Preface

These proceedings contain the papers presented at the sixth annual Genetic and Evolutionary Computation Conference (GECCO 2004). The conference was held in Seattle, during June 26–30, 2004.

A total of 460 papers were submitted to GECCO 2004. After a rigorous double-blind reviewing process, 230 papers were accepted for full publication and oral presentation at the conference, resulting in an acceptance rate of 50%. An additional 104 papers were accepted as posters with two-page extended abstracts included in the proceedings.

This year's GECCO constituted the union of the Ninth Annual Genetic Programming Conference (which has met annually since 1996) and the Thirteenth International Conference on Genetic Algorithms (which, with its first meeting in 1985, is the longest running conference in the field). Since 1999, these conferences have merged to produce a single large meeting that welcomes an increasingly wide array of topics related to genetic and evolutionary computation.

Since the fifth annual GECCO conference, the proceedings have been published by Springer-Verlag as part of their Lecture Notes in Computer Science series. This makes the proceedings available in many libraries as well as online, widening the dissemination of the research presented at the conference. In addition to these proceedings volumes, each participant of the GECCO 2004 conference received a CD containing electronic versions of the papers presented.

A new track entitled 'Biological Applications' was introduced this year to emphasize the use of evolutionary computing methods to various biological applications, such as bioinformatics and others.

In addition to the presentation of the papers contained in the proceedings, the conference included 16 workshops, 32 tutorials by leading specialists, the Evolutionary Computation in Industry special track, and presentation of late-breaking papers.

GECCO is sponsored by the International Society for Genetic and Evolutionary Computation (ISGEC). The ISGEC by-laws contain explicit guidance on the organization of the conference, including the following principles:

(i) GECCO should be a broad-based conference encompassing the whole field of genetic and evolutionary computation.

(ii) Papers will be published and presented as part of the main conference proceedings only after being peer reviewed. No invited papers shall be published (except for those of up to three invited plenary speakers).

(iii) The peer review process shall be conducted consistently with the principle of division of powers performed by a multiplicity of independent program committees, each with expertise in the area of the paper being reviewed.

(iv) The determination of the policy for the peer review process for each of the conference's independent program committees and the reviewing of papers for each program committee shall be performed by persons who occupy their

positions by virtue of meeting objective and explicitly stated qualifications based on their previous research activity.

(v) Emerging areas within the field of genetic and evolutionary computation shall be actively encouraged and incorporated in the activities of the conference by providing a semi-automatic method for their inclusion (with some procedural flexibility extended to such emerging new areas).

(vi) The percentage of submitted papers that are accepted as regular full-length papers (i.e., not posters) shall not exceed 50%.

These principles help ensure that GECCO maintains high quality across the diverse range of topics it includes.

Besides sponsoring the conference, the ISGEC supports the field in other ways. ISGEC sponsors the biennial "Foundations of Genetic Algorithms" workshop on theoretical aspects of all evolutionary algorithms. The journals *Evolutionary Computation* and *Genetic Programming and Evolvable Machines* are also supported by ISGEC. All ISGEC members (including students) receive subscriptions to these journals as part of their membership. ISGEC membership also includes discounts on GECCO registration rates as well as discounts on other journals. More details on ISGEC can be found online at http://www.isgec.org.

Many people volunteered their time and energy to make this conference a success. The following people in particular deserve the gratitude of the entire community for their outstanding contributions to GECCO 2004:

- Riccardo Poli, the General Chair of GECCO 2004 for his tireless efforts in organizing every aspect of the conference, which started well before GECCO 2003 took place in Chicago in July 2003
- David E. Goldberg, John Koza and Riccardo Poli, members of the Business Committee, for their guidance and financial oversight
- Stefano Cagnoni, for coordinating the workshops
- Maarten Keijzer, for editing the late breaking papers
- Past conference organizers, James Foster and Erick Cantú-Paz, for their constant help and advice
- John Koza, for his efforts as publicity chair
- Simon Lucas, for arranging competitions during GECCO 2004
- Mike Cattolico, for local arrangements
- Pat Cattolico, for her help in the local organization of the conference
- Carol Hamilton, Ann Stolberg, and the rest of the AAAI staff for their outstanding efforts administering the conference
- Thomas Preuss, for maintaining the ConfMaster Web-based paper review system
- Gerardo Valencia, for Web programming and design
- Jennifer Ballentine, Lee Ballentine and the staff of Professional Book Center, for assisting in the production of the proceedings
- Alfred Hofmann and Ursula Barth of Springer-Verlag for the production of the GECCO 2004 proceedings; and

the sponsors who made generous contributions to support student travel grants:

– Tiger Mountain Scientic
– Air Force Office of Scientific Research
– New Light Industries.

