EvoNews

Newsletter of EvoNet – The Network of Excellence in Evolutionary Computing

http://www.dcs.napier.ac.uk/evonet/ Issue 8, Autumn 1998

Success Breeds Success

Increased competition and tighter environmental regulations mean that optimisation is rapidly becoming a business necessity. It's not surprising, therefore, that the results of an informal web-based review conducted by EvoNet show a slow but steady take-up of evolutionary computing. Not only are evolutionary algorithms currently being used for design, control, prediction, distribution and scheduling problems in the manufacturing, retail, telecommunications and finance sectors, they are also being used as cutting-edge tools to break new ground in areas as diverse as computer aided drug design and computer game development.

A more rigorous, if less up-to-the minute, review of the field is provided in 'A Bibliography of Genetic Algorithm Business Application Research: 1988–June 1996' (see the May issue of *Expert Systems*, Vol 15, No 2). Presented by Bo Wong of Hong Kong Baptist University and Tom Bodnovich of Kent State University, the bibliography represents the fruits of an exhaustive literature search for articles about GA-based business/industrial applications.

Their findings make interesting reading: no articles about GA-based business applications were published prior to 1988; just 13 were published in the four-year period 1988–92; while 84 were published in the three and a half years to June 1996 (when the survey ended).

Growth

Quite clearly research into real world applications of evolutionary computing is a rapidly growing area, and according to Wong and Bodnovich: 'there is no doubt that research in business genetic algorithms will be increasing in the future'.

'I think we will see GAs begin to provide some structure for traditionally unstructured problems,' Tom Bodnovich told *EvoNews*.

Meanwhile Lawrence Davis, a software consultant and editor of *The Handbook of Genetic Algorithms*, reports that in the US at least, 'the technology transfer process is going on at a good pace.

'Last year a company that uses genetic algorithms to improve manufacturing schedules was sold for $53,000,000 US to another company that sells suites of manufacturing software tools. I believe this is the highest amount of money that has been paid to date for evolutionary computing.'

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Davis currently develops genetic and other algorithms to add to the Manugistics product suite for optimising schedules and assembly procedures. He reports that industrial scheduling is currently a very active area, where the use of evolutionary computing has received a good deal of media coverage.

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ABOUT EVONET

Evolutionary computing can be used to 'breed' progressively better solutions to the complex logistical problems faced by industry and commerce.

The European Commission has recognised it as one of the important new technologies of our time, and has funded a Network of Excellence in Evolutionary Computing, EvoNet, to assist in the transfer of knowledge and expertise to the manufacturing and service sectors.

As well as academic institutions and research groups, members of EvoNet include some of the key players in European industry – British Aerospace, Daimler-Benz, Dassault Aviation, Hewlett Packard Laboratories, Institut Francais de Petrol, Rolls Royce, and Siemens among others.

Membership of EvoNet is free and provides easy access to information about:

- training, conferences, workshops
- commercial applications of evolutionary computing techniques
- consultancy
- where to get advice and assistance
- collaborative research opportunities.

Companies, academic institutions, or interested individuals wishing to join, should contact: EvoNet, Dept of Computer Studies, Napier University, 219 Colinton Road, Edinburgh EH14 1DJ, UK.

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Success Breeds Success

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Evolutionary computing is also making its mark in the securities industry. 'I have frequently been asked to give talks and tutorials about genetic algorithms on Wall Street and in London to groups of people who trade for a living,' says Davis. 'My own consulting company, Tica Associates, has had three clients who were traders, and we have seen first-hand the impact that evolutionary computing can have on trading systems that were originally hand-designed.'

'Wherever there are hard optimisation problems, there is the potential to use evolutionary computation techniques to good effect.'

Davis maintains that many of the advertisements for software systems in journals for securities traders describe systems that incorporate genetic algorithms and/or neural networks. And although many of the organisations that field evolutionary applications prefer to keep the secret of their success to themselves, Davis points to two companies that have disclosed their reliance on evolutionary techniques – First Quadrant of Pasadena, California, who publicly announced that they use evolutionary computing to improve their management models of a fund worth over $12,000,000,000 US, and The Prediction Company in Santa Fe, New Mexico, who acknowledged that they used evolutionary techniques to improve the performance of their trading systems.

Chance

'Wherever there are hard optimisation problems, there is the potential to use evolutionary computation techniques to good effect,' Davis contends. The fact that the semiconductor, manufacturing, financial, and telecommunications industries have been the first beneficiaries of evolutionary computing is, he says, partly due to the huge financial payoff when optimisation problems in these domains are solved well. Mostly, though, he puts it down to luck.

'People with problems happened to find people who could apply evolutionary computation techniques at a time when evolutionary techniques weren't well known.'

The recent increase in media coverage will, he thinks, reduce the role of chance in technology transfer, as more and more companies become aware of the financial benefits evolutionary computing can offer.

Areas that Davis sees as 'ripe for the application of evolutionary computation techniques', and where success will bring a significant financial impact, include biotechnology and the design of new mechanical devices. Looking to the longterm, he predicts that 'a very dramatic, high-impact application of evolutionary computing techniques will be in the combination of robotics and artificial life'.

Since 1990 Davis' company, Tica Associates, has worked with 18 different client organisations to develop evolutionary computing approaches to real-world problems.

'Nearly all of the projects resulted in successful systems,' he reports, 'in the sense that the evolutionary computing approach generated results superior to those produced by any other known algorithms.'

Hybrids

In fact, most of the systems produced at Tica are hybrid systems. 'We nearly always use other algorithms in conjunction with evolutionary algorithms in the solutions that we produce for our clients,' says Davis. 'At some point in the development cycle I tell our clients that we will produce the best algorithm in the world to solve their problem. I also mention that this is a somewhat trivial claim, since we will incorporate all the other good algorithms in our solution, so we can't do worse.

'When you build real-world applications for a living, it doesn't take long to realise that your system does better if it uses the heuristics that humans use to solve a problem, as well as other effective techniques that already exist. These techniques might be used to create modifications of an existing solution, to seed the initial population, to do post-processing on a solution created through evolution, or to be the driver that turns an encoded solution into a good solution.

'One principle I have learned – sometimes through painful experience – in more than 15 years of applying these technologies is that if you have the chance to combine two effective techniques for solving an optimisation problem and you don't take that chance, you will probably lose.'

Applications

Over the years Davis has been involved in numerous projects where evolutionary algorithms have yielded better solutions than any competing technique.

He has worked principally in the areas of telecommunication network design, message routing, VLSI chip design and production planning. However he believes that there are many other areas where evolutionary approaches have been successfully applied.

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'We want to demonstrate the range of problems that evolutionary algorithms can tackle – as well as giving practitioners an opportunity to demonstrate their expertise.'

'Unfortunately, it is becoming increasingly difficult to find out about successful applications, since many practitioners don't wish to publicise their work and those who do publish tend to do it more and more in industry-related forums, rather than in evolutionary computing forums. There doesn't seem to be a single place where we can learn about the full range of existing applications.'

EvoNet administrator Jennifer Willies believes that the need for a central source of information about successful applications needs to be addressed.

'It's important to have access to practical examples to back our theory,' she comments. 'Real-world applications prove the principle we at EvoNet want to promote: that evolutionary algorithms offer industry a powerful and practical way to make savings.'

Database

With this in mind EvoNet invites contributions to its database of success stories. Summaries of successful real world applications will be published on the EvoNet website, together with an acknowledgement of the company or research group that provided the material.

'We are looking for commercial/industrial applications of evolutionary computing which we can use to further promote the technology to new users,' explains Willies. 'We want to demonstrate the range of problems that evolutionary algorithms can tackle – as well as giving practitioners an opportunity to demonstrate their expertise.

Lawrence Davis will be speaking about the commercial applications of evolutionary algorithms at the PPSN conference in Amsterdam on 27–30 September.

Success Stories

Optimising production strategies

Optimising production strategies in the oil and gas industry is a complex task involving a trade-off between inter-related benefits and penalties (for example, faster extraction offers a faster return on investment, but incurs higher costs since larger production and processing facilities are required). It is a high-value problem where a small percentage improvement can result – over decades – in vastly increased profitability. Working with BP to maximise the financial return from a group of interdependent oil and gas fields, Scottish software house Quadstone used a genetic algorithm to produce a variety of schedules that resulted in substantially higher predicted net returns than had been achieved by either a human planner or another optimisation method.

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http://www.quadstone.com

On-line control in the process industries

With the support of the Energy Technology Support Unit, researchers from the Intelligent Computer Systems Centre (University of the West of England) and Courtaulds Films have developed a genetic algorithm to continuously optimise the fuel consumption of multiple burners. Feedback from a single waste gas analyser allows the GA-based control system to dynamically adjust the air flow to individual burners so as to minimise energy consumption. The system is able to deal with gradual change as well as more rapid change, for example, changes in fuel load. The technology is applicable to many other load-balancing situations in the process industries, for example, in chemicals production, compressed air usage and in paper and textile manufacture.

http://www.ics.uwe.ac.uk/projects/boilers.html

Production scheduling in the car industry

An evolutionary scheduling system has substantially reduced energy costs in the pressing plant of a car factory. Developed by researchers at the Jozef Stefan Institute in Slovenia, the system consists of a greedy heuristic to generate the initial population of schedules, and an evolutionary algorithm to breed schedules that minimise energy consumption within peak demand periods.

