EvoNews

Newsletter of EvoNet – The Network of Excellence in Evolutionary Computing

http://www.dcs.napier.ac.uk/evonet/ Issue 9, Winter 1999

Optimise IT!

EvoNet invites strategic decision-makers and technical staff to a one-day industrial seminar that will focus on evolving solutions to problems in the aerospace, energy, telecommunications and scheduling fields.

'an opportunity to learn about a technique that can save your company money, improve your product or your production methods'

Entitled **Optimise IT: Natural Strategies for Industrial Optimisation**, the event is organised by EvoNet's EvoDOP and EvoStim working groups and will take place on 19 April in Amsterdam.

'Our aim is to demonstrate how evolutionary algorithms can be used to solve some of the problems encountered in certain key industrial sectors,' explains Thomas Bäck, who chairs the Dynamic Optimisation Group. 'We also want to increase awareness of the economic benefits of evolutionary computing.'

Real-world problems

'We plan to bring together industrialists and academics to investigate the real world problems that evolutionary computing can tackle, to demonstrate some successful industrial applications and encourage collaboration,' says Emma Hart of EvoStim.

She believes that the seminar's scheduling strand will be of relevance to anyone who has to deal with complex resource allocation problems – from jobshop scheduling in a factory to scheduling trains on a rail network, lessons in a college, advertisements on TV or matches at a sporting event.

'Optimise IT represents an opportunity to learn about a technique that can save you money, improve your product or your production methods,' saysThomas Bäck.

An impressive array of industrial speakers confirms the event's real-world focus.

- Dr Claus Hillermeier, a project manager at **Siemens AG**, will discuss the benefits of using evolutionary techniques in energy supply and power management.
- Dr Werner Haase, a project manager at **Daimler-Benz Aerospace**, will look at a number of examples where evolutionary techniques have been used for optimisation tasks in aerospace applications, including the multipoint airfoil optimisation problem, the pressure redesign problem, and the optimisation of flap effectiveness for composite delta wings.
- Jason Mann, a senior researcher and software engineer at **Nortel Smart Network Technology Labs**, will discuss evolutionary approaches to telecommunications network design.
- Martin Oates, from the Autonomous Management of Distributed Information Systems Project at **BT Labs**, will focus on the use of evolutionary techniques in adaptive distributed database management.
- Dr Peter Ross of **Edinburgh University** will draw on his wide experience of scheduling, time-tabling, facility layout, pipe routing and supply chain management problems, to discuss the practical aspects and advantages of applying evolutionary algorithms to time-tabling problems.
- Andrea Tettamanzi, director of research and development at **Genetica Advanced Software Architecture Srl**, will demonstrate EvoSchool, a package that his company devised to solve tough timetabling problems in Italian schools.
- The **industrial exhibition** organised to run alongside the workshop will provide companies that have developed EC-based software or services with a unique opportunity to demonstrate their expertise to their target audience.

Optimise IT promises to be a tightly focused forum where delegates will learn about a new and powerful optimisation technique and how to apply it to their problems.

'We have ensured that there is plenty of time available for industrial participants to discuss their problems and obtain a first assessment whether evolutionary algorithms could be helpful,' affirms Thomas Bäck. 'I am confident that we have excellent speakers, convincing applications and a unique collection of presentations in the industrial exhibition.'

For more information, see 'News and Events' on the EvoNet website (http: www.dcs.napier.ac.uk/evonet/).

See inside for EvoWorkshops'99

CARS AND COFFEE TABLES!

Contents

Your heart sinks when you read the design spec. Conflicting demands, multiple objectives, infeasible deadlines – this project's got the lot. You sigh…

… and summon your design team. They are skilled and experienced professionals: a project leader who bolts together new ideas from the body parts of old ones; a designer whose painstaking refinements will gradually improve the product; and a technician who builds and tests the prototypes. Despite their talent and creativity, you know that these people will spend many anxious months and many thousands of pounds producing a suboptimal design. That's the way it always has been and that's the way it always will be.

Your disgruntled gaze settles on your desktop computer. If only you could automate the process…

Good design, you remind yourself, can't be reduced to a set of commands. It's holistic, synergistic and, most of all, creative. Sure, modern software tools can help to realise a design, but the design process itself is so indefinable, so ineffably *Zen*, it will always remain beyond the range of computers.

Not according to Peter Bentley, editor of the newly published *Evolutionary Design by Computers*. While Bentley agrees that computers are mindless machines, capable only of following instructions, his book explores what happens when we instruct our mindless machines to model the mindless mechanistic process of evolution.