The track chairs deserve special thanks. Their efforts in recruiting program committees, assigning papers to reviewers, and making difficult acceptance decisions in relativly short times, were critical to the success of the conference:

– Owen Holland, A-Life, Adaptive Behavior, Agents, and Ant Colony Optimization
– Dipankar Dasgupta, Artificial Immune Systems
– James Foster and Wolfgang Banzhaf, Biological Applications
– Paul Darwen, Coevolution
– Hans-Georg Beyer, Evolution Strategies, Evolutionary Programming
– Dario Floreano, Evolutionary Robotics
– Edmund Burke, Evolutionary Scheduling and Routing
– Andy Tyrrell, Evolvable Hardware
– Dirk Thierens, Genetic Algorithms
– Lee Spector, Genetic Programming
– Pier Luca Lanzi, Learning Classifier Systems
– Andrea Tettamanzi, Real World Applications
– Mark Harman, Search Based Software Engineering

The conference was held in cooperation and/or affiliation with:

– The American Association for Artificial Intelligence (AAAI)
– The 2004 NASA/DoD Conference on Evolvable Hardware
– *Evolutionary Computation*
– *Genetic Programming and Evolvable Machines*
– *Journal of Scheduling*
– *Journal of Hydroinformatics*
– *Applied Soft Computing*

Above all, our special thanks are due to the numerous researchers and practitioners who submitted their best work to GECCO 2004, reviewed the work of others, presented tutorials, organized workshops, or volunteered their time in any other way. I am sure that the contributors to this proceedings will be proud of the results of their efforts and readers will get a glimpse of the current activities in the field of genetic and evolutionary computation.

April 2004   Kalyanmoy Deb

GECCO 2004 Conference Organization

Conference Committee

General Chair: Riccardo Poli
Proceedings Editor-in-Chief: Kalyanmoy Deb
Business Committee: David E. Goldberg, John Koza, Riccardo Poli
Chairs of Program Policy Committees:
   Owen Holland, A-Life, Adaptive Behavior, Agents, and Ant Colony Optimization
   Dipankar Dasgupta, Artificial Immune Systems
   James Foster and Wolfgang Banzhaf, Biological Applications
   Paul Darwen, Coevolution
   Hans-Georg Beyer, Evolution Strategies, Evolutionary Programming
   Dario Floreano, Evolutionary Robotics
   Edmund Burke, Evolutionary Scheduling and Routing
   Andy Tyrrell, Evolvable Hardware
   Dirk Thierens, Genetic Algorithms
   Lee Spector, Genetic Programming
   Pier Luca Lanzi, Learning Classifier Systems
   Andrea Tettamanzi, Real World Applications
   Mark Harman, Search Based Software Engineering

Late Breaking Papers Chair: Maarten Keijzer
Workshops Chair: Stefano Cagnoni

Workshop Organizers

E. Costa, F. Pereira , G. Raidl, Application of Hybrid Evolutionary Algorithms to Complex Optimization Problems
S.C. Upton and D.E. Goldberg, Military and Security Applications of Evolutionary Computation
H. Lipson, E. De Jong and J. Koza, Modularity, Regularity and Hierarchy in Open-Ended Evolutionary Computation
H. Suzuki and H. Sawai, Evolvability in Evolutionary Computation (EEC)
I. Parmee, Interactive Evolutionary Computing
M. Pelikan, K. Sastry and D. Thierens, Optimization by Building and Using Probabilistic Models (OBUPM 2004)
W. Stolzmann, P.L. Lanzi, S.W. Wilson, International Workshop on Learning Classifier Systems (IWLCS)
S. Mueller, S. Kern, N. Hansen and P. Koumoutsakos, Learning, Adaptation, and Approximation in EC, Jiri Ocenasek
M. O'Neill and C. Ryan, Grammatical Evolution (GEWS 2004)
T. Yu, Neutral Evolution in Evolutionary Computation
J.F. Miller, Regeneration and Learning in Developmental Systems (WORLDS)

I. Garibay, G. Holifield and A.S. Wu, Self-Organization on Representations for Genetic and Evolutionary Algorithms
A. Wright and N. Richter, Evolutionary Computation Theory
Jason H. Moore and Marylyn D. Ritchie, Biological Applications of Genetic and Evolutionary Computation (BioGEC 2004)
T. Riopka, Graduate Student Workshop
M.M. Meysenburg, Undergraduate Student Workshop