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http://www-ai.ijs.si/e8.html

Optimising retail dealership locations

Genetic algorithms have produced potentially more profitable solutions to the problem of locating car dealerships. When car industry giant Ford locates its retail outlets in the UK, the company uses a computerised model to simulate car distribution and sales on the basis of information about the position of dealers and supply points, and other geographic and statistical data. Initially a heuristic optimisation scheme was used to determine a pattern of dealerships that maximised sales, service or profit criteria. However, when the Edinburgh Parallel Computing Centre transferred the system to a parallel computer and investigated the use of genetic algorithms as an alternative optimisation technique, the resulting GAs provided better solutions not only in terms of predicted profits but in terms of the number of alternative strategies generated.

info@quadston.co.uk
http://www.quadstone.com

To contribute a success story, visit the EvoNet website at http://www.dcs.napier.ac.uk/evonet/ and follow the link through News and Events, to Success Stories. Alternatively, write to us at the EvoNet Office (see page 1 for our address).

Cracking the Code of Life

'I strongly believe that evolutionary algorithms constitute some of the most powerful development tools for optimisation strategies in biology.'

As a deluge of DNA floods in from genome projects, a new technology has emerged to handle it. Biocomputing, otherwise known as bioinformatics, is concerned with making sense of biological data – and given the immense amount of data available, one of its chief tasks is to devise algorithms capable of doing this automatically.

'Most biological sequence databases are in an exponential growth phase,' explains Cedric Notredame, a molecular biologist who has developed a number of GA-based tools to align related genetic sequences and so study their similarities. In this context, the first challenge is to produce a physical map of the genome – 'a highly non-trivial problem' as Notredame points out, 'given that all we have access to are partially overlapping pieces of DNA'.

The second challenge is to predict the biological function of parts of the genome. 'Most sequences are uncharacterised and come to us as naked fragments of DNA,' says Notredame. 'Performing wet lab experiments on each sequence is clearly not an option, hence the need for techniques that allow us to extrapolate information from experimentally characterised sequences to uncharacterised ones. Most pharmaceutical companies have realised the potential of bioinformatics. It's a cheap technique, and used sensibly it can dramatically reduce the cost of wet lab research.'

More and more powerful statistical tools have been devised to sieve meaning from the jumble of genetic data, to compare sequences, and to identify the likely function of unknown proteins by analogy with similar well-understood proteins. Along with a range of other techniques, evolutionary algorithms have been applied to bioinformatics problems – from genome mapping to protein folding and threading, multiple sequence alignment, RNA folding, and profile construction. However, it is in the domain of structure analysis that their use is best documented.

Although the function of a protein relates to its three-dimensional structure, which in turn relates to its original sequence, it is impossible to deduce function and structure from a given sequence. This is an area where evolutionary algorithms can provide a cheaper alternative to x-ray diffraction or NMR spectroscopy, and they have been used, for example, to breed progressively more probable 3D structures for a protein string, using a simple force field as a fitness function.

'When no good heuristic is available, EAs are the tools of choice for probing an area of research,' Notredame affirms. 'I strongly believe they constitute some of the most powerful development tools for optimisation strategies in biology. For instance, if you have several different models to optimise, each one requiring specific traditional optimisation algorithms, you may want to start with an EA strategy that will give you an idea of the best direction to follow. In short, EAs help you to keep your options open longer.'

In 1996 Notredame developed a genetic algorithm to compute multiple sequence alignments – an NP-complete problem which is central to many tasks in bioinformatics. By highlighting similarities

Contributions for EvoNews

As the newsletter of EvoNet, *EvoNews* provides a forum in which the commercial, industrial and academic sectors can share ideas and information about developments in Evolutionary Computing. We are looking for:

Articles
- short articles on industrial applications
- reports of successful collaborations
- inspirational articles about new concepts/approaches

News items
- information about events
- news about research grants
- details of new courses
- details of forthcoming relevant publications

Contributions should not be over technical (no complicated diagrams or maths). The copy deadline for the Winter issue of EvoNews is 30 November.

Computer-aided Molecular Design

EvoNet member success story

A team at Unilever Research has used genetic algorithms in tandem with neural nets to design new bactericidal peptides which may have applications in anti-bacterial cleaners and food preservatives. The neural nets were trained to predict bactericidal activity in peptides and then incorporated into the fitness function of a GA, so that populations of virtual peptides were progressively optimised from generation to generation. Using the genetic algorithm, over 400 potentially active 'virtual' bactericides were generated, five of which were selected to be synthesised.

and patterns in sequences, multiple alignments allow researchers to infer corresponding structural or phylogenic relationships. Notredame's approach (known as Sequence Alignment by Genetic Algorithm, or SAGA) blended Goldberg's simple GA model with the improvements proposed by Davis in *The Handbook of Genetic Algorithms*.

'We departed from traditional GAs in the sense that the representation is not binary coded but involves operations on real multiple sequence alignments,' he says. 'As a result, most of the work in SAGA has focused on defining operators that could mutate multiple sequence alignments and combine them through crossover. Although the purpose was not to reconstruct an evolutionary scenario, it is interesting to notice that in order to achieve optimisation, we had to design operators inspired by natural evolution.'

Bench marking with alternative programs showed unambiguously that at the time it was published, SAGA was the most accurate optimisation package for some of the widely used cost functions. Its main drawback was its lack of speed. However Notredame believes that as a development tool, SAGA proved 'invaluable for assessing a wide range of objective functions, and ultimately deciding which one to develop as a basis for a more efficient and more specific optimisation heuristic.'

More recently, Notredame has adapted SAGA to the more complex problem of RNA threading. Yet, although his own work with EAs has focussed on finding solutions to optimisation problems, he believes that evolutionary computing has another – ultimately more interesting – role to play in bioinformatics. Because they allow us to witness the evolution of a solution, EAs can be used as dynamic simulation tools with which to explore hidden biological processes.

'When you predict the structure of an RNA sequence through energy minimisation you are usually only interested in the end product of the GA, the solution,' explains Notredame. 'However, since the actual folding of the RNA is a biological process, it makes sense to try to simulate what happens in real life, in the GA. In this context, intermediate solutions of the GA become interesting, because they have something to do with things that may exist in the cell, but that we usually cannot see.'

Molecular biology is an area where there is no shortage of mathematically intractable problems. And, as John Koza observed during the panel discussion at EuroGP'98, it is also an area where there is no shortage of good quality data. Not only can public nucleotide and protein databases be accessed through the European Bioinformatics Institute, but there are countless additional resources available on the Web.

'The importance of compiling high quality datasets for training and validation is becoming more and more of a priority for the biological community,' says Notredame. 'And there's no doubt that this will help in developing accurate tools in the future.'

GAs make or break molecules

Until recently chemists have been unable to target preselected molecular bonds in order to cause a desired chemical reaction. Fire a laser at a chemical and it will tend to be the weakest links that break. If you want to break a specific bond – and only that bond – you may as well forget it. You'll never be able to map the inter-electron quantum mechanics of a chemical bond in enough detail to unravel it. Unless, that is, you use a genetic algorithm to give you some feedback.

Last year researchers at the University of California successfully used a GA to tune a laser to excite molecules into a desired chemical reaction. The technique, known as quantum feedback control, was first proposed in 1992 by Herschel Rabitz of Princeton University. It involves firing laser pulses of varying shape, frequency and duration at molecular samples and monitoring the results. These are then fed back through a genetic algorithm to breed progressively more effective pulses until at last the pulse that precipitates the desired reaction is found.

In the University of California experiment, it took an average of 30 individuals just ten generations to locate the optimum.

'The main reason for using the GA was its robustness with respect to experimental noise,' explains Chris Bardeen, who carried out the experiments. 'We based our choice on Rabitz's 1994 computer simulations, which showed that the GA outperformed simulated annealing in cases similar to those we expected in the experiment.'

Quantum feedback control provides new tool for chemists

Bardeen describes the GA he used as 'the simplest version – I have been told that there are much smarter versions. Our problem involved varying five parameters, but it is possible to vary 2,000 or more pulse shape parameters by taking advantage of the capabilities of the AOM pulse shaper. A combination of more knobs and a more efficient way to tweak them should result in much more complicated problems being attacked by this technique.'

Nevertheless, Bardeen is wary of pronouncing on the long-term benefits of quantum feedback control. 'The first experiments in this field are barely a year old,' he cautions. 'And the pharmaceutical companies have yet to come knocking at our door.' However, he believes that feedback and pulse-shaping techniques provide another way to learn about chemical systems.

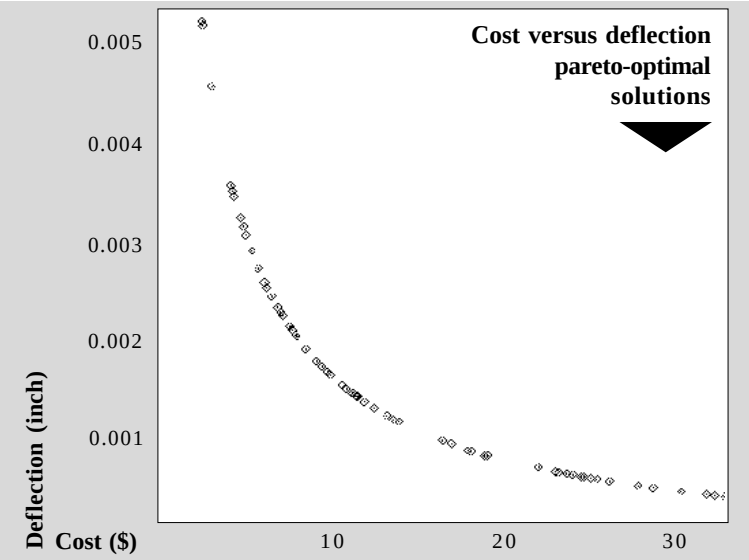
'Right now experimental chemists rely largely on human intuition to design experiments. By automating the process, we can use the "intuition" of the GA to lead us to interesting solutions that we did not necessarily expect.'

