searching range. This local restart strategy can make the performance of DE/cluster even be better than DE/rand on some multimodal test functions that are not linearly separable. The DE/cluster algorithm is tested on a test suite with 24 functions and it shows promising performance compared with the current best DE variants.

17:40-18:05 **Multi-population Differential Evolution with Adaptive Parameter Control for Global Optimization**
Wei-jie Yu, Jun ZHANG

Differential evolution (DE) is one of the most successful evolutionary algorithms (EAs) for global numerical optimization. Like other EAs, maintaining population diversity is important for DE to escape from local optima and locate a near-global optimum. Using multi-population algorithm is a representative method to avoid early loss of population diversity. In this paper, we propose a multi-population DE algorithm (MPDE) which manipulates multiple sub-populations. Different sub-populations in MPDE exchange information via a novel mutation operation instead of migration used in most multi-population EAs. The mutation operation is helpful to balance the fast convergence and population diversity of the proposed algorithm. Moreover, the performance of MPDE is further improved by an adaptive parameter control scheme designed based on the multi-population approach. Each sub-population in MPDE evolves with its own set of control parameters, and a learning strategy is used to adaptively adjust the parameter values. A set of benchmark functions is used to test the proposed MPDE algorithm. The experimental results show that MPDE performs better than, or at least comparably, to the classical single population DE with fixed parameter values and three existing state-of-the-art DE variants.

GP4: Best Paper Nominees and Modularity
Room: Pembroke
Session Chair: Lee Spector (Hampshire College)

16:50-17:15 **Reassembling Operator Equalisation - A Secret Revealed**
Sara Silva

The recent Crossover Bias theory has shown that bloat in Genetic Programming can be caused by the proliferation of small unfit individuals in the population. Inspired by this theory, Operator Equalisation is the most recent and successful bloat control method available. In this work we revisit two bloat control methods, the old Brood Recombination and the newer Dynamic Limits, hypothesizing that together they contain the two main ingredients that

make Operator Equalisation so successful. We reassemble Operator Equalisation by joining these two ingredients in a hybrid method, and test it in a hard real world regression problem. The results are surprising. Operator Equalisation and the hybrid variants exhibit completely different behaviors, and an unexpected feature of Operator Equalisation is revealed, one that may be the true responsible for its success: a nearly flat length distribution target. We support this finding with additional results, and discuss its implications.

17:15-17:40 **Rethinking Multilevel Selection in Genetic Programming**
Shelly Wu, Wolfgang Banzhaf

This paper aims to improve the capability of genetic programming to tackle the evolution of cooperation: evolving multiple partial solutions that collaboratively solve structurally and functionally complex problems. A multilevel genetic programming approach is presented based on a new computational multilevel selection framework [20]. This approach considers biological group selection theory to encourage cooperation, and a new cooperation operator to build solutions hierarchically. It extends evolution from individuals to multiple group levels, leading to good performance on both individuals and groups. The applicability of this approach is evaluated on 7 multi-class classification problems with different features, such as non-linearity, skewed data distribution and large feature space. The results, when compared to other cooperative evolutionary algorithms in the literature, demonstrate that this approach improves solution accuracy and consistency, and simplifies solution complexity. In addition, the problem is decomposed as a result of evolution without human interference.

17:40-18:05 **A Non-Destructive Grammar Modification Approach to Modularity in Grammatical Evolution**
John Swafford, Erik Hemberg, Michael O'Neill, Miguel Nicolau, Anthony Brabazon

Modularity has proven to be an important aspect of evolutionary computation. This work is concerned with discovering and using modules in one form of grammar-based genetic programming, grammatical evolution (GE). Previous work has shown that simply adding modules to GE's grammar, even with beneficial information, has the potential to disrupt fit individuals developed by evolution up to that point. This paper presents a solution to prevent the disturbance in fitness that can come with modifying GE's grammar. The results show an increase in performance from a previously examined grammar modification approach and also an increase in performance when compared to standard GE.

18:05-18:30 **Tag-Based Modules in Genetic Programming**
Lee Spector, Brian Martin, Kyle Harrington, Thomas Helmuth

In this paper we present a new technique for evolving modular programs with genetic programming. The technique is based on the use of "tags" that evolving programs may use to label and later to refer to code fragments. Tags may refer inexactly, permitting the labeling and use of code fragments to co-evolve in an incremental way. The technique can be implemented as a minor modification to an existing, general purpose genetic programming system and it does not require pre-specification of the module architecture of evolved programs. We demonstrate that tag-based modules readily evolve and that this allows problem solving effort to scale well with problem size. We also show that the tag-based module technique is effective even in complex, non-uniform problem environments for which previous techniques perform poorly. We demonstrate the technique in the context of the stack-based genetic programming system PushGP, but we also briefly discuss ways in which it may be used with other kinds of genetic programming systems.

ESEP2: Evolution Strategies and Evolutionary Programming (Best Paper Nominees)
Room: Ulster
Session Chair: Steffen Finck (ESEP)

16:50-17:15 **High Dimensions and Heavy Tails for Natural Evolution Strategies**
Tom Schaul, Tobias Glasmachers, Jürgen Schmidhuber

17:15-17:40 **Analysis of a Repair Mechanism for the (1,lambda)-ES Applied to a Simple Constrained Problem**
Dirk Arnold

We study the behaviour of a (1,lambda)-ES that applies a simple repair mechanism to infeasible candidate solutions for the problem of maximising a linear problem with a single linear constraint. Integral expressions that describe the strategy's one-generation behaviour are derived and used in a simple zeroth order model for the steady state of the strategy. Applied to the analysis of cumulative step size adaptation, the approach provides an intuitive explanation for the algorithm's behaviour as well as a condition on the setting of its parameters. A comparison with the strategy that

resamples infeasible candidate solutions rather than repairing them is drawn, and the qualitatively different behaviour is explained.

17:40-18:05 **Mirrored Sampling in Evolution Strategies With Weighted Recombination**
Dimo Brockhoff, Anne Auger, Nikolaus Hansen

This paper introduces mirrored sampling into evolution strategies with weighted multi-recombination. \emph{Pairwise selection} selects at most one of two mirrored vectors in order to avoid a bias due to recombination. \emph{Selective mirroring} only mirrors the originally worst solutions of the population. Convergence rates on the sphere function are derived also yielding lower bounds. The optimal ratio of mirrored offspring is 1/2 (maximal) for randomly selected mirrors and about 1/6 for selective mirroring, where the convergence rate reaches a value above 0.386. This is an improvement of more than 50% compared to the best known convergence rate of 0.25 with positive recombination weights. Selective mirroring is combined with CMA-ES and benchmarked on unimodal functions and on the COCO/BBOB-2010 testbed.

18:05-18:30 **Local-Meta-Model CMA-ES for Partially Separable Functions**
Zyed Bouzarkouna, Anne Auger, Didier Yu Ding

In this paper, we propose a new variant of the covariance matrix adaptation evolution strategy with local meta-models (lmm-CMA) for optimizing partially separable functions. We propose to exploit partial separability by building at each iteration a meta-model for each element function (or sub-function) using a full quadratic local model. After introducing the approach we present some first experiments using element functions with dimensions 2 and 4. Our results demonstrate that, as expected, exploiting partial separability leads to an important speedup compared to the standard CMA-ES. We show on the tested functions that the speedup increases with increasing dimensions for a fixed dimension of the element function. On the standard Rosenbrock function the maximum speedup of lambda is reached in dimension 40 using element functions of dimension 2. We show also that higher speedups can be achieved by increasing the population size. The choice of the number of points used to build the meta-model is also described and the computational cost is discussed.

DETA2: Best Paper Nominees
Room: Munster
Session Chair: Risto Miikkulainen (The University of Texas at Austin)

16:50-17:15 **Interactively Evolving Harmonies through Functional Scaffolding**
Amy Hoover, Paul Szerlip, Kenneth Stanley

While the real-time focus of today's automated accompaniment generators can benefit instrumentalists and vocalists in their practice, improvisation, or performance, an opportunity remains specifically to assist novice composers. This paper introduces a novel such approach based on evolutionary computation called functional scaffolding for musical composition (FSMC), which helps the user explore potential accompaniments for existing musical pieces, or scaffolds. The key idea is to produce accompaniment as a function of the scaffold, thereby inheriting from its inherent style and texture. To implement this idea, accompaniments are represented by a special type of neural network called a compositional pattern producing network (CPPN), which produces harmonies by elaborating on and exploiting regularities in pitches and rhythms found in the scaffold. This paper focuses on how inexperienced composers can personalize accompaniments by first choosing any MIDI scaffold, then selecting which parts (e.g. the piano, guitar, or bass guitar) the CPPN can hear, and finally customizing and refining the computer-generated accompaniment through an interactive process of selection and mutation of CPPNs called interactive evolutionary computation (IEC). The potential of this approach is demonstrated by following the evolution of a specific accompaniment and studying whether listeners appreciate the results.