Tutorial Speakers

Erik Goodman, Genetic Algorithms
John Koza, Genetic Programming
Thomas Bäck, Evolution Strategies
Kenneth De Jong, A Unified Approach to EC
Tim Kovacs, Learning Classifier Systems
Martin Pelikan, Probabilistic Model-Building GAs
Russ Eberhart, Particle Swarm Optimization
Steffen Christensen and Mark Wineberg, Introductory Statistics for Evolutionary Computation
W.B. Langdon, Genetic Programming Theory
Jonathan Rowe, Genetic Algorithm Theory
J. Foster and W. Banzhaf, Biological Applications
Chris Stephens, Taxonomy and Coarse Graining in EC
Darrell Whitley, No Free Lunch
Kalyanmoy Deb, Multiobjective Optimization with EC
Ingo Wegener, Computational Complexity and EC
Julian Miller, Evolvable Physical Media
Tetsuya Higuchi, Evolvable Hardware Applications
Franz Rothlauf, Representations
Lee Altenberg, Theoretical Population Genetics
Ingo Rechenberg, Bionik: Building on Biological Evolution
Marco Tomassini, Spatially Structured EAs
Hideyuki Takagi, Interactive Evolutionary Computation
Garry Greenwood, Evolutionary Fault Tolerant Systems
Maarten Keijzer, GP for Symbolic Regression
Conor Ryan, Grammatical Evolution
Dario Floreano, Evolutionary Robotics
Al Biles, Evolutionary Music
Peter Ross, EAs for Combinatorial Optimization
Jürgen Branke, Optimization in Dynamic Environments
Ian Parmee, Evolutionary Algorithms for Design
Xin Yao, Evolving Neural Networks
Arthur Kordon, Guido Smits and Mark Kotanchek, Industrial Evolutionary Computing

Keynote Speakers

Leroy Hood

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Erkan Korkmaz	Karlheinz Meier	Marie-Claude Portmann

A Word from the Chair of ISGEC

You may have just picked up your proceedings, in hard copy and CD-ROM, at GECCO 2004. We've chosen once again to work with Springer-Verlag, including our proceedings as part of their Lecture Notes in Computer Science (LNCS) series, which makes them available in many libraries, broadening the impact of the GECCO conference.

If you're now at GECCO 2004, we, the organizers, hope your experience is memorable and productive, and you will find the proceedings to be of continuing value. The opportunity for first-hand interaction among authors and other participants at GECCO is a big part of what makes it exciting, and we all hope you come away with many new insights and ideas.

If you were unable to come to GECCO 2004 in person, I hope you'll find many stimulating ideas from the world's leading researchers in evolutionary computation reported in the proceedings, and that you'll be able to participate in a future GECCO conferences, for example, next year, in the Washington, DC area!

The International Society for Genetic and Evolutionary Computation, sponsoring organization of the annual GECCO conferences, is a young organization, formed through merger of the International Society for Genetic Algorithms (sponsor of the ICGA conferences) and the organization responsible for the annual Genetic Programming Conferences. It depends strongly on the voluntary efforts of many of its members. It is designed to promote not only exchange of ideas among innovators and practitioners of well-known methods such as genetic algorithms, genetic programming, evolution strategies, evolutionary programming, learning classifier systems, etc., but also the growth of newer areas such as artificial immune systems, evolvable hardware, agent-based search, and others. One of the founding principles is that ISGEC operates as a confederation of groups with related but distinct approaches and interests, and their mutual prosperity is assured by their representation in the program committees, editorial boards, etc., of the conferences and journals with which ISGEC is associated. This also insures that ISGEC and its functions continue to improve and evolve with the diversity of innovation that has characterized our field.

The ISGEC saw many changes last year, in addition to its growth in membership. We anticipate yet more advances in the next year. A second round of Fellows and Senior Fellows will be added to our society this year, after last year's inaugural group. GECCO continues to be subject to dynamic development – the many new tutorials, workshop topics, and tracks will evolve again next year, seeking to follow and encourage the developments of the many fields represented at GECCO. The best paper awards will be presented for the third time at this GECCO, and we hope many of you will participate in the balloting. This year, most presentations at GECCO will once again be made electronically, displayed with the LCD projectors that ISGEC purchased last year. Our journals, Evolutionary Computation and Genetic Programming and Evolvable Machines, continue to prosper, and we are exploring ways to make them even more widely available.