Some interesting sites

- European Bioinformatics Institute: **http://www.ebi.ac.uk**
- National Centre for Bioinformatics: **http://www.ncbi.nlm.nih.gov**
- ExPASy Molecular Biology Server: **http://www.expasy.ch**
- The recently published *Computational Methods in Molecular Biology* includes a chapter on Evolutionary Approaches to Computational Biology. For more information, go to: **http://www.cs.jhu.edu/~salzberg/compbio-book.html**

Kanpur Genetic Algorithms Laboratory

KanGAL – the Genetic Algorithms Laboratory at the Indian Institute of Technology in Kanpur – is dedicated to pursuing research into genetic algorithms, fuzzy logic controllers and neural networks. The lab's primary focus is evolutionary computation and its application to engineering problems. Some recent GA applications and industrial collaborations are outlined below.



Car suspension design

Genetic algorithms have been used to design a more comfortable car suspension system. In collaboration with a well known car manufacturer, researchers at KanGAL used a 3D dynamic model of a car to optimise the design of dampers and stiffness coils. The figures below show that the GA-optimised suspension system causes passengers less vertical acceleration and so offers greater comfort than the manufacturer's existing design. The KanGAL modelling and optimisation framework can be used to design the suspension of most types of vehicle.

Transit scheduling GA

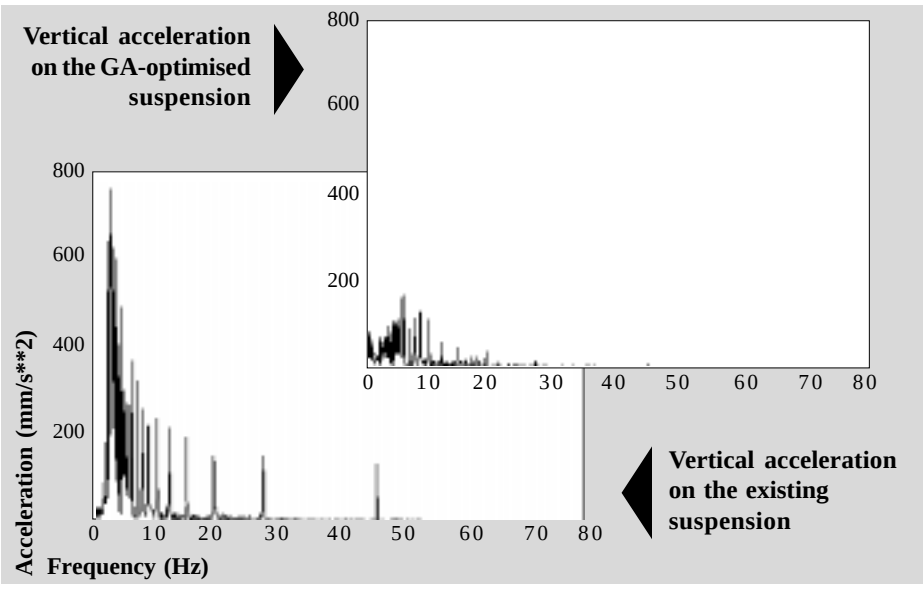
Researchers used a novel coding scheme representing arrival and departure times of vehicles to find optimal schedules in an urban transit system. Various considerations such as limited vehicle capacity and uncertainties in arrival times were incorporated into the GA scheduler. In many cases, GAs found optimal or near-optimal schedules for problems which were not possible to solve using mixed-integer programming methods.

Reheat furnace design

KanGAL researchers have developed a genetic algorithm to establish an optimal temperature profile to minimise fuel consumption for reheat furnaces. The work, which was done for a well known steel manufacturer, uses the finite difference technique to compute heat transfer from the furnace to the steel blooms.

Multi-objective optimiser

Classical methods must be applied a number of times to achieve the multiple solutions necessary for many engineering designs. Researchers at KanGAL have extended GAs to find multiple pareto-optimal solutions simultaneously. Using the non-dominated sorting method for the welded beam problem, they found a unique and efficient way to produce multiple pareto-optimal solutions with different cost and end deflection combinations.



Real-coded GAs

KanGAL researchers have developed a crossover operator for real-coded GAs used in schema processing. The resulting simulated binary crossover (SBX) operator respects interval schemata and has been found to perform better than other existing real-coded crossover operators. Based on this crossover, a combined GA (GeneAS) was developed to handle mixed-integer programming problems efficiently, and a number of mechanical component design problems were solved.

Truss structure design

GAs which incorporate the concept of basic and non-basic nodes were used to find optimal cross-sectional size and topology of trusses. The objective was to minimise truss weight, subject to satisfying a number of constraints related to stress and deflection limitations.

Robot navigation

A combination of GAs and fuzzy logic controllers has been used to find optimal paths for mobile robots in the presence of moving obstacles. GAs found the optimal rule base for the fuzzy logic controllers, which in turn quickly and reliably found obsta-

cle-free paths. Current studies include finding optimal gait strategies for negotiating ditches and uneven terrain.

About KanGAL

Members of the KanGAL team work on other applications, such as molecular structure design, continuous casting process design, chemical reactor design and image processing. Weekly study group seminars are held on various aspects of evolutionary computation and once a year the lab offers industrial courses on evolutionary methods in engineering design. On average, three to four Masters theses are completed each year at KanGAL. Currently three PhD students are working in the subject area.

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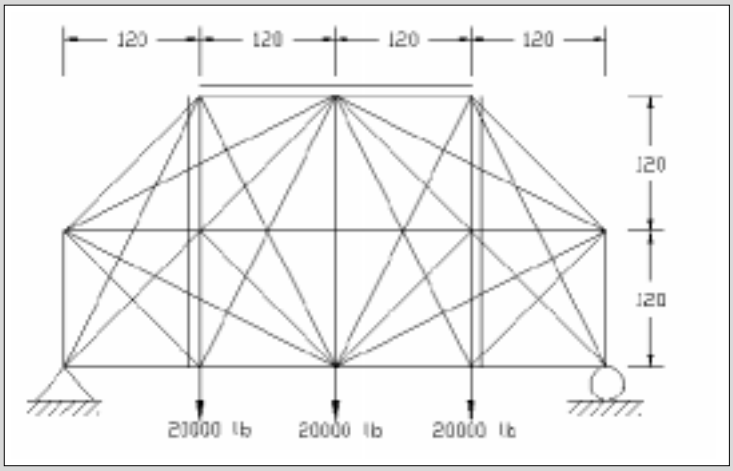
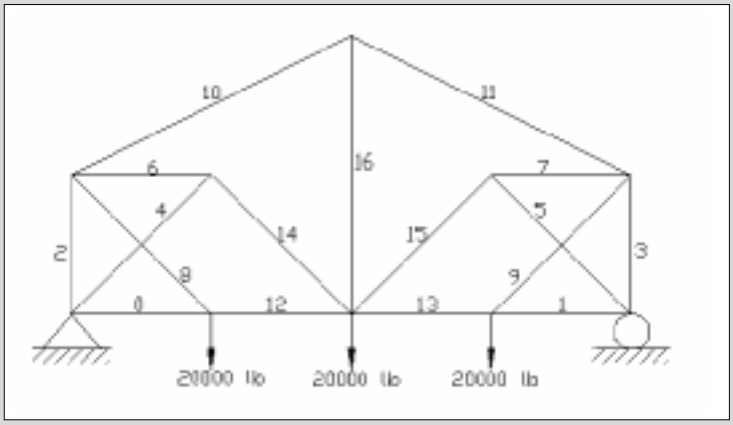
2-tier 39-member 12-node ground structure



Optimised truss



Introducing Evolvable Objects

EO stands for Evolvable Objects, a templates-based, ANSI-C++ compliant evolutionary computation library which can be downloaded free from the Web.

Developed by the GeNeura team at Granada University, EO provides an object-oriented toolbox for all kinds of evolutionary computation. 'Our aim was to create a framework which would run on any computer and operating system, could be easily extended, and would make evolutionary computing experiments easily repeatable,' explains J. J. Merello, who heads the team.

Although GeNeura is committed to testing and making new objects available to the EC community, J. J. Merello sees EO as an open development effort. 'We have set up the tools so that anybody can participate,' he says. Because EO is component-based, if you don't find the class you need in it, it is easy to subclass existing abstract or concrete classes. Programming with the library consists of selecting the fully working components whose behaviour is closest to that desired then overriding aspects of their behaviour until they act in the way you want. This can be done in a step by step way, always keeping a working program at each stage.

The GeNeura team believe that EO will prove easier to use and more robust than frameworks written in C, faster than those written in Java, and that it offers a significant improvement on established C++ libraries such as GALib, TOLKIEN and Evolvuton – some of which are pre-ANSI, or have ceased development.