17:15-17:40 **Interactive Evolution for the Procedural Generation of Tracks in a High-End Racing Game**
Luigi Cardamone, Pier Lanzi, Daniele Loiacono

We present a framework for the procedural generation of tracks for a high-end car racing game (TORCS) using interactive evolution. The framework maintains multiple populations and allow users to work both on their own population (in single-user mode) or to collaborate with other users on a shared population. The framework comprises a web frontend and an evolutionary backend. The former manages the interaction with users (e.g., manages registered and anonymous users, collects evaluations, provides access to all the evolved populations) and maintains the database server that stores all the present/past populations. The latter runs all the tasks related to evolution (selection,

recombination and mutation) and all the tasks related to the target racing game (e.g., the track generation). We present a set of two experiments involving five human subjects to evolve racing tracks alone (in a single-user mode) or cooperatively. Our preliminary results show that, in all the experiments, there is an increase of users' satisfaction as the evolution proceeds. Users stated that they perceived improvements in the quality of the individuals between subsequent populations and that, at the end, the process produced interesting tracks.

SS3: Self-* Search (Best Paper Nominees)
Room: Leinster
Session Chair: Marc Schoenauer (INRIA Saclay)

16:50-17:15 **Tuned Data Mining: A Benchmark Study on Different Tuners**
Wolfgang Konen, Patrick Koch, Oliver Flasch, Thomas Bartz-Beielstein, Martina Friese, Boris Naujoks

The complex, often redundant and noisy data in real-world data mining (DM) applications frequently lead to inferior results when out-of-the-box DM models are applied. A tuning of parameters is essential to achieve high-quality results. In this work we aim at tuning parameters of the preprocessing and the modeling phase conjointly. The framework TDM (Tuned Data Mining) was developed to facilitate the search for good parameters and the comparison of different tuners. It is shown that tuning is of great importance for high-quality results. Surrogate-model based tuning utilizing the Sequential Parameter Optimization Toolbox (SPOT) is compared with other tuners (CMA-ES, BFGS, LHD) and evidence is found that SPOT is well suited for this task. In benchmark tasks like the Data Mining Cup tuned models achieve remarkably better ranks than their untuned counterparts.

17:15-17:40 **Markov chain Hyper-heuristic (MCHH): an Online Selective Hyper-heuristic for Multi-objective Continuous Problems**
Kent McClymont, Ed Keedwell

In this paper we present the Markov chain Hyper-heuristic (MCHH), a novel online selective hyper-heuristic which employs reinforcement learning and Markov chains to provide an adaptive heuristic selection method. Experiments are conducted to demonstrate the efficacy of the method and comparisons are made with standard heuristics, a random hyper-heuristic and a multi-objective hyper-heuristic from the literature. The approaches are compared on a small number of evaluations of the multi-objective DTLZ test problems to reflect the computational limitations of expensive optimisation problems. The results demonstrate the MCHH robust and reliable performance on these problems.

17:40-18:05 **Policy Matrix Evolution for Generation of Heuristics**
Ender Ozcan, Andrew Parkes

Online bin-packing is a well-known problem in which immediate decisions must be made about the placement of items with various sizes into fixed capacity bins. The associated decisions can be based on an index policy in which each decision option is independently given a value and the highest value choice is selected. In this paper, we represent such heuristics as a simple matrix of scores for online bin packing and matrices giving good performance are then searched through evolution using a genetic algorithm. This might be regarded as parameter tuning of the packing heuristic but in which a fine-grained representation is used and so the number of parameters is larger than in standard parameter tuning. The tuned matrices perform better than the standard heuristics. They also reveal interesting structures and so have impact on questions of how heuristic score functions should be represented.

18:05-18:30 **Automatic Configuration of State-of-the-art Multi-objective Optimizers Using the TPLS+PLS Framework**
Jérémie Dubois-Lacoste, Manuel López-Ibáñez, Thomas Stützle

The automatic configuration of algorithms is a dynamic field of research. Its potential for producing highly performing algorithms may change the way we design algorithms. So far, automatic algorithm configuration tools have almost exclusively been applied to configure single-objective algorithms. In this paper, we investigate the usage of automatic algorithm configuration tools to improve multi-objective algorithms. In fact, this is the first article we are aware of where new state-of-the-art multi-objective optimizers are configured in an automatic way. This automatic configuration is done for five variants of multi-objective flow-shop problems. Our experimental results show that we can reach at least the same and often a better final quality than a recently proposed state-of-the-art algorithm for these problems.

ACO-SI4: Ant Colony Optimization and Swarm Intelligence (Best Paper Nominees)
Room: Connaught Suite 1
Session Chair: Dalila Martins Fontes (Universidade do Porto)

16:50-17:15 **Energy-Efficient and Location-Aware Ant Colony Based Routing Algorithms for Wireless Sensor Networks**
Christian Domínguez-Medina, Nareli Cruz-Cortés

In recent years, advances in miniaturization, low-power circuit design, simple, low power, yet reasonably efficient wireless communication equipment, and improved small-scale energy supplies have combined with reduced manufacturing costs to make a new technological vision possible, the Wireless Sensor Networks (WSN). As WSN are still a young research field, much activity is still on-going to solve many open issues. One is the data routing problem. The meta-heuristic Ant Colony Optimization (ACO) has been proposed to solve this issue. ACO based routing algorithms can add a significant contribution to assist in the maximisation of the network lifetime and in the minimisation of the latency in data transmissions, but this is only possible by means of an adaptable and balanced algorithm that takes into account the WSN main restrictions, for example sensor nodes of WSN are very constrained mainly in memory and power supply. A comparison of two ACO based routing algorithms for WSN is presented, taking into account current amounts of energy consumption under a WSN scenario proposed in this work. Furthermore, a new routing algorithm is defined.

17:15-17:40 **An Incremental Ant Colony Algorithm with Local Search for Continuous Optimization**
Tianjun Liao, Marco Montes de Oca, Dogan Aydın, Thomas Stützle, Marco Dorigo

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17:40-18:05 **Ant Colony System Based Wake-up Scheduling for Lifetime Maximization in Wireless Sensor Networks**
jing-hui Zhong, Jun ZHANG

Scheduling the sensor activities is an effective way to prolong the lifetimes of wireless sensor networks (WSNs). In this paper, we explore the problem of wake-up scheduling in WSNs with sensors having different lifetimes. A novel local wake-up scheduling (LWS) strategy is proposed to prolong the network lifetime with full coverage constraint. The proposed LWS strategy divides the sensors into a first layer set and a successor set. Sensors in the first layer set can satisfy the coverage constraint and are activated when the network starts working. When an active sensor runs out of energy, some sensors in the successor set would be activated to ensure the network operating properly. To optimize the LWS strategy, an ant colony system (ACS) based method, termed ACS-LWS, is presented in this paper. The proposed ACS-LWS makes use of the global search abilities of ACS and effective heuristic information to search promising solutions. The performance of ACS-LWS is compared with a most recent genetic algorithm based wake-up scheduling method (i.e., STHGA) and a greedy based LWS method. Simulation results on twenty WSNs with different characteristics reveal that ACS-LWS yields much better performance than the two algorithms.

18:05-18:30 **An Ant Colony Optimization Algorithm to Solve the Minimum Cost Network Flow Problem with Concave Cost Functions**
Marta Monteiro, Dalila Fontes, Fernando Fontes, Miguel Silva

In this work we address the Singe-Source Uncapacitated Minimum Cost Network Flow Problem with concave cost functions. Given that this problem is of a combinatorial nature and also that the total costs are nonlinear, we propose a hybrid heuristic to solve it. In this type of algorithms one usually tries to manage two conflicting aspects of searching behaviour: exploration, the algorithm's ability to search broadly through the search space; and exploitation, the algorithm ability to search locally around good solutions that have been found previously. In our case, we use an Ant Colony Optimization algorithm to mainly deal with the exploration, and a Local Search algorithm to cope with the exploitation of the search space. Our method proves to be very efficient while solving both small and large size problem instances. The problems we have used to test the algorithm were previously solved by other authors using other population based heuristics and our algorithm was able to improve upon their results, both in terms of computing time and solution quality.