The ISGEC is your society, and we urge you to become involved or continue your involvement in its activities, to the mutual benefit of the whole evolutionary computation community. Three members were re-elected to five-year terms on the Executive Board at GECCO 2003 – Ken De Jong, David Goldberg, and Erik Goodman.

Since that time, the ISGEC has been active on many issues, through actions of the Board and our two Councils – the Council of Authors and the Council of Conferences. Last year, the Board voted to combine the Council of Authors and Council of Editors into a single body, the Council of Authors.

The organizers of GECCO 2004 are shown in this front matter, but special thanks are due to Riccardo Poli, General Chair, and Kalyanmoy Deb, Editor-in-Chief of the proceedings, as well as to John Koza and Dave Goldberg, the Business Committee. Each year has seen many new features in GECCO, and it is the outstanding efforts of this group that "make GECCO come together."

Of course, we all owe a great debt to those who chaired or served on the various Core and Special Program Committees that reviewed all of the papers for GECCO 2004. Without their effort, it would not be possible to put on a meeting of this quality.

Another group also deserves the thanks of GECCO participants and ISGEC members – the members of the ISGEC Executive Board and Councils, who are listed on the next page. I am particularly indebted to them for their thoughtful contributions to the organization and their continuing demonstrations of concern for the welfare of the ISGEC.

I invite you to communicate with me (goodman@egr.msu.edu) if you have questions or suggestions for ways ISGEC can be of greater service to its members, or if you would like to get more involved in ISGEC and its functions.

Don't forget about the eighth Foundations of Genetic Algorithms (FOGA) workshop, also sponsored by ISGEC, the biennial event that brings together the world's leading theorists on evolutionary computation. FOGA will be held January 5–9, 2005 at the University of Aizu, Japan, which will be a fascinating place to visit for those of us who haven't spent much time in Japan. I hope you'll join many of your fellow ISGEC members there!

Finally, I hope to see you at GECCO 2005 in the Washington, DC area. Get your ideas for new things for GECCO 2005 to Una-May O'Reilly, the General Chair of GECCO 2005, when you see her at GECCO 2004, and please check the ISGEC Web site, www.isgec.org, regularly for details as the planning for GECCO 2005 continues.

Erik D. Goodman
ISGEC Chair

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Darrell Whitley, Colorado State University
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Council of Conferences, Una-May O'Reilly (Chair)

The purpose of the Council of Conferences is to provide information about the numerous conferences that are available to researchers in the field of Genetic and Evolutionary Computation, and to encourage them to coordinate their meetings to maximize our collective impact on science.

ACDM, Adaptive Computing in Design and Manufacture, April 2004, Ian Parmee, Ian.Parmee@uwe.ac.uk

EuroGP, European Conference on Genetic Programming, Portugal, April 2004, Ernesto Costa, ernesto@dei.uc.pt

EvoCOP, European Conference on Evolutionary Computation in Combinatorial Optimization, April 2004, Günther Raidl, raidl@ads.tuwien.ac.at and Jens Gottlieb, jens.gottlieb@sap.com

EvoWorkshops, European Evolutionary Computing Workshops, Portugal, April 2004, Stefano Cagnoni, cagnoni@ce.unipr.it

FOGA, Foundations of Genetic Algorithms Workshop, Japan, January 2005, Lothar M. Schmitt, info@foga05.org

GECCO 2004, Genetic and Evolutionary Computation Conference, Seattle, June 2004, Riccardo Poli, rpoli@essex.ac.uk

PATAT 2004, 5th International Conference on The Practice and Theory of Automated Timetabling, Pittsburgh, USA, August 2004, Edmund Burke, ekb@cs.nott.ac.uk

PPSN-VIII, Parallel Problem Solving from Nature, Birmingham, UK, September 2004, Xin Yao, xin@cs.bham.ac.uk

SAB, 8th International Conference on Simulation of Adaptive Behavior, John Hallam, john@mip.sdu.dk

EMO, 3rd Evolutionary Multi-Criterion Optimization, Guanajuato, Mexico, March 2005, Carlos Coello Coello, coello@cs.cinvestav.mx

An up-to-date roster of the Council of Conferences is available online at http://www.isgec.org/conferences.html.