'EO uses all the current C++ tools, which makes its code much more compact and easy to use,' says Merello. 'And unlike GALib, which emphasises genetic algorithms, EO covers all evolutionary computation algorithms – Evolution Strategies, Simulated Annealing, Evolutionary Programming and Genetic Programming; the first two have been implemented already, and the others are in progress.'

EO has been tested and works on the following platforms:

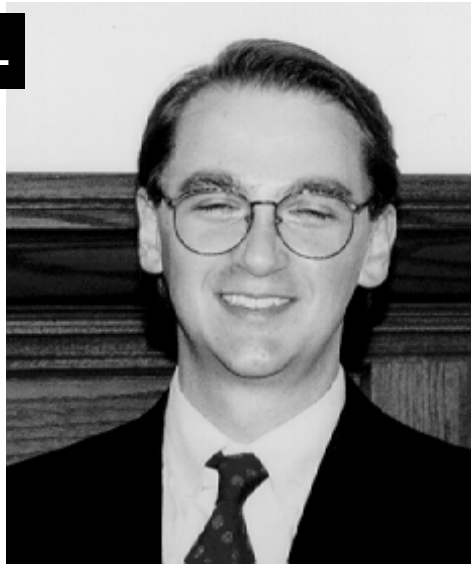
- **Linux with egcs 1.0.2**
- **Irix 4.0 with egcs 1.0.2**
- **Solaris with egcs 1.0.2 and gcc 2.8.1**
- **Win95/NT with CygWin/egcs 1.0.2, VC++ 5.0 and Borland Builder.**

To support open development of EO, GeNeura has set up a mailing list to solve technical problems, announce releases, publish patches and discuss evolutionary computation in general.

💻 **To subscribe contact: eodev@onelist.com**
EO can be downloaded from: http://geneura.ugr.es/~jmerelo/eo or ftp://geneura.ugr.es/pub/eo

Converging of the Ways

— an exclusive interview with DAVID FOGEL



Where do ideas come from? Do they spring fully formed from the heads of geniuses, or do they develop in fits and starts, passing from human brain to human brain, adapting, cross fertilising and gradually evolving in the virtual ideas factory that is collective human consciousness?

From the evidence of *Evolutionary Computation: The Fossil Record*, ideas are generated in parallel – lots of isolated, highly active brains and a modest amount of information transfer. As a result, evolutionary computing was invented on at least ten separate occasions in a 15-year timespan. 'It's a classic example of convergent evolution,' says the book's author, David Fogel.

David Fogel is of course the son of Lawrence Fogel who in 1960 invented Evolutionary Programming – an iterative mutation and selection procedure which in its first incarnation was used to evolve finite state machines to predict sequences of symbols. Four years later, and completely independently, Rechenberg, Schwefel and Bienert invented Evolution Strategies.

In fact, evolutionary computing appeared in various guises throughout the 'fifties and 'sixties – but made no impact on mainstream artificial intelligence research, which continued doggedly attempting to model the products, rather than the process, of evolution. Quite simply: 'Everyone who proposed an evolutionary computation before 1975 was ahead of their time,' says David Fogel. As a result, their work has frequently been misunderstood, lost or forgotten.

Fogel's response has been to republish 30 landmark papers from the history of evolutionary computing. 'There was and is a need to set the record straight,' he says. 'Only a small handful of pioneers in evolutionary computation have been given the credit they are due.' He cites, as an example, the use of recombination in population-based evolutionary simulations. 'This,' he says, 'did not arise in a single major innovation – as has been offered in some books – but was commonly applied in multiple independent investigations dating into the 1950s.'

He points to the work of Alex Fraser (who from 1957 onwards evolved binary strings in a population undergoing crossover) and Hans Bremermann (who in the early to mid-1960s used binary strings as well as real-valued strings with recombination from two or more parents). Both Fraser and Bremermann, he believes, could legitimately lay claim to the title of father of the genetic algorithm. As for the suggestion that Bremermann merely recommended using crossover but didn't do any experiments: 'This is simply not correct,' Fogel insists. 'Not only did Bremermann report experiments, he even reported the CPU time required and the conditions that appeared to affect the efficiency of his evolutionary algorithms.'

Although Fogel acknowledges that his purpose in *The Fossil Record* is to draw attention to these neglected pioneers, he's keen that this should not be at the expense of those who are already widely recognised. 'Giving credit is not like slicing up a pie: the more that goes to one, by consequence the less that goes to another. We should delight in the fact that evolutionary computation appears to have had about 10 independent beginnings, arising in different forms within a 15-year time period from 1953 to 1968.'

But *The Fossil Record* is much more than a catalogue of who thought what, when. It is a treasure trove – of unexpected spins on old ideas, of papers that went too quickly out of print, of conjectures that were never properly tested due to lack of computing power. Fogel believes that many of these ideas deserve further exploration (he identifies four in the panel on page 7) and with his book appearing on more and more course reading lists, he is, he says 'looking forward to hearing about students' projects on these ideas'.

> **'We should delight in the fact that evolutionary computation appears to have had about ten independent beginnings.... It's a classic example of convergent evolution.**

Despite his evident interest in the theoretical and mathematical basis of evolutionary computing, his publications (which include several books and numerous research papers) and his high profile on the conference circuit, David Fogel is first and foremost a practitioner. He is, after all, the son of the man who set up Decision Science Inc. – the first ever business to be based on evolutionary algorithms. Nowadays Lawrence Fogel is President of Natural Selection Inc, where his son is Vice President and Chief Scientist.

'We have been delivering commercial applications of evolutionary programming at NSI since we started in 1993,' David Fogel explains. 'The problem domains we find success in include pharmaceutical design, automatic target recognition and scheduling. We tend not to concentrate on one specific area of application, having worked in medical, financial, military, industrial, transportation, manufacturing, optical character recognition, and many other areas. We learn a great deal from the diversity of applications that cannot be learned by pigeon-holing in one area.'

In addition to developing evolutionary neural networks to detect and diagnose breast cancer from film screen mammograms, current research at NSI focuses on docking problems in molecular drug design. In particular, Fogel points to his work with Agouron Pharmaceuticals 'where evolutionary algorithms are being used to design new drugs and the programs are being used on a daily basis'.

Clearly EP has come a long way since the symbol-predicting finite state machines of the 1960s. It has been extended to real-valued and combinatorial problems, population sizes have been increased and selection is now probabilistic. In 1991, self-adaptation was added, with genetic operators being encoded on the chromosome and subject, themselves, to evolution.

According to conventional wisdom Evolutionary Programming ('as defined by Lawrence Fogel') relies exclusively on mutation as the genetic operator. This is a myth that Fogel is quick to dispel, pointing out that in the 1960s his father suggested a recombination of multiple machines in a majority logic operator (using three or more parents) which was not implemented because of the memory constraints of the machines of the time. He himself takes an undogmatic view of recombination, describing it as 'just another variation operator you can apply'.

'Recombination is just another tool in the arsenal of an evolutionary algorithmist.... In most cases, I find it to be applied inappropriately because it is used by default.'

'Sometimes it is reasonable and sensible to employ, other times it is harmful. There are many forms of recombination and each has its place and by consequence has other places where it fails. We know from the No Free Lunch theorems that there cannot be one best operator for all problems, so we have to try to discern for which problems a particular operator will be most suited. For example, blending recombinations accelerate convergence on a sphere function – but of course we don't want to use evolutionary algorithms to locate the minimum of a bowl, as there are much better heuristics for this. One-point crossover may work well when components are independent and can be strung into ever longer "building blocks", but we know from Ralf Salomon's work at University of Zurich that when the components of a problem become increasingly interdependent this operator breaks down.

'Recombination, in all of its forms, is just another tool in the arsenal of an evolutionary algorithmist, and it should be applied when appropriate. In most cases, I find it to be applied inappropriately because it is used by default, simply as a matter of course. This is where experience has to come into play to make the proper judgement about algorithm design. There's no substitute for real-world experience.'

He takes an equally practical approach to representation. 'You should pick what best suits the problem at hand,' he says. 'If you face a continuous-valued problem, you will probably have a better view of the situation if you use floating point vectors rather

Continued on page 8.

"ideas to excavate from the fossil record"

Reed et al. (1967)

Co-evolution in gaming with self-adaptation deserves further attention – we now know a great deal more about self-adaptation. Although extremely innovative, their implementation was somewhat straightforward. It would be interesting to see how self-adaptation can vary search operators in co-evolutionary situations.

Bremermann; Kaufman; L. J. Fogel et al.

The idea of using multiparent recombination has been pursued lately (particularly by Gusz Eiben). It would be interesting to go back to some of the early proposals for multiparent recombination in Bremermann and Kaufman and see if the population sizes that are available now would make any considerable difference to the rate of optimisation, and on which functions. It would also be interesting to implement the multiparent recombination of L. J. Fogel et al. (1966) on finite state machines, which was a majority logic of 3+ machines: the problem was that the number of states of the offspring increases with the product of the size of the parents, thus quickly exceeding the memory of the machine 35+ years ago.

Friedman (1956)

Friedman's proposals to have autonomous robots evolve essentially neural controllers have been reinvented within the last decade, but it would be useful to see if the specific neural constructs that he suggested 41 years ago would offer any greater flexibility. Sometimes we get caught in the trap of following habit and sticking to the specific architectures we are familiar with (for example: multilayer perceptrons). Friedman offered a host of different possible constructs.