RWA6: Differential Evolution & Evolutionary Strategies
Room: Connaught Suite 2
Session Chair: Steven Gustafson (GE Global Research)

16:50-17:15 **Using Differential Evolution to Optimize 'Learning from Signals' and Enhance Network Security**
Paul Harmer, Michael Temple, Mark Buckner, Ethan farquhar

Computer and communication network attacks are commonly orchestrated through Wireless Access Points (WAPs). This paper summarizes proof-of-concept research activity aimed at developing a physical layer Radio Frequency (RF) air monitoring capability to limit unauthorized WAP access and improve network security. This is done using Differential Evolution (DE) to optimize the performance of a "Learning from Signals" (LFS) classifier implemented with RF "Distinct Native Attribute"(RF-DNA) fingerprints. Performance of the resultant DE-optimized LFS classifier is demonstrated using 802.11a WiFi devices under the most challenging conditions of intra-manufacturer classification, i.e., using emissions of like-model devices that only differ in serial number. Using identical classifier input features, performance of the DE-optimized LFS classifier is assessed relative to a Multiple Discriminant Analysis / Maximum Likelihood (MDA/ML) classifier that has been used for previous demonstrations. The comparative assessment is made using both Time Domain (TD) and Spectral Domain (SD) fingerprint features. For all combinations of classifier type, feature type, and signal-to-noise ratio considered, results show that the DEoptimized LFS classifier with TD features is superior and provides up to 20% improvement in classification accuracy with proper selection of DE parameters.

17:15-17:40 **Application of Evolutionary Algorithms in Detecting SMS Spam at Access Layer**
M. Rafique, Nasser Alrayes, Muhammad Khan

In recent years, Short Message Service (SMS) has been widely exploited in arbitrary advertising campaigns and the propagation of scam. In this paper, we first analyze the role of SMS spam as an increasing threat to mobile and smart phone users. Afterward, we present a filtering method for controlling SMS spam on the access layer of mobile devices. We analyze the role of different evolutionary and non-evolutionary classifiers for our spam filter by assimilating the byte-level features of SMS. We evaluated our framework on real-world benign and spam datasets collected from Grumbletext and the users in our social networking community. The results of carefully designed experiments demonstrated that the evolutionary classifiers, like the Structural Learning Algorithm in Vague Environment (SLAVE), could efficiently detect spam messages at the access layer of a mobile device. To the best of our knowledge, the current work is the first SMS spam filter based on evolutionary classifier that works on the access layer of a mobile device. The results of our experiments show that our framework, using evolutionary algorithms, achieves a detection accuracy of more than 93%, with false alarm rate of < 0.13% in classifying spam SMS. Moreover, the memory requirement for incorporating SMS features is relatively small, and it takes less than one second to classify a message as spam or benign.

17:40-18:05 **GPU-Accelerated High-Accuracy Molecular Docking using Guided Differential Evolution**
Martin Simonsen, Christian Pedersen, Mikael Christensen, René Thomsen

The objective in molecular docking is to determine the best binding mode of two molecules in silico. A common application of molecular docking is in drug discovery where a large number of ligands are docked against a protein to identify potential drug candidates. This is a computationally intensive problem especially if flexibility of the molecules are taken into account. In this paper we show how MolDock, which is a high accuracy method for flexible molecular docking using a variant of differential evolution, can be parallelised on both CPU and GPU. The methods presented for parallelising the workload result in an average speedup of 3.9x on a 4-core CPU and 27.4x on a comparable CUDA enabled GPU when docking 133 ligands of different sizes. Furthermore, the presented parallelisation schemes are generally applicable and can easily be adapted to other common flexible docking methods.

18:05-18:30 **RankDE: Learning a Ranking Function for Information Retrieval using Differential Evolution**
Danushka Bollegala, Nasimul Noman, Hitoshi Iba

Learning a ranking function is important for numerous tasks such as information retrieval (IR), question answering, and product recommendation. For example, in information retrieval, a Web search engine is required to rank and return a set of documents relevant to a query issued by a user. We propose \textit{RankDE}, a ranking method that uses differential evolution (DE) to learn a ranking function to rank a list of documents retrieved by a Web search engine. To the best of our knowledge, the proposed method is the first DE-based approach to learn a ranking function for IR. We evaluate the proposed method using LETOR dataset, a standard benchmark dataset for training and evaluating ranking functions for IR. In our experiments, the proposed method significantly outperforms previously proposed rank learning methods that use evolutionary computation algorithms such as Particle Swam Optimization (PSO) and Genetic

Programming (GP), achieving a statistically significant mean average precision (MAP) of 0.339 on TD2003 dataset and that of 0.430 on the TD2004 dataset. Moreover, the proposed method shows comparable results to the state-of-the-art non-evolutionary computational approaches on this benchmark dataset. We analyze the feature weights learnt by the proposed method to better understand the salient features for the task of learning to rank for information retrieval.

ALIFE3: Best Paper Nominees
Room: Elgin
Session Chair: Giovanni Squillero (ALIFE Chair)

16:50-17:15 **Evolution of Neural Symmetry and its Coupled Alignment to Body Plan Morphology**
Ben Jones, Andrea Soltoggio

Body morphology is thought to have heavily influenced the evolution of neural architecture. However, the extent of this interaction and its underlying principles are largely unclear. To help us elucidate these principles, we examine the artificial evolution of a hypothetical nervous system embedded in a fish-inspired animat. The aim is to observe the evolution of neural structures in relation to both body morphology and required motor primitives. Our investigations reveal that increasing the pressure to evolve a wider range of movements also results in higher levels of neural symmetry. We further examine how different body shapes affect the evolution of neural structure; we find that, in order to achieve optimal movements, neural structure becomes integrated in order to compensate for asymmetrical body morphology. Our study clearly indicates that different parts of the animat -- specifically, nervous system and body plan -- evolve in concert with, and become highly functional with respect to, the other parts. The autonomous emergence of morphological and neural computation in this model contributes to unveiling the surprisingly strong coupling of such systems in nature.

17:15-17:40 **Digital Enzymes: Agents of Reaction Inside Robotic Controllers for the Foraging Problem**
Chad Byers, Betty Cheng, Philip McKinley

Over billions of years, natural selection has continued to select for a framework based on (1) parallelism and (2) cooperation across various levels of organization within organisms to drive their behaviors and responses. We present a novel design for a reactive, bottom-up controller founded on the respective biological processes of signal transduction (reaction) and parallel, enzymatic reactions (bottom-up). We use enzymes to explore the potential for evolving simulated robot controllers for the central-place foraging problem. The properties of the robot and stimuli present in its environment are encoded in a digital format ("molecule") capable of being manipulated and altered through self-contained computational programs ("enzymes") executing in parallel inside each controller to produce the robot's foraging behavior. Evaluation of this design in unbounded worlds reveals evolved strategies employing one or more of the following complex behaviors: (1) swarming, (2) coordinated movement, (3) communication of "concepts" using a "primitive language" based on sound and color, (4) cooperation, and (5) division of labor.

17:40-18:05 **Spontaneous Evolution of Structural Modularity in Robot Neural Network Controllers**
Josh Bongard

In order to scale up robots to perform more complex tasks, it is necessary to create less than fully connected neural network controllers. However, manually designing such internal neural structure is not intuitive, and thus should be placed under evolutionary control. Here I show how spontaneous structural modularity can arise in the connectivity of evolved robot controllers if the controllers are boolean networks, and are selected to converge on point attractors that correspond to successful robot behaviors.

SBSE3: Search-Based Software Engineering (Best Paper Nominees)
Room: O'Connell
Session Chair: Moshe Sipper (Ben-Gurion University)

16:50-17:15 **Searching for Invariants using Genetic Programming and Mutation Testing**
Sam Ratcliffe, David White, John Clark

Invariants are concise and useful descriptions of a program's behaviour. As most software is not annotated with invariants, previous research has attempted to automatically generate them from source code. In this paper, we propose a new approach to invariant generation using search. We reuse the trace generation front-end of existing tool

Daikon and integrate it with genetic programming and a mutation testing tool. We demonstrate that our system can find the same invariants through search that Daikon produces via template instantiation, and we also find useful invariants that Daikon does not. We then present a method of ranking invariants such that we can identify those that are most interesting, through a novel application of program mutation.