> **'I think in the next five years or so this technology will mature into a collection of software products.'**

What happens, quite simply, is that computers become capable of innovation and even creativity: Computer Aided Design becomes Computer Design.

For many this won't be such an astonishing revelation. After all, the design process and evolution both involve the same basic procedures – bolting together disparate bits of information (recombination), small refinements (mutations), testing and feedback (survival of the fittest). Besides, evolutionary computing has been applied to design optimisation problems for more than two decades.

What is surprising, though, is the extent to which the field of evolutionary design has developed, and the range of what has been achieved so far.

'This area is more than engineering design, and it's a great deal more than just optimisation,' says Bentley. 'Evolution can be used to perform optimisation, but give it a bit more freedom, let it change the number

A coffee table built from an evolved design.

Can computers be creative?

of parameters as well as their values, or let it come up with its own representation and parameterisation, and its true potential begins to emerge.'

Evolutionary computing, as Bentley's book shows, can create designs from scratch. Artefacts that have been successfully evolved by computer include satellite booms, load cells, flywheels, computer networks, artistic images, sculptures, virtual creatures, house and hospital architectural plans, bridges, cranes, analogue circuits and even coffee tables.

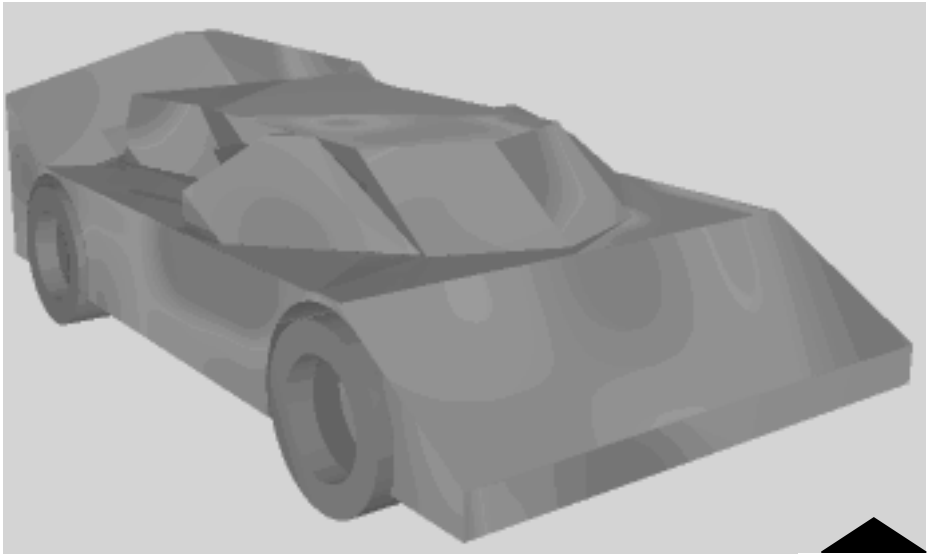
'Computers have evolved some very creative designs,' says Bentley. 'Novel circuits that outperform human-designed circuits by using components in bizarre ways that no human had thought of; extraordinary structural designs that have minimal vibrations; flowing architectural designs that astonish in their grace and beauty. Even when evolving a humble coffee table, the computer was able to generate fresh, intricate designs, time after time.'

So what does this add up to in terms of the workplace? Are evolutionary design systems set one day to replace human designers? Quite the reverse. According to Bentley, designers and artists will be the main beneficiaries of research in this area. This is because automating part of the design process will allow them not only to improve the performance of their designs, but also to explore a much wider range of possible solutions.

'I think in the next five years or so this technology will mature into a collection of software products,' he says. 'Add-on evolutionary modules to CAD packages will allow designers to optimise a variety of aspects of their designs, as they design them. Art packages will have evolutionary form-generation systems as standard tools – indeed, one art package already uses evolution to allow the generation of novel textures.'

He predicts an increased take-up of the technology, particularly in areas that need good new designs very quickly – such as Formula One cars, fashion and product branding. 'Research is already underway in all of these areas,' he says.

Nevertheless, the problem remains: how do you convince people that this is a respectable technology? How do you persuade designers to use a technique they believe is unpredictable and random?



A sports car design, evolved to be aerodynamic.

Bentley argues that, despite appearances, evolution is not random: 'It may have random elements to its search, but the process is unarguably directed. This means that it may often be highly original and inventive, and it will almost always give you a good design.'