Papers Nominated for Best Paper Awards

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. The Chairs of Core and Special Program Committees selected the papers that received the most nominations for consideration by the conference. One winner for each program track was chosen by secret ballot of the GECCO attendees after the papers had been presented in Chicago. The titles and authors of all 32 papers nominated for the best paper award for GECCO 2004 are given below:

Robot Trajectory Planner Using Multi-objective Genetic Algorithms: Eduardo Pires, José Machado, and Paulo Oliveira

Evolved Motor Primitives and Sequences in a Hierarchical Recurrent Neural Network: Rainer Paine and Jun Tani

Actuator Noise in Recombinant Evolution Strategies on General Quadratic Fitness Models: Hans-Georg Beyer

An Analysis of the $(\mu + 1)$ EA on Simple Pseudo-Boolean Functions: Carsten Witt

On the Choice of the Population Size: Tobias Storch

Gradient-Based Learning Updates Improve XCS Performance in Multistep Problems: Martin Butz, David E. Goldberg, and Pier Luca Lanzi

High Classification Accuracy Does Not Imply Effective Genetic Search: Tim Kovacs and Manfred Kerber

Mixed Decision Trees: Minimizing Knowledge Representation Bias in LCS: Xavier Llorà and Stewart Wilson

Genetic Programming Neural Networks as a Bioinformatics Tool for Human Genetics: Marylyn Ritchie, Christopher Coffey, and Jason Moore

Fuzzy Dominance Based Multi-objective GA-Simplex Hybrid Algorithms Applied to Gene Network Models: Praveen Koduru, Sanjoy Das, Stephen Welch, and Judith L. Roe

Evaluating Evolutionary Testability with Software-Measurements: Frank Lammermann, Andre Baresel, and Joachim Wegener

Hybridizing Evolutionary Testing with the Chaining Approach: Phil McMinn and Mike Holcombe

Vulnerability Analysis of Immunity-Based Intrusion Detection Systems Using Evolutionary Hackers: Gerry Dozier, Douglas Brown, John Hurley, and Krystal Cain

pi Grammatical Evolution: Michael O'Neill, Anthony Brabazon, Miguel Nicolau, Sean McGarraghy, and Peter Keenan

Evolving Caching Strategies for the Internet: Jürgen Branke, Pablo Funes, and Frederik Thiele

A Descriptive Encoding Language for Evolving Modular Neural Networks: Jae-Yoon Jung and James A. Reggia

Shortcomings with Tree-Structured Edge Encodings for Neural Networks: Gregory Hornby

Evolving Quantum Circuits and Programs through Genetic Programming: Paul Massey, John Clark, and Susan Stepney

Adaptive and Evolvable Network Services: Tadashi Nakano and Tatsuya Suda

Using Clustering Techniques to Improve the Performance of a Multi-objective Particle Swarm Optimizer: Gregorio Toscano Pulido and Carlos Coello Coello

An Interactive Artificial Ant Approach to Non-photorealistic Rendering: Una-May O'Reilly, Yann Semet, and Fredo Durand

A Broad and Narrow Approach to Interactive Evolutionary Design – An Aircraft Design Example: Oliver Bandte and Sergey Malinchik

Evolutionary Drug Scheduling Model for Cancer Chemotherapy: Liang Yong, Mok Shu Kam Tony, and K.S. Leung

An Enhanced Genetic Algorithm for DNA Sequencing with Positive and Negative Errors: Thang Bui and Waleed Youssef

Efficient Clustering-Based Genetic Algorithms in Chemical Kinetic Modelling: Lionel Elliott, Derek Ingham, Adrian Kyne, Nicolae Mera, Mohamed Pourkashanian, and Sean Whittaker

Autonomous Controller Design for Unmanned Aerial Vehicles Using Multi-objective Genetic Programming: Choong Oh and Gregory Barlow

Automated Extraction of Problem Structure: Anthony Bucci, Jordan Pollack, and Edwin de Jong

Similarities between Co-evolution and Learning Classifier Systems and Their Applications: Ramón Alfonsos Palacios-Durazo and Manuel Valenzuela-Rendón

Feature Subset Selection, Class Separability, and Genetic Algorithms: Erick Cantú-Paz

What Basis for Genetic Dynamics?: Chris Stephens and Chryssomalis Chryssomalakos

Dependency Structure Matrix Analysis: Off-line Utility of the Dependency Structure Matrix Genetic Algorithm: Tian-Li Yu and David Goldberg

Distributed Constraint Satisfaction, Restricted Recombination, and Hybrid Genetic Search: Gerry Dozier, Hurley Cunningham, Winard Britt, and Funing Zhang

Mating Scheme for Controlling the Diversity-Convergence Balance for Multiobjective Optimization: Hisao Ishibuchi and Yohei Shibata