17:15-17:40 **Using Multi-objective Metaheuristics to Solve the Software Project Scheduling Problem**
Francisco Chicano, Francisco Luna, Antonio J. Nebro, Enrique Alba

The Software Project Scheduling (SPS) problem relates to the decision of who does what during a software project lifetime. This problem has a capital importance for software companies. In the SPS problem, the total budget and human resources involved in software development must be optimally managed in order to end up with a successful project. Companies are mainly concerned with reducing both the duration and the cost of the projects, and these two goals are in conflict with each other. A multi-objective approach is therefore the natural way of facing the SPS problem. In this paper, a number of multi-objective metaheuristics have been used to address this problem. They have been thoroughly compared over a set of 36 publicly available instances that cover a wide range of different scenarios. The resulting project schedulings of the algorithms have been analyzed in order to show their relevant features. The algorithms used in this paper and the analysis performed may assist project managers in the difficult task of deciding who does what in a software project.

17:40-18:05 **Finding Short Counterexamples in Promela Models Using Estimation of Distribution Algorithms**
Jan Staunton, John Clark

Model checking is an automatic technique that exhaustively checks the state space of a system/program to prove if a specification is satisfied. If an error is detected, the precise circumstances of the issue are returned to the user in the form of a counterexample. Exhaustively checking the state space of a large system, a system with many concurrent components for example, is often intractable. In this scenario, heuristic mechanisms can be employed with the task of detecting errors rather than proving the system is correct. Recently, a metaheuristic EDA-based approach to detecting deadlock in multithreaded Java software has shown great promise in this area. In this paper, we extend that work to search Promela models for counterexamples. We show that the EDA-based technique can find errors where algorithms such as A* search fail. We also show the ability of the EDA to find shorter errors than those discovered by traditional heuristic methods.

Saturday 16 July 10:40 – 12:20

GA8: Co-evolution
Room: Lansdowne
Session Chair: Kenneth De Jong (George Mason University)

10:40-11:05 **Approximating n-player behavioural strategy Nash equilibria using coevolution**
Spyridon Samothrakis, Simon Lucas

Co-evolutionary algorithms are plagued with a set of problems related to intransitivity that make it questionable what the end product of a co- evolutionary run is or can achieve. With the introduction of solution concepts into coevolution, part of the issue was alleviated, however efficiently representing and achieving game theoretic solution concepts is still not a trivial task. In this paper we propose a co-evolutionary algorithm that approximates behavioural strategy Nash equilibria in n-player zero sum games, by exploiting the min-max solution concept. In order to support our case we provide a set of experiments in both games of known and unknown equilibria. In the case of known equilibria, we can confirm our algorithm converges to the known solution, while in the case of unknown equilibria we can see a steady progress towards Nash.

11:05-11:30 **Smart Use of Computation Resource Based on Contribution for Cooperative Co-evolutionary Algorithms**
Mohammad Nabi Omidvar, Xiaodong Li, Xin Yao

Standard Cooperative Co-evolution uses a round-robin method to select subcomponents to undergo optimization. In a non-separable (epistatic) optimization problem, dividing the computational budget equally between all of the subcomponents is not necessarily the best strategy. When dealing with non-separable problems, there is usually an imbalance between the contribution of various subcomponents to the global fitness of the individuals. Using a round-robin fashion treats all of the subcomponents equally and wastes the computational budget. In this paper, we propose a Contribution Based Cooperative Co-evolution (CBCC) that selects the subcomponents based on their contributions in the global fitness. This alleviates the imbalance issue and allows the computational resources to be used more efficiently. Experiments on several benchmark functions with the “imbalance issue” show that this new scheme is promising especially when it is combined with a grouping algorithm that captures interacting variables in common subcomponents.

11:30-11:55 **Iterated N-Player Games on Small-World Networks**
Raymond Chiong, Michael Kirley

The evolution of strategies in iterated multi-player social dilemma games is studied on small-world networks. Two different games with varying reward values -- the N-player Iterated Prisoner's Dilemma (N-IPD) and the N-player Iterated Snowdrift game (N-ISD) -- form the basis of this study. Here, the agents playing the game are mapped to the nodes of different network architectures, ranging from regular lattices to small-world networks and random graphs. In a given game instance, the focal agent participates in an iterative game with N-1 other agents drawn from its local neighbourhood. We use a genetic algorithm with synchronous updating to evolve agent strategies. Extensive Monte Carlo simulation experiments show that for smaller cost-to-benefit ratios, the extent of cooperation in both games decreases as the probability of re-wiring increases. For higher cost-to-benefit ratios, when the re-wiring probability is small we observe an increase in the level of cooperation in the N-IPD population, but not the N-ISD population. This suggests that the small-world network structure with small re-wiring probabilities can both promote and maintain higher levels of cooperation when the game becomes more challenging.

11:55-12:20 **A Cooperative Coevolutionary Genetic Algorithm for Learning Bayesian Network Structures**
Arthur Carvalho

We propose a cooperative coevolutionary genetic algorithm for learning Bayesian network structures from fully observable data sets. Since this problem can be decomposed into two dependent subproblems, that is to find an ordering of the nodes and an optimal connectivity matrix, our algorithm uses two subpopulations, each one representing a subtask. We describe the empirical results obtained with simulations of the Alarm and Insurance networks. We show that our algorithm outperforms the deterministic algorithm K2.

GP5: Applications
Room: Pembroke
Session Chair: Peter Alexander Whigham (Univ. of Otago)

10:40-11:05 **Evolving Patches for Software Repair**
Thomas Ackling, Brad Alexander, Ian Grunert

Software defects are a major concern in software systems. Unsurprisingly, there are many tools and techniques to facilitate the removal of defects through their detection and localisation. However, there are few tools that attempt to repair defects. To date, evolutionary tools for software re- pair have evolved changes directly in the program code being repaired. In this work we describe an implementation: PyEDB, that encodes changes as a series of code modifications or patches. These modifications are evolved as indi- viduals. We show PyEDB to be effective in repairing some small errors, including variable naming errors, in Python programs. We also demonstrate that evolving patches rather than programs simplifies the removal of spurious errors.

11:05-11:30 **Morphological Image Enhancement Procedure Design By Using Genetic Programming**
Jun Wang, Ying Tan

In this paper, we propose a genetic programming algorithm to design the morphological image enhancement procedure. Given a group of morphological operations and logical operations as function set, this algorithm evolves to produces a rational procedure which can enhance the input images. A novel mechanism which combines the ground truth method and feature significance is brought forward to evaluate the performance of images enhanced by generated procedures. In each generation, the best fitted individuals are selected on the basis of fitness values, and some individuals participate crossover or mutation with a probability . After generations evolution, this algorithm output the best individual. Seven morphological operations and five logical operations are used in this algorithm. Furthermore, the structuring elements of morphological operations are randomly generated and varied in the whole pattern space. These methods promote the expressive ability of generated procedures. Examined by the binary image features extraction, the procedure generated by this algorithm is more accurate and intelligible than previous works. In the task of gray scale image enhancement, the generated procedure is applied to infrared finger vein images to enhance the region of interest. More accurate features are extracted and the accuracy of authentication is promoted.

11:30-11:55 **Co-Evolving Robocode Tanks**
Robin Harper

Robocode is a java based programming platform where robot tanks, controlled by programs written in java, compete. In this paper Grammatical Evolution is used to evolve java programs to control a robocode robot. This paper demonstrates how Grammatical Evolution together with spatial co-evolution in age layered planes (SCALP) can harness co-evolution to evolve relatively complex behaviour, including robots capable of beating robocode's sample robots as well as some more complex human coded robots. The results of the co-evolution are similar to the results obtained by direct evolution against a range of human coded robots, which provides encouragement as to the efficacy of the co-evolution system.

11:55-12:20 **Evolving a robust trader in a cyclic double auction market**
Peter Whigham, Rasika Withanawasam

A computational model of a double auction market is introduced and extended to allow a controlled cyclic behaviour in the price signal to be developed. Traders are evolved to maximise profit in this market using Grammatical Evolution, and their properties studied for a range of periods and amplitude of the price signal. The trader grammar allows decision making based on simple trading rules incorporating the concepts of moving-average oscillators and trading range break-out. The results of this investigation demonstrate that traders evolve a short waiting period between decisions, and that there underlying decision logic reflects the scale of the market price frequency. Evidence is presented that suggests evolving a robust profit-making trader, for a range of price frequency changes, requires the training data to have high frequency variation. This preliminary study is unique in its approach to computational double auction markets and suggests a number of interesting directions for future work.