And while he accepts that it's impossible to guarantee that evolution will always generate an acceptable design, he points out that the same could be said for human designers.

It seems that people are beginning to understand this. 'Engineers are using evolution in a variety of design optimisation problems, with great success,' reports Bentley. 'Architects are beginning to take notice of the astonishing and inspirational forms generated by computer evolution. Artists are beginning to use evolution as another 'paintbrush', generating some amazing images and sculptures.'

And for those who still doubt the creative potential of evolutionary design by computers, Bentley points to nature, where everything from butterfly's wing to rhino's horn bears the hallmark of great design.

'Let's face it,' he says. 'Natural evolution is so good at evolutionary design that many people still believe that life must be the result of a deity. I know of no human designer whose work is so extraordinary that whole cultures believe it to be an act of God.'

- *Evolutionary Design by Computers*
- Peter Bentley (Editor)
- Published by Academic Press Ltd
- ISBN: 0-12-089070-4
- A CD-ROM accompanies the book

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 forthcoming conferences and workshops
- 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 Spring issue of EvoNews is 1 March 1999.

EvoNet Working Group on Financial Applications of Evolutionary Computing

As financial institutions accumulate ever-more electronic data about stocks and shares, companies and customers, they require ever-better tools with which to extract valuable information from the surfeit of digital dross. After all, this is a sector where hard, high value optimisation problems proliferate, and small percentage improvements can transform a company's profitability and competitiveness.

It's against this backdrop that EvoNet recently established a new working group to support the development of financial applications of evolutionary computing. The aim is to spearhead exchange and collaboration by bringing the interested parties together in one group, where they can benefit from mutually developed solutions and identify areas where further research is required.

According to Andrea Tettamanzi, Co-chair of the new working group, evolutionary computing has so far been applied to three main problems in the financial sector: trading, portfolio optimisation and credit scoring.

'In trading, one wants to evolve the best strategies for trading commodities in real-time,' he explains. 'This includes forecasting short-term trends, sometimes even with a horizon of minutes. Portfolio optimisation, on the other hand, is full of hard operational research problems, especially when one wants to use non-standard risk indices or flexible constraints, and combine them with marketing criteria and multi-stage investment planning.'

Credit scoring

The third type of problem – credit scoring – is one with which evolutionary approaches have already achieved a great deal of success. Credit scoring involves taking a sample group of customers whose behaviour is known and using it to generate a mathematical model that will predict the behaviour of customers outside the known group. It's an approach that has been used in a number of commercial EC-based software packages (such as Quadstone's Decisionhouse or Cap Gemini's Omega) and it can be applied to a range of associated datamining tasks, from targeting mailings to fraud detection.

But while evolutionary algorithms can detect relationships between profiles (of customers, businesses or financial trends) and some other feature (such as reliability or responsiveness), they are by no means the only tools at the dataminer's disposal.

> **'Whereas most techniques produce models that are either good *or* transparent, evolutionary computing can do both.'**

Why not use decision trees or neural networks?

Tettamanzi's Co-chair, Gusz Eiben, has applied evolutionary techniques to credit scoring, fraud detection, customer retention and prospect selection. He believes that the advantage of evolutionary computing – and particularly of genetic programming – is that it offers good quality models that are easy to interpret.

'Whereas most techniques produce models that are either good *or* transparent, evolutionary computing can do both,' he says.

Interpretability

The importance of interpretability shouldn't be underestimated. It's obvious that anyone using a decision support tool wants to be sure that the decisions they recommend have a rational basis: they need to be able to see and understand the reasoning behind a decision. As a result, people tend to reject opaque techniques such as neural networks.

'Financial organisations want some insight about *why* a computer suggests a particular course of action,' explains Eiben. 'Simply saying "the computer said so" isn't good enough, because they may, for example, have to explain to a customer why a loan wasn't authorised.'

Another advantage of evolutionary computing is its flexibility.

'With evolutionary techniques you can add, change or remove optimisation criteria seamlessly, without having to re-code your system,' says Tettamanzi. 'Also, it's possible to use more sophisticated indices (as in the case of portfolio optimisation), or non-linear models (as in the credit scoring case), which can't be dealt with by conventional techniques.'

Activities

Working Group activities planned for this Spring include:

- drawing up a European 'map' of individuals and institutions with expertise in the area
- offering consultancy in the form of free or low cost analysis of submitted data, thus significantly lowering the threshold costs for companies interested in this technology
- producing a state of the art report on current financial applications of EC and its potential future take-up – this will incorporate a set of guidelines for tackling frequently occurring problems.