Freidberg (1958)

Friedberg's learning machine was not as successful as was desired (and not as poor as was reported by Minsky), but there were some implementation issues in Friedberg due to the slow computers that were available. These may, in fact, have prohibited real success. I suspect if we were to revisit these experiments the essential mechanisms that Friedberg proposed for automatic programming of machine language could be shown to be workable.

GP'98: Conference Report

This year the Third Annual Conference on Genetic Programming was held at the University of Wisconsin in Madison, Wisconsin, USA. I arrived on 21 July, expecting good things of Madison as on the way from the airport the taxi-driver informed us that it had been voted *the* nicest town in America in 1949!

The conference was housed in the Memorial Union building which overlooks Lake Mendota. The lakeside terrace outside the building was always bustling with people enjoying the sunshine and the cooler lake breeze. At night people from the town flocked to the area to enjoy the plentiful beer and free live music.

There were 23 tutorials this year, divided into parallel sessions spread over four days. Unfortunately it was only possible to attend six tutorials. I thought the standard was high and much appreciated the work that the tutors had put in. I especially enjoyed Kumar Chellapilla's tutorial on Evolutionary Programming for its clarity; Takashi Gomi's on Evolutionary Robotics was chaotic but very entertaining (with many video clips), and John Koza's was fun too with his many good humoured digs at the expense of the AI community.

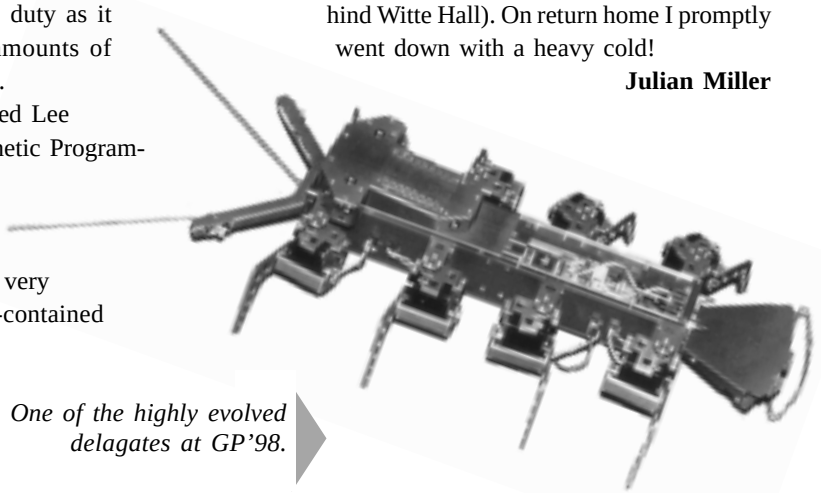
Although the number of registrants was down on the previous year, the interest was still very high and John Koza thought that it had stabilised to a sustainable level. Thursday and Friday began with plenary sessions in the Great Hall, with announcements and talks from the highest rated papers, and an invited talk by a fast-talking, wise-cracking Thomas Sterling on budget priced gigaflop computing using clusters of networked PCs. The highest rated paper at the conference was by Robert Nachbar who had devised a form of GP which could represent organic molecules. He showed how it was possible to evolve novel molecules which had a desired chemical activity. It was certainly an impressive piece of work. There were many other fine papers in the conference and of course any mention of specific papers which stand out are entirely personal choices. I admired Sean Luke and Lee Spector's honesty and persistence in their paper 'A Revised Comparison of Crossover and Mutation in Genetic Programming' for admitting and rectifying serious flaws in their previous work on the subject. Obtaining statistically significant data for comparative studies is often seen as unglamorous but it requires a great deal of devotion to duty as it entails huge amounts of computer time.

I appreciated Lee Spector's 'Genetic Programming for Quantum Computers' as I found it a very clear and self-contained treatment.

Bob Reynolds' paper on 'Cultural Algorithms with Evolutionary Programming' was very thought provoking and I also enjoyed Fernando Lobo's talk on 'Compressed Introns in a Linkage Learning Genetic Algorithm'. I know that I will be dipping into the GP proceedings for some time to come and finding much inspiration therein.

On the whole I found the Memorial Union building an excellent place to hold a conference. I liked the idea of discussants for papers and found myself agreeing with John Koza that maybe some of the talks should have been restricted to *ten* minutes. This might have forced presenters to skip the detail (which we could obtain from the printed proceedings) and concentrate on the main points. I can't speak about previous GP conferences but I found GP'98 to be extremely friendly and can only hope that this spirit is maintained at GECCO next year. Coming from sun-starved Britain I also enjoyed the plentiful sunshine and the sand between my toes (playing volley ball behind Witte Hall). On return home I promptly went down with a heavy cold!

Julian Miller



One of the highly evolved delagates at GP'98.

Converging of the Ways

Continued from page 7.

than encoding your solution in binary, octal, hex, or something else. If you need to process a series of algorithmic steps, perhaps a parse tree, or a finite state machine, or a neural network may be appropriate.'

For Fogel, the key point here is that: 'it's now possible to prove that there is nothing to be gained in one representation that cannot be gained in another (given a few not-so-restrictive assumptions about the representations). So there is no general advantage to coding things in binary, or anything else for that matter. Again, the best advice is to use what makes sense to you as the engineer.'

But historic preferences for particular representations and genetic operators are what distinguish the main schools of evolutionary computing. If these preferences pass away, so too will the distinction between approaches. And that – according to David Fogel – will be no bad thing. After four years researching the history of evolutionary computing, he has a unique historical perspective on the field, and strong views about the way forward.

'Given the independent developments of Genetic Algorithms, Evolution Strategies and Evolutionary Programming, each followed similar but slightly different paths until the early 1990s. GAs strongly emphasised binary strings, one-point crossover, building blocks, and proportional selection. ES emphasised floating-point representations, plus or comma selection, and self-adaptation of Gaussian mutations. EP emphasised variable length encodings on dynamic problems with respect to arbitrary payoff functions. Since the late 1980s and early 1990s, each of these methods has been extended to include the main facets of the others. We now have all of these variants using arbitrary representations, variation operators, and selection mechanisms. So it makes little sense to keep describing things in terms of GA, ES, or EP. It's much more useful to describe things as "evolutionary computation" and "evolutionary algorithms" and move on from there.'

Report back from ESSEC'98

The first summer school organised by EvoNet in Tours, France, was a tremendous success. The participants included MSc and PhD students, teachers and researchers from industry and academia. Some had been using EAs for years, some had simply heard the term and wanted to find out what EAs were all about. Either way, the sessions included something for everyone.

On Monday morning we were treated to an introduction to evolutionary computation from Zbigniew Michalewicz, who encouraged delegates to experiment with different techniques and to invent new ones – 'We can play God' with virtual populations, we can make our own rules, why not re-invent sex, age, cancer or incest? Lamarck may have been dismissed from 'real' biology, but perhaps we can use his ideas in EAs.

In the afternoon Hans-Paul Schwefel described some of the early work on Evolution Strategies, including the remarkable nozzle optimisation experiment, which flew in the face of accepted wisdom at the time, and experiments where evolutionary computation achieved optimisations remarkably similar to those found in the natural world, such as a 'minimal effort' system of tubes for blood circulation. He commented on the super-exponential growth of the field and gave some insight into the differences between the various paradigms.

In his overview of evolutionary programming on Tuesday morning, Thomas Bäck stressed that the boundaries between the 'sub-disciplines' were becoming increasingly blurred, with ideas from each strand being incorporated into practical programs. In his second presentation he outlined the classical schema theory, touching on k-armed bandits and the building block hypothesis. He also presented an alternative perspective as provided by evolution strategies.

In the afternoon Ben Paechter led delegates through a series of 'hands-on' experiments, many of which were drawn from the EvoNet Flying Circus (http://www.dcs.napier.ac.uk/evonet/). Delegates were able to execute a range of evolutionary algorithms and 'tune' the parameters. Being able to vary the population size and crossover operator allowed students to get a feel for the importance of these issues in obtaining fast, reliable optimisation.

Delegates get to grips with evolutionary algorithms in the 'hands on' session.

On Wednesday Wolfgang Banzhaf introduced genetic programming and described a number of methods for representing GP constructs. In answer to the question, 'Why might we use genetic programming?' he suggested that one day writing programs by hand would be as unusual as building chairs by hand is today.

An informal session in the later part of the morning involved a panel taking questions from the delegates. The discussion covered a wide range of issues including parallel EAs, diploids and hybrid systems. There was general enthusiasm for hybrid systems and the panel agreed that for practical purposes hybrid EAs are most effective.

One of the issues Zbigniew Michalewicz considered in his discussion of heuristic methods on Thursday, was the question of what to do about infeasible members of the population. Simply ignoring such items or penalising them too heavily results in a loss of efficiency. Alternatives such as repair and dynamic penalties were put forward. He also introduced his Genocop system which is available from http://www.coe.uncc.edu/~gnazhiya/gchome.html.

This was followed by a whirlwind tour of EA applications by Marc Schoenauer. Examples with continuous search spaces were contrasted with those with discrete search spaces.

At the second panel session delegates were warned about the pitfalls of making comparisons between EAs and analytical methods. Students should be cautious of claiming to solve NP problems – note that not all instances of problems in this class are 'hard'. Where possible researchers should test their techniques on problems drawn from well known sources such as the OR-Library (http://mscmga.ms.ic.ac.uk/info.html).