PS2: Parallel Evolutionary Systems (Session 2)
Room: Ulster
Session Chair: Man Leung Wong (Lingnan University, Hong Kong)

10:40-11:05 **On the Effectiveness of Crossover for Migration in Parallel~Evolutionary Algorithms**
Frank Neumann, Pietro Oliveto, Günter Rudolph, Dirk Sudholt

11:05-11:30 **Many-threaded Implementation of Differential Evolution for the CUDA Platform**
Pavel Krömer, Václav Snášel, Jan Platoš, Ajith Abraham

Differential evolution is an efficient populational meta -- heuristic optimization algorithm successful in solving difficult real world problems. Due to the simplicity of its operations and data structures, it is suitable for a parallel implementation on multicore systems and on the GPU. In this paper, we design a simple yet highly parallel implementation of the differential evolution using the CUDA architecture. We demonstrate the speedup obtained by the proposed parallelization of the differential evolution on a NP hard combinatorial optimization problem and on a benchmark function of many variables.

11:30-11:55 **Using commodity cloud storage services for distributed evolutionary algorithms**
Maribel García-Arenas, Juan Merelo-Guervós, Antonio Mora-García, Pedro Castillo-Valdivieso

Cloud computing, in general, is becoming part of the toolset the scientific uses to perform compute-intensive tasks. In particular, cloud storage is an easy and convenient way of storing files that will be accessible over the Internet, but also a way of distributing those files and performing distributed computation using them. In this paper we describe how such a service commercialized by Dropbox is used for pool-based evolutionary algorithms. A prototype system is described and its peformance measured over a deceptive combinatorial optimization problem, finding that, for some type of prob- lems and using commodity hardware, cloud storage systems can profitably be used as a platform for distributed evolu- tionary algorithms. Preliminary results show that Dropbox is, indeed a viable alternative for execution of pool-based distributed evolutionary algorithms, showing a good scaling behavior with up to 4 computers.

11:55-12:20 **Parallel Island-Based Multiobjectivised Memetic Algorithms for a 2D Packing Problem**
Carlos Segura, Eduardo Segredo, Coromoto León

Bin Packing problems are NP-hard problems with many practical applications. A variant of a Bin Packing Problem was proposed in the GECCO 2008 competition session. The best results were achieved by a mono-objective Memetic Algorithm (MA). In order to reduce the execution time, it was parallelised using an island-based model. High quality results were obtained for the proposed instance. However, subsequent studies concluded that stagnation may occur for other instances. The term multiobjectivisation refers to the transformation of originally mono-objective problems as multi-objective ones. Its main aim is to avoid local optima. In this work, a multiobjectivised MA has been applied to the GECCO 2008 problem. Several multiobjectivisation schemes have been tested. Also, a parallelisation of the multiobjectivised MA has been developed. Results have been compared with the best up to date mono-objective approaches. Computational results have demonstrated the validity of the proposals. They have provided benefits in terms of solution quality, and in terms of time saving.

EMO5: Applications II & Theory
Room: Munster
Session Chair: Boris Naujoks (Cologne University of Applied Sciences)

10:40-11:05 **Population-ACO for the Automotive Deployment Problem**
Irene Moser, James Montgomery

The automotive deployment problem is a real-world constrained multiobjective assignment problem in which software components must be allocated to processing units distributed around a car's chassis. Prior work has shown that evolutionary algorithms such as NSGA-II can produce good quality solutions to this problem. This paper presents a population-based ant colony optimisation (PACO) approach that uses a single pheromone memory structure and a range of local search operators. The PACO and prior NSGA-II are compared on two realistic problem instances. Results indicate that the PACO is generally competitive with NSGA-II and performs more e
ffectively as problem complexity - size and number of objectives - is increased.

11:05-11:30 **A RankMOEA to Approximate the Pareto Front of a Dynamic Principal-Agent Model**
Juan Herrera, Katya Rodrígez-Vazquez, Itza Curiel Cabral, Sonia Di Giannatale Menegalli

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11:30-11:55 **Accumulative Sampling for Noisy Evolutionary Multi-Objective Optimization**
Taejin Park, Kwang Ryel Ryu

Objective evaluation is subject to noise in many real-world problems. The noise can deteriorate the performance of multi-objective evolutionary algorithms, by misleading the population to a local optimum and reducing the convergence rate. This paper proposes three novel noise handling techniques: accumulative sampling, a new ranking method, and a different selection scheme for recombination. The accumulative sampling is basically a kind of dynamic resampling, but it does not explicitly decide the number of samples. Instead, it repeatedly takes additional samples of objectives for the solutions in the archive at every generation, and updates the estimated objectives using all the accumulated samples. The new ranking method combines probabilistic Pareto rank and crowding distance into a single aggregated value to promote the diversity in the archive. Finally, the fitness function and selection method used for recombination are made different from those for the archive to accelerate the convergence rate. Experiments on various benchmark problems have shown that the algorithm adopting all these features performs better than other MOEAs in various performance metrics.

11:55-12:20 **Comparison-Based Complexity of Multiobjective Optimization**
Olivier Teytaud

THEORY2: Runtime Analysis
Room: Leinster
Session Chair: Carola Winzen (Max-Planck-Institut fuer Informatik)

10:40-11:05 **Domain specific analysis and modeling of Optimal Elimination of Fitness Functions with Optimal Sampling**
Gautham Anil, Paul Wiegand

Run-time analysis of an algorithm over a domain can tell us the performance we can expect from that algorithm on that domain. However, sometimes, it can be useful to know the best performance achievable on a domain, to give context to algorithm performance. Black-box complexty is a measure that can tell us this best achievable performance. We extend a previous work which presented an algorithm called Optimal Elimination of Fitness Function that is by itself conditionally optimal over all problem classes albeit impractical. We compliment this algorithm with an optimal sample selection strategy which removes the conditionality. Consequently, the performance of this combined algorithm over a domain is the black-box complexity of that domain, providing a new technique for deriving black-box complexity. Additionally, we suggest techniques to perform run-time analysis of this algorithm. We discuss using those techniques to build an algorithm that is targeted, practical, yet equivalent to the combined algorithm over the target domain. We demonstrate these techniques on the domain of Generalized Leading Ones by deriving its black-box complexity and developing an efficient equivalent algorithm.

11:05-11:30 **Fitness-Levels for Non-Elitistic Populations**
Per Lehre

This paper introduces an easy to use technique for deriving upper bounds on the expected runtime of non-elitistic population-based evolutionary algorithms (EAs). Applications of the technique show how the efficiency of EAs is critically dependant on having a sufficiently strong selective pressure. Parameter settings that ensure sufficient selective pressure on commonly considered benchmark functions are derived for the most popular selection mechanisms. Together with a recent technique for deriving lower bounds, this paper contributes to a much-needed analytical tool-box for analysis of evolutionary algorithms with populations.

11:30-11:55 **Sharp Bounds by Probability-Generating Functions and Variable Drift**
Benjamin Doerr, Mahmoud Fouz, Carsten Witt

We introduce to the runtime analysis of evolutionary algorithms two powerful techniques: probability-generating functions and variable drift analysis. They are shown to provide a clean framework for proving sharp upper and lower bounds. As an application, we improve the results by Doerr et al.~(GECCO~2010) in several respects. First, the upper bound on the expected running time of the most successful quasirandom evolutionary algorithm for the OneMax function is improved from $1.28n\ln n$ to $0.99n\ln n$, which breaks the barrier of $n\ln n$ posed by coupon-collector processes. Compared to the classical 1+1 EA, whose runtime will for the first time be analyzed with respect to terms of lower order, this represents a speedup by more than a factor of $e=2.71\dots$

11:55-12:20 **PAC Learning and Genetic Programming**
Timo Kötzing, Frank Neumann, Reto Spöhel

Genetic programming (GP) is a very successful type of learning algorithm that is hard to understand from a theoretical point of view. With this paper we contribute to the computational complexity analysis of genetic programming that has been started recently. We analyze GP in the well-known PAC learning framework and point out how it can observe quality changes in the evolution of functions by random sampling. This leads to computational complexity bounds for a simple concept class of linear pseudo-Boolean functions. Furthermore, we show that approximations of an ideal function can be learned in a smaller amount of time.

ACO-SI5: Ant Colony Optimization and Swarm Intelligence (Session 5)
Room: Connaught Suite 1
Session Chair: Dhananjay Thiruvady (Monash University)

10:40-11:05 **Empirical Computation of the Quasi-optimal Number of Informants in Particle Swarm Optimization**
Jose Garcia-Nieto, Enrique Alba

In the standard particle swarm optimization (PSO), a new particle is generated using two main informant elements: the best position the particle has found so far and the best performer among its neighbors. In fully informed PSO, each particle is influenced by all the remaining ones in the swarm, or by a series of neighbors structured in static topologies (ring, square, or clusters). In this paper, we generalize and analyze the number of informants that take part in the calculation of new particles. Our aim is to discover if a quasi-optimal number of informants exists for a given problem. The experimental results seem to suggest that 6 to 8 informants could provide our PSO with higher chances of success in continuous optimization for well-known benchmarks.