New members are welcome. For industrialists, the Working Group provides easy access to leading experts in the field, and to information about the problem-solving capabilities of this technique. For academics it provides access to real world problems and genuine data. For both, it represents an opportunity for collaboration and jointly developed solutions.

For more information, contact:

- Gusz Eiben (gusz@wi.leidenuniv.nl)
- Andrea Tettamanzi (tettaman@genetica-soft.com)

EvoNet Working Group on Evolutionary Computing in the Aerospace Industry

A new EvoNet Working Group will bridge the gap between the aerospace industry and the current state of the art in evolutionary computing.

Given the complexity of many aerospace problems, and the stringent safety demands involved, current practice in the industry tends to rely on tried and tested techniques. While some aerospace applications of EC have been investigated (examples include air traffic management, spacecraft propulsion, and aircraft design and structural optimisation) evolutionary techniques have yet to be widely accepted.

The evolutionary paradigm may offer a means of tackling previously insoluble problems, but for most aerospace engineers it remains an unknown quantity and they are unlikely to incorporate it into the standard toolbox for difficult aerospace problems until they become more familiar with its capabilities and limitations.

The new working group aims to oversee this process by actively promoting information exchange between academia and industry. According to the group's coordinator, Egbert Boers, both sectors can only gain from collaboration.

'Industrial members will benefit by gaining access to the most up to date research, expertise and demonstrations of evolutionary computation,' he explains. 'Furthermore, they will gain an information channel with which to affect the direction of theoretical research; researchers in academia need to be aware of the distinctive requirements of the aerospace industry, the complexity of many problems, the safety demands that need to be taken into account, and environmental and economic factors that have to be in balance.

'Membership of the Working Group will allow academics to better tune their future research efforts to what is needed in practice. They will gain more test cases for new ideas, and more feedback on the applicability of new theoretical concepts.'

Boers believes that evolutionary techniques are an efficient way to find good solutions to optimisation problems, especially where analytical methods are infeasible. Areas where he thinks evolutionary computation is likely to prove its worth include: 'problem areas where several alternative solutions have to be simultaneously available; dynamic environments, where a reasonable, stable solution might be preferable to a "better" but unstable solution; and interactive environments where there should be a suboptimal solution available at any time.'

'One of the Working Group's objectives will be to compile a target list of problem areas where we expect evolutionary computation to make substantial contributions,' he explains. 'We will subsequently stimulate research in these areas by assisting funding applications.'

The EvoNet Working Group on Evolutionary Computing in the Aerospace Industry is actively seeking additional members.

For more information, contact:

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  National Aerospace Laboratory
  (NLR), Amsterdam, The Netherlands

Working Group Objectives

- **Promote information exchange between aerospace partners in the area of evolutionary computation.**
- **Identify problems in aerospace for which applications of EC could provide solutions.**
- **Initiate and co-ordinate aerospace related EC research proposals.**
- **Promote EC applications and, through demonstration, improve their acceptance in aerospace.**
- **Detect and stimulate fundamental research areas of importance to aerospace.**
- **Detect and disseminate trends in the application of EC in aerospace.**

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 du Petrole, 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:

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Sense from Subjectivity

With one of its offices based at the Technical University, Berlin, where Ingo Rechenberg and his colleagues developed evolution strategies in the mid 'sixties, it's hardly surprising that German software house Iteration GmbH specialises in computer aided optimisation – and in particular evolution strategies.

'Nowadays very few areas fall outside the scope of computer-aided optimisation,' saysdeveloper and researcher Michael Herdy. 'It's an approach that is steadily gaining importance as computers grow more powerful.'

One of the company's key competencies lies in computer-aided optimisation using subjective quality criteria. 'This means that we apply evolution strategies to optimisation problems where subjective assessment by human senses is necessary,' says Herdy.

Michael Herdy, a developer and researcher with Iteration GmbH

'Nowadays very few areas fall outside the scope of computer-aided optimisation. It's an approach that is steadily gaining importance as computers grow more powerful.'

Taste test

Problems like this abound in the food industry, where ingredients frequently have to be combined to create a target product with a unique and constant taste. Herdy points to a number of examples, such as whisky blends, honey blends and – the case his own company worked on – the problem of mixing several different types of coffee to yield a desired taste.