The term 'statistical mechanics' drew a decidedly lukewarm response from panel members. Although the need for some theoretical work was undisputed, it was suggested that to date the theoreticians were lagging far behind the practitioners. Gusz Eiben drew an analogy to probability theory – people made a living from gambling for centuries, but it is only relatively recently that probability theory has been set down in a sound, consistent framework.

In the afternoon Gusz Eiben spoke about dynamic, adaptive and self-adaptive parameter control, and in particular about parameter adjustment 'on the fly'.

On Friday Marco Dorigo introduced ant colony optimisation – a novel approach to distributed combinatorial optimisation inspired by the foraging behaviour of ant colonies. Michele Sebag discussed some major approaches and applications in machine learning. Phil Husbands considered two areas of Artificial Life that make heavy use of evolutionary computing techniques – artificially evolving autonomous agents (especially autonomous mobile robots) and the use of evolutionary simulations as a tool for modelling biological phenomena.

Coinciding with France's extraordinary triumph at the climax of the World Cup and Bastille day, the social program had a festive air.

Many thanks to the organisers who worked their socks off.

Andrew Cumming

Network Optimisation

This autumn EvoNet will be asking its membership to help improve the effectiveness of the network by taking part in a simple feedback algorithm.

'Basically, we're undertaking some market research,' explains EvoNet administrator Jennifer Willies. 'We've put together a questionnaire which we hope our members will take the time to complete. We want to know what sort of services they want from EvoNet, and also how they can best receive information. For example, many of our industrial members operate behind fire walls. Their access to the Web is severely restricted, so we need to know what alternative means of communication suits them best.'

In its first year and a half, EvoNet concentrated on developing better collaboration between researchers. Now, says Willies, the network is entering a new phase.

'Our emphasis is very much on transferring the fruits of research to industry, so we are looking at the channels of communication between our members, and between the members and the network itself.

'The questionnaire is a chance for our members to influence the development of the network, and to ensure that it supplies the services they need in a form they can accept.'

Website

Work on optimising EvoNet's communication networks has been ongoing since June, when Chris Osborne joined EvoNet as Technical Manager. The structure and style of the website have been thoroughly overhauled and the content of the web pages has been considerably extended.

Additions to the website include a new section about evolutionary computing, more comprehensive information about individual members and working groups, a repository where members can submit papers on evolutionary computing, and a message board for announcements.

'All the membership information on the website now comes directly from the database,' explains Chris Osborne. 'And I have incorporated a search mechanism so that it's now possible for members to perform a search on a keyword and find all the other EvoNet members with a specific interest.'

Over the next few months he plans to add more information to the database. However, as he points out, his efforts to build an interactive website that encourages networking very much rely on members providing adequate and accurate information about their interests.

Consultancy register

To promote information exchange the EvoNet website now includes six registers, covering consultancy, recruitment, training, research projects, industrial placements and students seeking placements.

The consultancy register is a free listing service open to all registered EvoNet members. Over the next year it is expected to develop into a full online searchable consultancy brokerage.

'We want to establish EvoNet as the organisation that everyone thinks of when they are looking for expertise in this area,' explains Jennifer Willies. 'We see bringing together people with problems and people with solutions as a key aspect of our technology transfer role.'

EvoNet Registers

As the European information exchange for evolutionary computing, EvoNet has established six web-based registers.

- ✓ **A register of consultants with expertise in evolutionary computing**
- ✓ **A register of career opportunities in evolutionary computing**
- ✓ **A register of European national projects in the field of evolutionary computing**
- ✓ **A register of academic courses on evolutionary computing**
- ✓ **A register of companies offering student placements**
- ✓ **A register of students seeking industrial placements**

These registers are up and running now. Whether you're a company offering expertise or a student looking for experience, you can add your details to the appropriate register simply by visiting the EvoNet website at http://www.dcs.napier.ac.uk/evonet/ and following the Services link.

New Book Announcement

Evolutionary Algorithms for VLSI CAD

- By Rolf Drechsler
- Published by Kluwer Academic Publishers, Boston
- **ISBN 0-7923-8168-8**

Evolutionary Algorithms in VLSI CAD presents the basic concepts of EAs, and considers their application in VLSI CAD. It shows how EAs can be used to improve integrated circuit design tools and processes. Several successful applications from different areas of circuit design, such as logic synthesis, mapping and testing, are described in detail. The book is intended for CAD developers and researchers as well as those using evolutionary techniques to support modern design tools and processes.

For more information (including ordering and pricing information), check the Kluwer Academic Publisher website: http://www.kcap.nl/book.htm/0-7923-8168-8

The EvoNet Questionnaire

To ensure that EvoNet provides the products and services you need, please fill in the following questionnaire and return it to the EvoNet Office, Department of Computer Studies, Napier University, 219 Colinton Road, Edinburgh EH14 1DJ, UK.

Products and services

Please indicate those services in which you might be interested.

Web-based register of evolutionary computing consultants
- ❑ to advertise your company
- ❑ to identify specialist researchers

Web-based register of industrial placements
- ❑ to advertise a research placement
- ❑ to find an appropriate researcher

Web-based register of courses on evolutionary computing in Europe
- ❑ to advertise a course ❑ to find a course

Web-based register of national research projects on evolutionary computing within Europe
- ❑ to find research results
- ❑ to find suitably experienced researchers

Web-based register of career opportunities
- ❑ to advertise job vacancies/research positions
- ❑ to find employment/research opportunities in Europe

Advertising opportunities
- ❑ advertising features in the EvoNews newsletter
- ❑ links on the EvoNet website
- ❑ direct-mail services (insertions with EvoNet mailings)

A matching-up service
- ❑ to connect you to specialists
- ❑ to a database of relevant case studies/research publications

Networking possibilities
- ❑ at EvoNet events (conferences, courses, seminars, workshops)
- ❑ access to specialist researchers in the EvoNet working groups
- ❑ problem-solving discussion groups, on-line advice and help-lines, etc

Training opportunities
- ❑ industrial training placements in specific projects
- ❑ specialist seminars and workshops
- ❑ academic training courses

Access to more information via
- ❑ access to the EvoNet Flying Circus
- ❑ more information about (and links to) useful applications
- ❑ an up-to-date digest of technology developments in a range of industrial sectors
- ❑ surveys and state-of-the-art reports in specialist areas
- ❑ pre-print service list
- ❑ public domain library
- ❑ access to an electronic repository of published papers in Europe
- ❑ a journal of scientific research in the field of evolutionary computing

Products
- ❑ purchase/licensing of problem-solving software
- ❑ state-of-the-art reports on specialist subjects
- ❑ specialist seminars and colloquia
- ❑ electronic organising of conferences
- ❑ an EvoNet CD of case studies and demos

Information distribution

Preferred source(s) of information?
- ❑ EvoNews newsletter sent to you and/or your colleagues
- ❑ EvoList, the electronic bulletin, sent to you by email
- ❑ other paper-based material, including an EvoNet publicity brochure
- ❑ web-based material, including the Flying Circus and links to other sources
- ❑ on-site presentation within your own organisation

Is the www easily accessible to you and, if so, at what access level?
- ❑ full access at your desk
- ❑ partial access at your desk, or nearby
- ❑ very limited access
- ❑ no access

Your interests

Please tick the topics that are of particular interest to you
- ❑ Scheduling, timetabling, routing
- ❑ Forecasting, prediction, data-mining
- ❑ Evolutionary electronics/evolvable hardware
- ❑ Biological/biochemical applications
- ❑ Design ❑ Control
- ❑ Image processing ❑ Signal processing
- ❑ Optimisation ❑ Engineering
- ❑ Evolutionary robotics ❑ Other (please specify)

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What best describes your interest in EvoNet?

- ❑ Finding appropriate industrial applications
- ❑ Finding more research information for particular problems
- ❑ Obtaining state-of-the-art reports, case studies, access to electronic repository
- ❑ Finding partners for research projects (application-oriented)
- ❑ Finding partners for research projects (longterm research)
- ❑ Setting up specific industrial projects with other EvoNet members
- ❑ Participation in (or co-organisation of) conferences, workshops, seminars
- ❑ Providing services, products, case studies, consultancy services
- ❑ Providing training courses and other educational opportunities
- ❑ Providing or finding industrial placements/secondments
- ❑ Other (please specify) __________

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What services (if any) currently offered by EvoNet do you find useful?

Please feel free to describe in greater detail your interest areas or what you would like to see developed further by EvoNet:

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Your organisation

Which most closely describes your organisation?

- ❑ Industrial or commercial enterprise
- ❑ University or higher education
- ❑ Research organisation or public institution
- ❑ Other (please specify) __________

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If you are an industrial or commercial enterprise, which would you be classified as?

- ❑ Large company
- ❑ SME (small-to-medium sized enterprise)
- ❑ Consultants

Number of employees

(For universities and research institutions, the number of research staff in your department):

- ❑ 50 or less
- ❑ 51–250
- ❑ 251–500
- ❑ 501–1000
- ❑ 1001–5000
- ❑ 5000+

Which industrial sector best describes your organisation?