11:05-11:30 **Ant Colony Optimization for Determining the Optimal Dimension and Delays in Phase Space Reconstruction**
wei-neng Chen, Jun ZHANG

The selection of parameters in time-delay embedding for phase space reconstruction is crucial to chaotic time series analysis and forecasting. Although various methods have been developed for determining the parameters of embedding dimension and time delay for uniform embedding, the study of parameter selection for non-uniform embedding is progressed at a slow pace. In a non-uniform embedding which enables different dimensions in the phase space to have different time delays, the optimal selection of time delays presents a difficult optimization problem with combinatorial explosion. To solve this problem, this paper proposes an ant colony optimization (ACO) approach. The advantages of ACO for the embedding parameter selection problem are in two aspects. First, as ACO builds solution in an incremental way, it does not need to use a fixed embedding dimension as the encoding length of a solution. Instead, both the embedding dimension and the time delays can be optimized together. Second, ACO enables the use of problem-based heuristics. Therefore heuristics designed based on the original observed time series can be used to accelerate the search speed of ACO. Experimental results show that the proposed algorithm is promising.

11:30-11:55 **Car Sequencing with Constraint-Based ACO**
Dhananjay Thiruvady, Bernd Meyer, Andreas Ernst

ECP5 - Getting a Job: What to do and what not to do
Room: Connaught Suite 2
Session Chair: Jorn Mehnen (Cranfield University)

RWA7: Multiobjective
Room: Connaught Suite 2
Session Chair: Rituparna Datta (IIT Kanpur)

10:40-11:05 **Multi-Objective Optimization of Dynamic Memory Managers using Grammatical Evolution**
J. Manuel Colmenar, José Risco-Martín, David Atienza, J. Ignacio Hidalgo

The dynamic memory manager (DMM) is a key element whose customization for a target application reports great benefits in terms of execution time, memory usage and energy consumption. Previous works presented algorithms to automatically obtain custom DMMs for a given application. Nevertheless, those approaches are based on grammatical evolution where the fitness is built as an aggregate objective function, which does not completely exploit the search space, returning the designer the DMM solution with best fitness. However, this approach may not find solutions that could fit in a concrete hardware platform due to a very low value of one of the objectives while the others remain high, which may represent a high fitness. In this work we present the first multi-objective optimization methodology applied to DMM optimization where the Pareto dominance is considered, thus providing the designer with a set of non-dominated DMM implementations on each optimization run. Our results show that the multi-objective optimization provides Pareto-optimal alternatives due to a better exploit of the search space obtaining better hypervolume values than the aggregate objective function approach.

11:05-11:30 **Multiple Objective Optimisation applied to Route Planning**
Antony Waldock, David Corne

This paper presents an evaluation of different multi-objective optimisation algorithms when applied to the problem of planning a route over an unstructured environment, where a route has a number of objectives defined using real-world data sources.

The paper firstly introduces the problem of planning a route over an unstructured environment (one where no pre-determined set of possible routes exists) and defines the data sources, Digital Terrain Elevation Data (DTED) and NASA Landsat Hyperspectral data, used to calculate the route objectives (time taken, exposure and fuel consumed). A number of different route planning problems are then used to compare the performance of two single-objective optimisation algorithms and a range of multi-objective optimisation algorithms selected from the literature.

The experimental results show that the multi-objective optimisation algorithms result in significantly better routes than the single-objective optimisation algorithms and have the advantage of returning a set of routes that represent the trade-off between objectives. The MOEA/D and SMPSO algorithms are shown, in these experiments, to outperform the other multi-objective optimisation algorithms for this type of problem. Future work will focus on how these algorithms can be integrated into a route planning tool and especially on reducing the time taken to produce routes.

11:30-11:55 **Spanning the Pareto Front of a Counter Radar Detection Problem**
Hans Moen, Harald Hovland

Radar system design and optimization are complex problems recently cast in the framework of multi-objective evolutionary algorithms. However, in the problem of counter radar detection and tracking, the state-of-the-art multi-objective optimization algorithm NSGA-II is unable to span the complete 2D Pareto front of the asymptotic and convex problem domain, leaving out vital information on the radar-jammer system dynamics. Common modifications to the domination principle employed will to some degree increase the span of the Pareto front, at the expense of slower convergence and a less dense front. In this paper, a Spanning Evolutionary Algorithm (SEA) is introduced to overcome these problems. The SEA characterizes all solutions by one single metric and uses interpolated attraction points along the boundary of the solution set as basis for selecting and evolving solutions in the optimizer. The SEA is proposed and analyzed in the context of the conflicting multi-objective optimization criteria of search efficiency, density distribution and span of the complete Pareto front of the counter radar detection problem. The SEA is shown to produce high performance solutions not easily obtained using the well-established optimization methods of NSGA-II and epsilon-MOEA.

11:55-12:20 **Multi-Objective Design and Analysis of Robot Gripper Configurations Using an Evolutionary-Classical Approach**
Rituparna Datta, Kalyanmoy Deb

This paper is concerned with the determination of optimum forces extracted by robot grippers on the surface of a grasped rigid object. A multi-criteria optimization of robot gripper design problem is solved with two different configurations involving two conflicting objectives and a number of constraints. The objectives involve minimization of the difference between maximum and minimum gripping forces and simultaneous minimization of the transmission ratio between the applied gripper actuator force and the force experienced at the gripping ends. Two different configurations of the robot gripper are designed by a state-of-the-art algorithm (NSGA-II) and the obtained results are compared with a previous study. Due to presence of geometric constraints, the resulting optimization problem is highly non-linear and multi-modal. For both gripper configurations, the proposed methodology outperforms the results of the previous study. The Pareto-optimal solutions are thoroughly investigated to establish some meaningful relationships between the objective functions and variable values. In addition, it is observed that one of the gripper configurations completely outperforms the other one from the point of view of both objectives, thereby establishing a complete bias towards the use of one of the configurations in practice.

ECOM4: New Algorithmic Strategies
Room: Elgin
Session Chair: Shu Liu (the University of Tokyo)

10:40-11:05 **P-GLS-II: An Enhanced Version of the Population-based Guided Local Search**
Nasser Tairan, Qingfu Zhang

We have recently proposed a Population-based Guided Local Search (P-GLS) framework for solving difficult combinatorial optimization problems. In P-GLS, several agents of guided local search (GLS) procedures are run in a parallel way. These agents exchange information acquired from their previous search to make their further search more rational. We suggested based on the well-known proximate optimality principle (POP) that the shared features between the current agents' local optimal solutions are more likely to be part of the best solution to the problem; therefore these features should not be penalized. However, sometimes some of these common features may not exhibit in a global optimal solution. In this paper, two frameworks are proposed as substantial improvement of P-GLS. They apply new penalization strategies that increase favoring common features based on their occurrences in the agents' local optimal solutions during the search. The performance of the new algorithms, examined on the Traveling Salesman Problem (TSP), is investigated and evaluated in terms of solution quality and the speed. The experimental results demonstrate that the new algorithm outperforms parallel GLS algorithm without collaboration and other state-of-the-art algorithms.

11:05-11:30 **Harmony Search with Differential Mutation Based Pitch Adjustment**
Kai Qin, Florence Forbes

Harmony search (HS), as an emerging metaheuristic technique mimicking the improvisation behavior of musicians, has demonstrated strong efficacy of solving various numerical and real-world optimization problems. This work presents a harmony search with differential mutation based pitch adjustment (HSDM) algorithm, which improves the original pitch adjustment operator of HS using the self-referential differential mutation scheme that features differential evolution – another celebrated metaheuristic algorithm. In HSDM, the differential mutation based pitch adjustment can dynamically adapt the properties of the landscapes being explored at different searching stages. Meanwhile, the pitch adjustment operator's execution probability is allowed to vary randomly between 0 and 1, which can maintain both wild and fine exploitation throughout the searching course. HSDM has been evaluated and compared to the original HS and two recent HS variants using 16 numerical test problems of various searching landscape complexities at 10 and 30 dimensions. HSDM consistently demonstrates superiority on most of test problems.