'Commercially available coffees contain up to ten different kinds of coffee, whose quality and taste vary from year to year,' Herdy explains. 'Like wine, coffee is an agricultural product and its taste depends on the weather conditions, the nature of the soil and the characteristics of the plant. Consequently, it's necessary to continually adjust mixtures, not only to create new coffee blends, but also to keep the taste of a brand constant.'

Working with a group of expert coffee tasters from a Berlin-based coffee roasting company, Iteration GmbH used an evolution strategy to adapt a mixture of five coffee types to achieve the taste of a target blend of coffee. The mixture was found after eleven generations with no difference to the taste of the target coffee.

Michael Herdy believes that for the coffee-blending problem computer-aided optimisation has proved its advantage over conventional techniques.

'At present it takes a lot of expert knowledge to find a solution to this problem,' he explains. 'However, when an evolution strategy and subjective selection are used, only coffee tasters with a good sense of taste are needed, instead of experts with years of experience. The taster no longer needs to decide how to change the coffee towards the target coffee, but must only decide which of several cups of coffee is nearest in taste to the target coffee.'

New blends

'Additionally, an evolution strategy with subjective selection can find blends of coffee which experts probably won't find. This is because experts, following their experience, usually choose a similar path in the optimisation space towards the target coffee. For example, they would never change the amount of all coffee components at the same time – which opens the door to further optimisations.

'Experiments have shown that different blends of coffee can have the same taste. So it is possible to minimise the costs of the blend at the same time as the taste is adapted to the taste of the target coffee.'

Colour mixing

Another area where computer-aided optimisation needs to be combined with subjective selection is colour mixing problems, where aesthetic considerations come into play.

Working with Villeroy & Boch, Iteration has developed OptiCer, a tool to optimise the composition of glazes to yield a desired colour and surface quality in the ceramics industry.

'OptiCer is being applied in experimental research and development of glazes, in which the assessment is carried out subjectively by experts,' reports Herdy, and he goes on to point out that the software has already proved its usefulness in one of the most problematic areas in the ceramics industry – developing completely new glazes.

'Using the traditional development process, our partners would have had to try out over 1,000 new combinations of raw materials to develop a completely new glaze. With OptiCer we have already achieved good re-

sults after only 16 generations, with 10 raw material combinations each – a total of 160 combinations. The time and cost savings speak for themselves.'

Language-independent ES

To allow customers to try their own hand at evolution strategies, Iteration has developed Dynamic Linked Libraries (DLLs) which can be integrated into existing software running under Microsoft Windows.

'These are language-independent,' explains Herdy. 'So whether you use Pascal, Basic or Visual C++, you can run the DLL inside your program and use evolution strategies.

'The advantage for our customers is that they don't have to pay us to understand their problem: they already understand their problem. With the DLL they have access to the most up-to-date methods and can employ them on a standard computer. It is possible to realise a complete evolution-strategic optimisation via only a few API-function calls. The DLL manages all the resources and the storage necessary for the optimisation process. You just have to concentrate on modelling and solving your problem.'

For further information, contact:

- herdy@iteration-gmbh.de

A Question of Taste

Optimisation starts with a parent mixture of components (the number and type of components is fixed during the optimisation, only the amount of each component is variable).

Using a (1, 5)-ES, the computer generates the composition of five offspring mixtures, which are created with the help of a computer-controlled mixing machine.

The experimenter then decides subjectively which of the offspring is nearest to the target mixture. The result is fed back into the computer, which starts the next generation. No fitness values are assigned to the offspring and no ranking takes place. The selected offspring becomes the parent of the next generation and a new cycle begins.

(Copyright: Prof. I. Rechenberg)

Book Review

- ***Hardware Evolution: Automatic Design of Electronic Circuits in Reconfigurable Hardware by Artificial Evolution***
- **By Adrian Thompson**
- **Published in the Distinguished Dissertations Series, by Springer-Verlag, London 1998**
- **ISBN 3-540-76253-1**

It is not often that one can recommend the reading of a PhD thesis for pleasure, but Adrian Thompson's book is an exception. *Hardware Evolution* is very clearly and elegantly written and remarkably uncluttered with technical detail. I think it will serve as a source of inspiration for years to come.

For me the true excitement of this work lay in two areas. Firstly, it demonstrated that electronic circuits can be evolved without a conventional design methodology, and secondly, it showed that by evolving circuits directly in the implementational medium (intrinsically), evolution can exploit all the physical resources available.