- ❑ Primary industries (e.g. agriculture)
- ❑ Manufacturing (processes and products)
- ❑ Retail, distribution, transport
- ❑ Space, defence
- ❑ Telecommunications, energy and utilities
- ❑ Human services, healthcare and education
- ❑ Finance and trading
- ❑ Leisure activities, entertainment and media
- ❑ Bioinformatics and emerging industries
- ❑ Other (please specify) __________

____

Contact information

Your Title (Dr, Mr, Ms, etc):

First Name:

Last Name:

Position:

Telephone:

Fax:

Email:

❑ Please tick this box if you are not already a member of EvoNet, but would like to join.

EvoNet is aware of its responsibilities under Data Protection legislation and will not disclose this information to third parties without prior permission.

Organisation Name (in full, please do not abbreviate):

Department Name:

Address (please include town, postal code and country):

Telephone:

Fax:

Email:

URL:

Evolutionary Computation Journal

Special Issue on Advances in Genetic Algorithms: Research Trends and Perspectives

Submission deadline: 1 March 1999

It is more than 20 years since John Holland published *Adaptation in Natural and Artificial Systems*. Although appreciation of the intellectual scope and significance of this monograph was initially limited to Holland's students and colleagues, over the years the influence of his ideas has steadily grown.

Today, John Holland is regarded in many circles as a visionary whose insights address critical issues relevant to scientific inquiries in fields as diverse as economics, immunology, cognitive science and ecology. His research has also provided much of the intellectual foundation for the new science of complexity.

Holland's insights have provided the starting point for many computational models of adaptation, including genetic algorithms, classifier systems, genetic programming and Echo. As we approach the 25th anniversary of the publication of Holland's landmark book, now is an opportune time to assess the impact of Holland's work on our understanding of adaptive systems and evolutionary computation. What are the common themes that have emerged from the diverse research efforts stemming from Holland's ideas? How close are we to a deeper theoretical understanding of the phenomena Holland has characterised so clearly and persuasively? What research remains to be done?

This special issue will focus on the impact and significance of the themes underlying John Holland's research, examining what has been accomplished, open research issues, and promising lines of inquiry. Topics of interest include, but are not limited to:

- characterisations of Holland's vision of adaptive systems and the implications of that vision
- discussions of open issues, trends or unsolved problems in GAs, Echo, etc
- descriptions of important developments or promising research directions related to Holland's work
- research that illustrates the themes of Holland's work in new and interesting ways
- comparisons of Holland's ideas with views from other paradigms or related disciplines.

Authors intending to submit a manuscript should contact one of the guest editors as soon as possible to discuss the suitability of their ideas for this special issue.

Guest Editors

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Special Issue on Multi-criteria Optimisation

Submission deadline: 15 February 1999

The focus in multi-criteria optimisation is on finding a number of pareto-optimal solutions (that is, alternative compromises among conflicting objectives), rather than finding a single, globally optimal solution. Many practical search and optimisation problems are better posed as multi-criteria optimisation problems and are therefore important to study.

Classical search and optimisation methods convert multiple objective functions into one scalar function, and can at best find a single pareto-optimal solution at a time. In order to achieve multiple trade-off solutions, these methods are applied repeatedly, each time varying the user-defined parameters for aggregating the multiple objectives. In contrast, evolutionary methods can find multiple pareto-optimal solutions simultaneously, using population-based searches. Because of this parallel searching and freedom from user-defined parameters, evolutionary approaches have a unique advantage over classical methods in solving multi-criteria optimisation problems.

The special issue will include various implementations of evolutionary approaches for multi-criteria optimisation and their applications to real-world problems. In particular, the following broad topics will be considered:

- theoretical issues (such as convergence to the pareto-optimal set)
- implementation of multi-criteria evolutionary methods and proof-of-principle results
- comparison of different evolutionary methods (and classical methods)
- real-world applications
- test problem sets for multi-criteria optimisation
- integration of evolutionary approaches with the multi-criteria decision process.

The guest editors are particularly concerned with pragmatic issues, such as sensitivity of the solutions or the scalability of the approaches.

Prospective authors are invited to submit original, full-length papers before 15 February 1999. Papers must comply with the stylistic requirements of the *Evolutionary Computation Journal* (8,000 to 12,000 words in length, single-sided and double-spaced).

Please send five hard-copies or a post-script file of your paper before 15 February 1999 to:

✉ Kalyanmoy Deb
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University of Dortmund
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The special issue will also include short descriptions of any public domain software implementing multi-criteria optimisation using EC methods. Interested parties should contact one of the guest editors for details.

GECCO'99 – call for papers and participation

Next year the two largest EC conferences – ICGA and GP – join forces to form the Genetic and Evolutionary Computation Conference. The merger may or may not be permanent, but the motive is magnificent. In the words of Conference Chair, David Goldberg: 'We felt it was important to try to assemble the largest high quality genetic and evolutionary computation event ever held.'

The philosophy behind GECCO'99 is inclusiveness – the organisers expect all flavours of evolutionary computing to be represented by well over 500 researchers from around the world. So far the list of co-operating organisations and conferences includes EvoNet, AAAI, ANTS 98, Evolution Artificielle, ICES, PPSN and SAB, with others joining almost weekly.

The organisers believe their review procedure respects the norms and traditions of the different methods within the field. 'Each of the six committees or demes will be free to impose its own criteria, review standards, and decision-making procedures and authors will choose the deme that best reflects the content of their papers,' explains Goldberg.

To encourage merit and minimise political considerations, senior members of the program committee have been selected from among the ranks of book authors. As a result, the program committee is filled with many of the most prominent names in the field.

'The large European contingent is testimony to the high quality and publication prowess of European researchers,' says Goldberg. 'Some of these researchers have not had access to the halls of decision making at earlier conferences, but the new procedure invites them in without the need to curry favour with the conference chairman. Likewise, the reviewers are chosen from those who have published a recent peer reviewed paper in a conference, edited volume, or journal.'

'We believe that GECCO will be *the* genetic and evolutionary computing event of the decade.'

One of the challenges for any large conference is ensuring that the setting is sufficiently intimate for scientific interchange. 'We have a number of ideas to give our big top the intimacy of a smaller workshop,' says Goldberg. 'Specifically, we plan to take the best elements of both GP and ICGA and combine them. This will mean having a PhD workshop, posters, bird-of-a-feather workshops, and a number of scheduling innovations to promote long periods out of the lecture halls, where small group discussions can flourish. Given the large, self-contained conference venue, it should also be possible to encourage socialising with both formal and informal activities in the pools, on the tennis courts and in the pubs.

'In short, we believe that GECCO will be the genetic and evolutionary computing event of the decade, and we encourage EvoNet members to plan their paper submissions and travel arrangements early.'

💻 **http://www-illigal.ge.uiuc.edu/gecco/**

Congress on Evolutionary Computation

Call for Participation and Papers

Papers are invited for CEC99, which takes place on 6–9 July 1999, in Washington DC.

Topics include, but are not limited to: theory, application, empirical analysis, and philosophy concerning all manner of evolutionary computation including evolution strategies, evolutionary programming, genetic algorithms, genetic programming, classifier systems, artificial life, DNA computing, evolvable hardware, evolutionary robotics, and any hybridized search, optimization, or machine learning techniques drawing on computational models of evolution.

Papers investigating issues common to all evolutionary computations are especially encouraged.

For further information visit:
💻 **http://garage.cps.msu.edu/cec99**

Call for Book Proposals on Genetic Programming

The Kluwer book series on genetic programming will cover applications of genetic programming, theoretical foundations of genetic programming, technique extensions, and implementation issues. It will be the first collection of monographs, edited collections, and advanced texts to cover this rapidly growing field. In order to publish material that is timely and reflects the state of the art, the series will focus on books of relatively narrow scope and moderate length and will feature a rapid publication schedule.

Topics may include, but are not limited to: design, control, classification, system identification, data mining, pattern recognition and image analysis, data and image compression, evolvable machine language, evolvable hardware, and automatic programming of multi-agent and distributed systems.

Prospective authors wishing to discuss an idea for a book which would fit in this series, or to receive specific information regarding book proposal requirements, please contact:

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Book Review

- ***Bio-Inspired Computing Machines***
- **Edited by Daniel Mange and Marco Tomassini**
- **Published by Presses Polytechniques et Universitaires Romandes (http://ppur.epfl.ch)**

Bio-Inspired Computing Machines largely concentrates on the pioneering work done at the Logic Systems Laboratory of the Swiss Federal Institute of Technology in Lausanne. As the first book to be exclusively devoted to biologically-inspired computing machines, it will be invaluable to graduate and research students wishing to explore this new field.

The text is based on a graduate course held at EPFL in 1997. It is exceptionally well referenced and has twelve chapters covering digital systems, cellular automata and programming, biologically inspired hardware systems with self-testing and self-repairing, field programmable gate arrays and field programmable processor arrays, Lindenmayer systems, artificial neural networks and autonomous robotic agents.

I found the first four chapters to be very clearly and simply written. Of the remaining chapters, 'Programming Cellular Machines by Cellular Programming', 'Artificial Neural Networks: Algorithms and Hardware Implementation', and 'Evolution and Learning in Autonomous Robotic Agents' were especially well presented. However, I found the four chapters on hardware rather heavy going. Without a good grounding in digital logic design, a student would struggle with these chapters. Nevertheless, the ideas were interesting; self-repairing and self-replicating hardware is an area that will almost certainly develop considerably in the next century.