11:30-11:55 **Imitation Tendencies of Local Search Schemes in Baldwinian Evolution**
Shu Liu, Hitoshi Iba

11:55-12:20 **Predictive Parameter Control**
Aldeida Aleti, Irene Moser

Saturday 16 July 14:40 – 16:50

GA9: Selection
Room: Lansdowne
Session Chair: David Corne (Heriot-Watt University)

14:40-15:05 **Polynomial Selection Scheme with Dynamic Parameter Estimation in Cellular Genetic Algorithm**
Jiradej Vatanutanon, Hitoshi Iba, Nasimul Noman

Recent study has introduced the powerful selection scheme in cellular genetic algorithm that can produce all range of selective pressure. The parameters used in that study, however, are empirically estimated by numbers of experiments. In this study, we propose the idea to perform parameter estimation from a theoretical perspective. From the concept of maximizing the probability to find the new best solution together with hill-climbing optimization, it is able to search for an optimal parameter in each generation. The selection scheme with the optimal parameter yields the numbers of mating that maximize the probability of finding better solution and this optimal parameter changes during run; therefore, it is adaptive to the behavior of a particular evolution. In order to confirm the capability of this parameter estimation method, we conducted experiments using an ordinary manually tuned static parameter and estimated dynamic parameter obtained from this parameter estimation method. The experimental results show that the algorithm with estimated parameter performs better than the former method even with the best tuned parameter. Therefore, by applying this parameter estimation to the selection scheme stated at the beginning, we would able to create a new universal adaptive paradigm for the cellular evolutionary algorithm.

15:05-15:30 **Real-Space Evolutionary Annealing**
Alan Lockett, Risto Miikkulainen

Standard genetic algorithms can discover good fitness regions and later forget them due to their Markovian structure, resulting in suboptimal performance. Real-Space Evolutionary Annealing (REA) hybridizes simulated annealing and genetic algorithms into a provably convergent evolutionary algorithm for Euclidean space that relies on non-Markovian selection. REA selects any previously observed solution from an approximated Boltzmann distribution using a cooling schedule. This method enables REA to escape local optima while retaining information about prior generations. This paper compares REA experimentally to six popular optimization algorithms, including Differential Evolution, Particle Swarm Optimization, Correlated Matrix Adaptation Evolution Strategies, the real-coded Bayesian Optimization Algorithm, a real-coded genetic algorithm, and simulated annealing. REA converges faster to the global optimum and succeeds more often on two out of three difficult, multimodal, non-separable benchmarks and performs strongly on all three. In particular, REA vastly outperforms the real-coded genetic algorithm and simulated annealing, proving that the hybridization is better than either algorithm alone. REA is therefore an interesting and effective algorithm for global optimization of difficult fitness functions.

15:30-15:55 **How Hard should we Run? - Trading off Exploration and Exploitation in Dynamic Evolutionary Algorithms**
Yun-Geun Lee, Robert McKay

All evolutionary algorithms trade off exploration and exploitation in optimisation problems; dynamic problems are no exception. We investigate this trade-off, over a range of algorithm settings, on dynamic variants of three well-known optimisation problems (One Max, Royal Road and knapsack), using Yang's XOR method to vary the scale and rate of change. Extremely exploitative algorithm settings performed best for a surprisingly wide range of problems; even where they were not the most effective, they still performed competitively, and even in those cases, the best performers were still far more exploitative than most would anticipate.

GP6: Difficulty
Room: Pembroke
Session Chair: Leonardo Vanneschi (University of Milano-Bicocca)

14:40-15:30 **Structural Difficulty in Estimation of Distribution Genetic Programming**
Kangil Kim, Robert McKay, MinHyeok Kim

Estimation of Distribution Algorithms were introduced into Genetic Programming over 15 years ago, and have demonstrated good performance on a range of problems, but there has been little research into their limitations. We apply two such algorithms – scalar and vectorial Stochastic Grammar GP – to Daida's well-known Lid problem, to better understand their ability to learn specific structures. The scalar algorithm performs poorly, but the vectorial version shows good overall performance. We then extended Daida's problem to explore the vectorial algorithm's ability to find even more specific structures, finding that the performance fell off rapidly as the specificity of the required structure increased. Thus although this particular system has less severe structural difficulty issues than standard GP, it is by no means free of them.

15:30-16:20 **The K Landscapes: a Tunably Difficult Benchmark for Genetic Programming**
Leonardo Vanneschi, Luca Manzoni, Mauro Castelli

The NK landscapes are a well known benchmark for genetic algorithms (GAs) in which it is possible to tune the ruggedness of the fitness landscape by simply modifying the value of a parameter K. They have successfully been used in many theoretical studies, allowing researchers to discover interesting properties of the GAs dynamics in presence of rugged landscapes. A similar benchmark does not exist for genetic programming (GP) yet. Nevertheless, during the EuroGP conference debates of the last few years, the necessity of defining new benchmark problems for GP has repeatedly been expressed by a large part of the attendees. This paper is intended to fill this gap, by introducing an extension of the NK landscapes to tree based GP, that we call K landscapes. In this benchmark, epistasis are expressed as growing mutual interactions between the substructures of a tree as the parameter K increases. The fact that the problem becomes more and more difficult as the value of K increases is experimentally demonstrated. Interestingly, we also show that GP "bloats" more and more as K increases.

ESEP3: Evolution Strategies and Evolutionary Programming (Session 3)
Room: Ulster
Session Chair: Nikolaus Hansen (INRIA Saclay)

14:40-15:05 **Using the Uncertainty Handling CMA-ES for finding Robust Optima**
Johannes Kruisselbrink, Edgar Reehuis, Andre Deutz, Thomas Baeck, Michael Emmerich

Algorithms that search for robust optima often evaluate the effective fitness (robust fitness) based on stochastic approximation schemes. In this setting, finding robust optima can be recast as an optimization problem with a uncertain/noisy objective function. This paper studies whether state-of-the-art uncertainty handling techniques, proposed in the context of optimizing noisy objective functions, can be applied for finding robust optima. In this paper, the UH-CMA-ES is modified to handle approximations of the effective fitness. This approach is evaluated empirically and compared to other schemes that aim to find robust solutions. The experimental results on multiple benchmark problems show that using the UH-CMA-ES for finding robust solutions yields a comparable method for multi-modal problems, while it outperforms other schemes on unimodal problems.

15:05-15:30 **Adaptive Coordinate Descent**
Ilya Loshchilov, Marc Schoenauer, Michele Sebag

Independence from the coordinate system is one source of efficiency and robustness for the Covariance Matrix Adaptation Evolution Strategy (CMA-ES). The recently proposed Adaptive Encoding (AE) procedure generalizes CMA-ES adaptive mechanism, and can be used together with any optimization algorithm. Adaptive Encoding gradually builds a transformation of the coordinate system such that the new coordinates are as decorrelated as possible with respect to the objective function. But any optimization algorithm can then be used together with Adaptive Encoding, and this paper proposes to use one of the simplest of all, that uses a dichotomy procedure on each coordinate in turn. The resulting algorithm, termed Adaptive Coordinate Descent (ACD), is analyzed on the Sphere function, and experimentally validated on BBOB testbench where it is shown to outperform the standard (1 + 1)-CMA-ES, and is found comparable to other state-of-the-art CMA-ES variants.

DETA3: Music and Arts
Room: Leinster
Session Chair: Christian Gagné (Université Laval)

14:40-15:05 **An Executable Graph Representation for Evolutionary Generative Music**
James McDermott, Una-May O'Reilly

We propose a new representation for evolutionary music based on executable graphs in which nodes execute arithmetic functions. Input nodes supply time variables and abstract control variables, and multiple output nodes are mapped to MIDI data. The motivation is that multiple outputs from a single graph should tend to behave in related ways, a key characteristic of good music. While the graph itself determines the short-term behaviour of the music, the control variables can be used to specify large-scale musical structure. This separation of music into form and content enables novel compositional techniques well-suited to writing for games and film, as well as for standalone pieces. A mapping from integer-array genotypes to executable graph phenotypes means that evolution, both interactive and non-interactive, can be applied. Experiments with and without human listeners support several specific claims concerning the system's benefits.

15:05-15:30 **Multi-Objective Feature Selection in Music Genre and Style Recognition Tasks**
Igor Vatolkin, Mike Preuß, Günter Rudolph

Feature selection is an important prerequisite for music classification which in turn is becoming more and more ubiquitous since entering the digital music age. Automated classification into genres or even personal categories is currently envisioned even for standard mobile devices. However, classifiers often fail to work well with all available features, and simple greedy methods often fail to select good feature sets, making feature selection for music classification a natural field of application for evolutionary approaches in general, and multi-objective evolutionary algorithms in particular. In this work, we study the potential of applying such a multi-objective evolutionary optimization algorithm for feature selection with different objective sets, which has not been tried yet up to our knowledge. The result is promising, thus calling for deeper investigations of this approach.