Electronic design is a typical example of the human, top-down, symbolic way of thinking. Historically this began with the identification of suitable building blocks such as transistors, resistors and capacitors. Simple configurations of these were analysed and perfected to become higher level building blocks which in turn were configured into even higher level building blocks. At each level of abstraction many simplifications are made so as to ensure that the description of the system remains tractable. This process of symbolising and generalising is natural to humans and has proved extremely effective in the field of science. However there is an alternative, which is remarkably effective in the development of sophisticated biological systems. It is the method of trying things out and preserving them if they prove useful. Abstraction does not take place, simplifying assumptions are not made. It is this extraordinarily simple process which has led to the creation of ourselves, the symbolic species. It was this freedom that Thompson wanted to allow in an electronic system.

He describes his experiments in evolving a sonar equipped, wall avoiding robot using RAM, controllable switches, and a genetically controlled global clock. He shows how it proved relatively easy to evolve a minuscule circuit which controlled the robot and allowed it to avoid walls. Later he discusses his now famous work on the frequency discrimination task which was accomplished by evolving the configuration bits of a 10 x 10 section of a gate array (Xilinx 6216 beta). Again the evolved circuit proved to be very efficient. Although the chip was designed for digital circuits, it was analogue in operation with certain cells influencing the overall function even though they were not electrically directly connected in the circuit path from input to output.

It is not possible in a short review to cover all the interesting features of this work. *Evolvable Hardware* raises as many questions as it answers – which in my view makes it all the more interesting. No library would be complete without it.

Julian Miller

Fast breeder

EvoNews talks to Peter Nordin, the man behind the system that is being billed as the world's fastest genetic programming package.

Launched last October by Register Machine Learning Technologies, Discipulus evolves programs in raw binary on common or garden Pentium PCs and spits them out, decompiled, in industry standard ANSI C.

Accelerated evolution

The package is being marketed not on its nifty Windows graphical user interface, but on its speed. It is, so its developers claim, 60 to 200 times faster than comparable learning systems. The secret of this accelerated evolution lies in AIM Learning Technology, an approach invented by Dr Peter Nordin and developed at the University of Dortmund in Germany.

AIM (which stands for 'Automatic Induction of Machine Code') has been the subject of over thirty academic papers, but until recently the technology was confined to RISC architectures.

'We wanted to make the technique as broadly available as possible,' says Nordin. 'Since we deal directly with the binary machine code for the evolved programs, the transition to CISC architecture was quite a challenge.'

The result is Discipulus, a genetic programming package that runs on Windows INTEL PCs using Pentium, Pentium Pro and Pentium II processors. The system implements a subset of the Pentium floating point instructions, giving users access to over forty different instructions, including addition, subtraction, multiplication, division, conditional jumps, trigonometric, logarithmic and many other functions.

Features

Users can select either GP or simulated annealing. They can use demes, dynamic subset selection and several other cutting edge automatic programming technologies. Nordin describes the program as 'feature rich'.

'Most customers have, to date, needed only a portion of the capabilities of Discipulus and most of its limitations are not limitations at all. For example, population size is limited only by the memory available on the computer so we have successfully run populations of 500,000 on desktop computers.'

To spare users any direct contact with the machine code, Discipulus comes with almost 50 preset configurations of instructions and register setups. And for those who want to control every detail of the machine code configuration themselves, Nordin points out that the machine code is 'wrapped in a graphical user interface that lets you specify the exact instruction configuration and the bias assigned to each individual instruction'.

> **'Until you have had access to something this fast, you really cannot appreciate how much of a difference it makes.'**

With Version 1.0 released last October and Version 1.1 currently in Beta, the system is constantly being updated. 'We have added batch run capabilities to Version 1.1,' says Nordin. 'And we are currently working on adding the ability to evolve programs that save state information when iterating through sequential data such as time series data or gene sequences. We have prototypes of this approach running and it works very well.'

But features, functions and interface aside, one gets the impression that for its developers the most remarkable thing about Discipulus is its sheer speed. According to Nordin, projects that would take two months on typical GP systems would probably take a day or less on Discipulus.

'Until you have had access to something this fast, you really cannot appreciate how much of a difference it makes. You can perform more experiments and therefore achieve better, more significant, results. You can run very large populations with hundreds of demes on a single desktop computer on very difficult problems. You can also have the time to test many more different setups.