Julian Miller

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online

Interesting Websites

http://lancet.mit.edu/ga/
GAlib contains a set of C++ genetic algorithm objects. The library includes tools for using genetic algorithms to do optimisation in any C++ program using any representation and genetic operators. The documentation includes an extensive overview of how to implement a genetic algorithm.

http://GARAGe.cps.msu.edu/software/software-index.html
GALOPPS, the 'Genetic ALgorithm Optimised for Portability and Parallelism System', is a generic C genetic algorithm tool that provides an enormous range of options for genetic algorithm experiments. It is available for both PC and Unix systems, and four formats are now available. A threaded version of GALOPPS (Unix only) is available by special request.

http://www.emk.e-technik.th-darmstadt.de/~thomasw/gp.html
The GP kernel is a C++ class library that can be used to apply genetic programming techniques to all kinds of problems. The library defines a class hierarchy. An integral component is the ability to produce automatically defined functions as found in Koza's *Genetic Programming II*. Technical documentation (postscript format) is included. There is also a short introduction to genetic programming.

http://www.channel1.com/users/gps1/
KDNuggets™ Directory: Data Mining and Knowledge Discovery Resources – includes a free electronic newsletter, a guide to commercial and public-domain tools for data mining and knowledge discovery, datasets for testing data mining methods, and information on companies, jobs and solutions.

http://www.geneticprogramming.com/
The Genetic Programming Notebook – a comprehensive site, including tutorials, FAQs and links.

http://www.krl.caltech.edu/~charles/alife-game/
Project Von Neumann is a full scale international venture to build a professional grade freeware computer game with evolving enemies.

http://www.aridolan.com/ad/adb/adib.html
The New Alife Database is a successor to the first Alife Database. Unlike the first version, it is not specifically oriented towards online experimentation and code sharing. It is a much larger and more comprehensive database, where the data is automatically gathered by an intelligent search bot that scans the world wide web for Alife related pages

http://www.cs.ucl.ac.uk/staff/A.Qureshi/gpsys.html
GPsys (pronounced gipsys) is a Java (requires Java 1.1 or later) based genetic programming system developed by Adil Qureshi. The software, including documentation, source and executables, is made available for non-commercial use only.

EvoNet Websites

- **Napier University, Edinburgh**
  http://www.dcs.napier.ac.uk/evonet/
- **Ecole Polytechnique, Paris**
  http://blanche.polytechnique.fr/www.evonet/
- **University of Granada**
  http://krypton.ugr.es/Coordinator/evonet_f.htm
- **University of Dortmund**
  http://ls11-www.informatik.uni-dortmund.de/evonet/

To keep ONLINE up-to-date, please email mij@dcs.napier.ac.uk with any interesting EC-related ftps, newsgroups, bookmarks or mailing lists.

All the events listed on these pages include coverage of, or welcome papers on, evolutionary computing techniques.

ants

27–30 September 1998

PPSN: Parallel Problem Solving from Nature, Amsterdam, The Netherlands

Contact T. Baeck, M. Schoenauer
baeck@icd.de
marc.schoenauer@polytechnique.fr
http://www.wi.leidenuniv.nl/CS/ALP/ppsn 98. html

15–16 October 1998

ANTS'98: From Ant Colonies to Artificial Ants – First International Workshop on Ant Colony Optimisation
Brussels, Belgium

Contact Marco Dorigo
☎ +32 2 6503169 (voice)
+32 2 6502715 (fax)
ants98@iridia.ulb.ac.be
http://iridia.ulb.ac.be/ants98/ants98.html

24–27 November 1998

SEAL'98: The Second Asia-Pacific Conference on Simulated Evolution And Learning, Canberra, Australia

Contact Dr Xin Yao
☎ +61 2 6268 8184 (voice)
+61 2 6268 8581 (fax)
SEAL98@cs.adfa.oz.au
http://www.cs.adfa.oz.au/conference/seal98

30 November – 2 December 1998

Complex Systems '98: Complexity Between the Ecos – From Ecology to Economics, University of New South Wales, Sydney, Australia

Contact Dr Russell Standish
r.standish@unsw.edu.au
http://parallel.acsu.unsw.edu.au/complex/c98

4–9 January 1999

PSB99: 4th Pacific Symposium on BioComputing (conference track on information-theoretic approaches to biology), Mauni Lani, Hawaii

Contact Dr David Dowe
dld@cs.monash.edu.au
http://www.cs.monash.edu.au/%7Edld/PSB99/PSB99.Info.CFPs.html

20–22 May 1999

ISMVL 99: 29th IEEE International Symposium on Multiple-Valued Logic, Freiburg im Breisgau, Germany

Deadline: 1 November 1998

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☎ +49 761 203 8145 (voice)
drechsle@informatik.uni-freiburg.de
http://www.informatik.uni-freiburg.de/~drechsle/ismvl99/index.html

26 May 1999

EvoSCONDI'99: European Workshop on Evolutionary Computation for Systems, Control and Drives Industry, Goteborg, Sweden

Contact
evoscondi@dcs.napier.ac.uk

26–27 May 1999

EuroGP'99: Second European Workshop on Genetic Programming, Goteborg, Sweden

Contact
R.Poli@cs.bham.ac.uk
nordin@fy.chalmers.se
http://www.cs.bham.ac.uk/~rmp/eebic/eurogp99/

29 May 1999

EuroECTel'99 European Workshop on Evolutionary Computing and Telecommunications, Goteborg, Sweden

Contact
ectel-chair@dcs.napier.ac.uk

1–4 June 1999

IIA'99 and SOCO'99: Third International ICSC Symposia on Intelligent Industrial Automation and Soft Computing, Genova, Italy

Deadline: 10 September 1998

Contact Conference Organiser
operating@icsc.ab.ca
http://www.icsc.ab.ca/soco99.htm
http://www.icsc.ab.ca/iia99.htm

14–18 June 1999

MAPSP'99: Fourth Workshop on Models and Algorithms for Planning and Scheduling Problems, Renesse, The Netherlands

Deadline: 1 March 1999

Contact
MAPSP99@win.tue.nl
http://www.win.tue.nl/~mapsp99

CEC 99

23–25 October 1998

Integrated Planning for Autonomous Agent Architectures, Robots and Biology: Developing Connections, Orlando, Florida, USA

Contact
☎ 650 328 3123 (voice)
650 321 4457 (fax)
💻 fss@aaai.org
http://www.aaai.org/Symposia/Fall/1998/fssparticipation-98.html

23–28 October 1998

FEA 98: International Workshop on Frontiers in Evolutionary Algorithms (part of the 4th Joint Conference on Information Systems), Research Triangle Park, North Carolina, USA

Contact
💻 **http://www.cs.umsl.edu/Faculty/janikow/FEA**

25–30 October 1998

ICCS'98: Second International Conference on Complex Systems, Nashua, USA

Contact
💻 **http://necsi.org**

euroGP

6–9 January 1999

International Conference on Evolutionary Computation in Engineering, Indian Institute of Technology Madras, Chennai, India

Contact Dr S. Mohan
☎ 91 44 2351365 ext. 3466/3464 (voice)
91 44 2350509/ 91 44 2352545 (fax)
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mohan@civil.iitm.ernet.in
http://www.msci.memphis.edu/~dasgupta /EC-India/CFP.html

6–9 April 1999

ICANNGA: Fourth International Conference on Artificial Neural Networks and Genetic Algorithms, Portoroz, Slovenia

Contact University of Ljubljana
☎ +386 61 1768 387 (voice)
+386 61 1264 647 (fax)
💻 icannga@fri.uni-lj.si
http://cherry.fri.uni-lj.si/icannga99.html

12–16 April 1999

BioSP3: Second Workshop on Bio-Inspired Solutions to Parallel Processing Problems, San Juan, Puerto Rico, USA

Deadline: 1 November 1998

Contact Juergen Branke
☎ ++49 (721) 608 6585 (voice)
++49 (721) 693717 (fax)
💻 ercal@umr.edu
http://www.cs.umr.edu/~ercal/biosp3/BioSP3.html

27 May 1999

EvoStim'99 European Workshop on Evolutionary Scheduling and Timetabling, Goteborg, Sweden

Contact
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28 May 1999

EvoIASP'99 European Workshop on Evolutionary Image and SignalProcessing, Goteborg, Sweden

Contact
💻 evoiasp-chair@dcs.napier.ac.uk

28–29 May 1999

EvoRobot'99 the Second European Workshop on Evolutionary Robotics, Goteborg, Sweden

Contact
💻 evorob-chair@dcs.napier.ac.uk

GECCO

6–9 July 1999

CEC99: Congress on Evolutionary Computation, Washington DC, USA

Deadline: 15 January 1999

Contact
💻 CEC99@natural-selection.com
http://garage.cps.msu.edu/cec99

14–17 July 1999

GECCO: Genetic and Evolutionary Computation Conference, Orlando, Florida, USA

Deadline: 27 January 1999

Contact David E. Goldberg
💻 deg@uiuc.edu
http://www-illigal.ge.uiuc.edu/gecco/

13–17 September 1999

ECAL99: 5th European Conference on Artificial Life, Swiss Federal Institute of Technology, Lausanne, Switzerland

Deadline: 28 February 1999

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http://www.epfl.ch/ecal99

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Printed by:
Metro Press, 64-66 Albion Road,
Edinburgh EH7 5QZ.

EvoNews is the quarterly newsletter of EvoNet, the European 'Network of Excellence' in Evolutionary Computing.

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