15:30-15:55 **Takeover and the Trade-off Between Originality and Diversity in the Artificial Evolution of Melodies**
Alan de Freitas, Frederico Guimarães

One of the greatest problems when using genetic algorithms to evolve melodies is creating an aesthetically conscious measure of fitness. In this paper, we describe a new approach with a minimum measure of fitness in which a set of good individuals is returned at the end of the process. Details about the implementation of a population of measures and some genetic operators are described in this work before an implicit way to evaluate fitness is given. We define a Takeover Matrix to measure the relationship between different generations and its compromise between originality and diversity. By means of this Takeover Matrix, the evolutionary process itself can be used as a criterion instead of using only ordinary individual measures of fitness. The results show the implications of using the proposed approach and demonstrate that the proposed algorithm is able to generate good sets of melodies. The algorithm can be used not only for developing new ideas but also to extend earlier created melodies with influence from the initial population.

15:55-16:20 **Evolving Art with Scalable Vector Graphics**
Eelco den Heijer, A.E. Eiben

In this paper we introduce the use of Scalable Vector Graphics (SVG) as a representation for evolutionary art. We describe the technical aspects of using SVG in evolutionary art, and explain the genetic operators mutation and crossover. Furthermore, we compare the use of SVG with existing representations in evolutionary art. We performed a number of experiments in an unsupervised evolutionary art system using two aesthetic measures as fitness functions, and compared the outcome of the different experiments with each other and with previous work with symbolic expression as the representation.

GA10: Optimization
Room: Connaught Suite 1
Session Chair: Antonio Martí Campoy (Universidad Politécnica de VAlencia)

14:40-15:05 **An EA-based Approach to Design Optimization using Evidence Theory**
Rupesh Srivastava, Kalyanmoy Deb

For problems involving uncertainties in design variables and parameters, a bi-objective, evolutionary algorithm (EA) based approach to design optimization using evidence theory is proposed and implemented in this paper. In addition to a functional objective, a plausibility measure of failure of constraint satisfaction is minimized. Despite some interests in classical optimization literature, such a consideration in EA is rare. Due to EA's flexibility in its operators, non-requirement of any gradient, its ability to handle multiple conflicting objectives, and ease of parallelization, evidence-based design optimization using an EA is promising. Results on a test problem and a couple of engineering design problems show that the modified evolutionary multi-objective optimization (EMO) algorithm is capable of finding a widely distributed trade-off frontier showing different optimal solutions corresponding to different levels of plausibility failure limits. Furthermore, a single-objective evidence based EA is found to produce better optimal solutions than a previously reported classical optimization procedure. Handling uncertainties of different types are getting increasingly popular in applied optimization studies and more such studies using EAs would be needed to make EAs useful and pragmatic in practical optimization problem-solving tasks.

15:05-15:30 **Adaptive Strategies Applied to Evolutionary Search for 2D DCT Cellular Automata Rules**
Gina Oliveira, Luiz Martins, Enrique Fynn

Cellular automata (CA) are able to perform complex computations through local interactions. The investigation of how CA computations are carried out can be made by the usage of CA rules to solve specific tasks. The well-known problem called density classification task (DCT) is investigated, with focus on its two-dimensional version. Evolutionary algorithms have been widely used in the search for DCT rules. A sample of lattices with Gaussian distribution is commonly used to evaluate rule quality. However, uniform lattices are easier to classify, allowing an initial selective pressure needed to start the convergence. A comparative evaluation of three adaptive strategies is presented here: they start using easy lattices to classify and as effective rules are being obtained the difficult level is progressively increased toward the target evaluation. Several experiments were performed to evaluate the strategies efficiency and new rules were found, which outperform the best ones published.

15:30-15:55 **A Non-deterministic Adaptive Inertia Weight in PSO**
Kusum Deep, Madhuri Arya, Jagdish Bansal

Particle Swarm Optimization (PSO) is a relatively recent swarm intelligence algorithm inspired from social learning of animals. Successful implementation of PSO depends on many parameters. Inertia weight is one of them. The selection of an appropriate strategy for varying inertia weight w is one of the most effective ways of improving the performance of PSO. Most of the works done till date for investigating inertia weight have considered small values of w, generally in the range [0,1]. This paper presents some experiments with widely varying values of w which adapts itself according to improvement in fitness at each iteration. The same strategy has been implemented in two different ways giving rise to two inertia weight variants of PSO namely Globally Adaptive Inertia Weight (GAIW) PSO, and Locally Adaptive Inertia Weight (LAIW) PSO. The performance of the proposed variants has been compared with three existing inertia weight variants of PSO employing a test suite of 6 benchmark global optimization problems. The experiments show that the results obtained by the proposed variants are comparable with those obtained by the existing ones but with better convergence speed and less computational effort.

15:55-16:20 **An algorithm for deciding minimal cache sizes in Real-Time Systems**
Antonio Martí Campoy, Francisco Rodriguez Ballester, Eguenio Tamura Moritmitsu, Rafael Ors Carot

When designing real-time systems, predictability is of utmost importance. With a predictable behaviour, locking cache memories are a practical alternative to conventional caches. Offering similar performance to conventional caches, a locking cache allows a simple, accurate schedulability analysis. But locking caches may also help to reduce, size of system, by means of reducing cache size. Reducing cache size, also cost and power consumption may be reduced. This way, both predictability and cost saving is provided by means of locking cache. This work presents a set of algorithms, aimed to select the contents of a locking cache that provides the minimum locking cache size, while the system remains schedulable. Several experimental results are analysed, and show that new algorithms offers better results than previous approaches.

ALIFE4: Theory
Room: Elgin
Session Chair: Giovanni Squillero (ALIFE Chair)

14:40-15:05 **How to Promote Generalisation in Evolutionary Robotics: the ProGAb Approach**
Tony Pinville, Sylvain Koos, Jean-Baptiste Mouret, Stéphane Doncieux

In Evolutionary Robotics (ER), controllers are assessed in a single or a few environments. As a consequence, good performances in new different contexts are not guaranteed. While a lot of ER works deal with robustness, i.e. the ability to perform well on new contexts close to the ones used for evaluation, no current approach is able to promote broader generalisation abilities without any assumption on the new contexts. In this paper, we introduce the ProGAb approach, which is based on the standard three data sets methodology of supervised machine learning, and compare it to state-of-the-art ER methods on two simulated robotic tasks: a navigation task in a T-maze and a more complex ball-collecting task in an arena. In both applications, the ProGAb approach: (1) produced controllers with better generalisation abilities than the other methods; (2) needed two to three times fewer evaluations to discover such solutions.

15:05-15:30 **Why and How to Measure Exploration in Behavioral Space**
Charles OLLION, Stéphane Doncieux

Exploration and exploitation are two complementary as- pects of Evolutionary Algorithms. Exploration, in partic- ular, is promoted by specific diversity keeping mechanisms generally relying on the genotype or the fitness value. Re- cent works suggest that, in the case of Evolutionary Robotics or more generally behavioral system evolution, promoting exploration directly in the behavioral space is of critical im- portance. In this work an exploration indicator is proposed, based on the sparseness of the population in the behavioral space. This exploration measure is used on two challenging neuro-evolution experiments and validated by showing the dependence of the fitness at the end of the run on the ex- ploration measure during the very first generations. Such a prediction ability could be used to design parameter settings algorithms or selection algorithms dedicated to the evolution of behavioral systems. Several other potential uses of this measure are also proposed and discussed.

15:30-15:55 **Morphological and Environmental Scaffolding Synergize when Evolving Robot Controllers**
Josh Bongard

Scaffolding---initially simplifying the task environment of autonomous robots---has been shown to increase the probability of evolving robots capable of performing in more complex task environments. Recently, it has been shown that changes to the body of a robot may also scaffold the evolution of non trivial behavior. This raises the question of whether two different kinds of scaffolding (environmental and morphological) synergize with one another when combined. Here it is shown that, for legged robots evolved to perform phototaxis, synergy can be achieved, but only if morphological and environmental scaffolding are combined in a particular way: The robots must first undergo morphological scaffolding, followed by environmental scaffolding. This suggests that additional kinds of scaffolding may create additional synergies that lead to the evolution of increasingly complex robot behaviors.