'And because Discipulus runs on the most widespread computer architecture, you can run experiments in many different environments, from a notebook to your home PC. In fact, you can start a Discipulus run and then minimise it and use your computer as a word processor. Discipulus is so fast that it does practical program evolution running in the background!'

The key to all this speed is machine code. Computers process information so much faster when you allow them to talk their mother tongue: evolved programs run faster and evolution accelerates. In which case, why on earth decompile your superfast solution programs to ANSI C?

Portability

'Because that way you can combine the speed of machine code with the portability and readability of a high level language,' says Nordin.

'By decompiling to ANSI C, the output is an evolved program that can then be called in any C program on virtually any processor that has a compiler that supports the ANSI C standard. So you could evolve, let's say, a speech recognition program on a fast Pentium machine and then compile it to an embedded processor as part of a larger application.'

Readability is also important. Unlike other soft computing methods, such as neural networks, GP provides interpretable output that can be analysed in terms of what variables are used and what influence they have on the results. It makes sense, then, to ensure that the output is in a high level language that is itself amenable to analysis.

Discipulus users include Fortune 500 companies, banks and major universities. 'Our customers are mainly using it for datamining, modelling and education,' reports Nordin. 'The response so far ranges from the very positive to the downright enthusiastic.'

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Success Stories

Optimising radiotherapy treatment

One of the side effects of radiotherapy is that the repeated doses of radiation can destroy healthy tissue as well as cancerous tumours. In order to more precisely target the tumour, radiotherapy beams can be 'shaped' by means of techniques such as multileaf collimators or individual compensators. Given any set of beam shapes the resulting 3D radiation intensity pattern can be predicted. Until recently, however, it was not possible to invert the process and deduce the set of beam shapes required to generate a particular pattern. Now researchers from **The Computational Intelligence Group** at Coventry University have used genetic algorithms to successfully tackle this problem, evolving sets of candidate input beams to achieve a desired output. Results show that this approach enables the maintenance of high levels of radiation at the tumour site, while significantly reducing the impact of unwanted radiation in other areas.

C.Reeves@coventry.ac.uk
http://www.mis.coventry.ac.uk/~colinr/cig.html

A new approach to shipping software

John Deere, the world's leading producers of agricultural equipment, have opted for an off-the-shelf GA-based software solution to manage production at some of their factories. Their choice, **Evolver** from **Palisade Corporation**, uses genetic algorithms to analyse and find the best solution to complex optimisation problems. For John Deere, Evolver provides an inexpensive alternative to custom shipping software, allowing the company to streamline factory scheduling, balancing an increasing number of manufacturing constraints while maximising production output. Classes of manufacturing constraints considered include: manufacturing hours available, sequencing/spacing, changeovers, parts/components availability, priority to orders (retail and earliest scheduled shipping date) and shipping off the end of the line. Results so far have been good with management staff at John Deere reporting increased efficiency and flexibility in factory scheduling.

Richard Clooke +44 (0) 1752 204310
www.palisade-europe.com

Optimising retail outlet locations

A combination of genetic algorithms and fuzzy logic allows a UK-based pub, bar and restaurant operator to identify the best location for new outlets of its wide range of brands. Having identified the various location and demographic criteria required for each brand, staff at Bass Taverns' strategic planning department use GA-based software developed by **searchspace** to identify hot spots best suited to each brand. While a genetic algorithm uncovers the best potential sites, fuzzy logic widens the range of locations that can be considered. David Turner, the geographical information systems manager at Bass Taverns, reports that the software has made the company's decision making sharper and more comprehensive and has helped it pick up opportunities it had previously been missing.

info@searchspace.co.uk
http://www.searchspace.co.uk/

To contribute a success story, visit the EvoNet website at http://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 20 for our address).

Strategies for the Rea

Professor Hans-Paul Schwefel talks to EvoNews

The physical world is a dirty, noisy place, full of misinformation. It's a place where edges are blurred and one thing shades into another. You can't represent it using a set of nicely rounded digits. The real world is analogue, and if you want to describe it you have to use numbers that match – floating point numbers that are grubby at the edges, the numbers of the real world.

The first attempts to use simulated evolution to optimise a physical object took place at the Technical University of Berlin (TUB). Nowadays Ingo Rechenberg is Professor of Bionics and Evolutionary Engineering at TUB and Hans-Paul Schwefel is Professor of Computer Science at the University of Dortmund, but back in the early 'sixties they were mere student assistants, and the most sophisticated computing aid they could aspire to was a table calculator.

'Ingo Rechenberg and I met at the Institute of Fluid Dynamics TUB,' in 1963,' reports Hans-Paul Schwefel. 'At that time we were both studying aero- and space craft propulsion. Influenced by lectures on cybernetics and bionics, we wanted to create a research robot that could perform successive wind tunnel experiments to find the optimal shape of wings, fuselages and the like.'

The basis of all experimentation is trial and error, but the success of most experimentation relies on the knowledge and intuition of the experimenter. Rechenberg and Schwefel wanted to take the experimenter out of the equation, they wanted to blindfold the watchmaker and automate the process.

To demonstrate the feasibility of their wind tunnel robot, they designed a system of six plane planks linked by five adjustable hinges. It was a model that existed only on paper and in their heads, but it was simple and could supply them with the feedback they needed to road-test a series of optimisation strategies.

'Deterministic variation according to one variable at a time and steepest descent/ascent got stuck prematurely before the known optimum – a flat structure – was found,' reports Schwefel. 'So binomially distributed random changes from the so far best shape were used finally.'

'Why look for GA variants that provide a similar performance... if evolution strategies have already provided such performance for more than twenty years?'

This was the so-called (1+1) Evolution Strategy, based on random mutation and deterministic survival of the fittest.

'Of course we immediately dreamt of more individuals than just one parent and one descendant per generation,' confirms Schwefel. 'But it wasn't experimentally practical. The first computers only became accessible later on.'

During the mid 'sixties the TUB Institute of Fluid Dynamics must have been a veritable ferment of evolutionary activity: while Schwefel conducted computer simulations on a ZUSE Z23 (and revealed the limitations of the two-membered ES), Rechenberg investigated real valued variables and Gaussian mutations, and a third student, Peter Bienert, built an automaton based on the simple rules they had devised. All this, as Schwefel points out, was on top of their normal duties. And it all ended abruptly.

Despite a supportive article in *Das Spiegel* and some rather flattering copycat activity in other engineering institutes, the newly spawned Evolution Strategies met with a sceptical and hostile reception.

'In 1966, a year after we received our diplomas and became scientific co-workers, we were instructed either to devote ourselves solely to research work in fluid dynamics or to leave the Institute,' remembers Schwefel. 'We decided to leave, despite having no prospect for funding or earnings.'

Determined not to let the doors of academia clang permanently shut behind them, they began submitting funding proposals to the DFG (the German Research Foundation). 'Neither of us even had a PhD at the time,' Schwefel recalls, 'and we were completely unaware that only professors could apply for grants.'

In the four years before they were reunited at the Institute of Measurement and Control Technology, Rechenberg gained a PhD and Schwefel worked at the AEG Research Institute, where among other things he used the simple ES to optimise the shape of a supersonic two-phase flashing nozzle. 'The successful result was presented at air fairs in Hanover and Paris,' he reports.

Back in academia once more, Schwefel made use of all the available computer power to write Algol and Fortran routines for real-coded ES – public domain programs that could be turned to civil engineering optimisation tasks. He also extended the technique, adding the so-called 'multimembered' Evolution Strategies, $(\mu+\lambda)$ and (μ,λ)-ES.

It was during this period that he began systematically to collect literature on optimisation techniques. Stumbling first upon the Fogel/Owens/Walsh 1965 research report, then upon the corresponding Wiley book, and finally, in 1977, upon Holland's work, he learnt that research into evolutionary computing was proceeding in

l World

parallel on the far side of the Atlantic. He sent Holland a copy of his dissertation. 'Holland,' he says, 'responded politely, but never mentioned our work in his articles.'

It wasn't until 1991, when Schwefel attended ICGA, that he finally met up with his US counterparts. This fact – that for almost three decades Evolution Strategies developed in geographic and intellectual isolation from mainstream EC research – feeds into the myth that *ergo* Evolution Strategies have been neglected and overlooked. Outside the US mainstream, they may be, but as Schwefel points out, 'Evolution Strategies are the canonical way for real-valued variables,' and in Germany, the European heartland of heavy engineering, they have not been overlooked. Rather, they have been seen as an alternative to rules of thumb and intuition. And they have been applied to any number of continuous parameter problems involving dimension and shape – optimising optical lenses, nuclear reactor cores, reinforced concrete shells, aircraft wings and arm prostheses.

All of which is not to say that Evolution Strategies cannot be applied to discrete optimisation problems. They have, for example, been applied to a range of routing and scheduling problems, from water supply to refuse removal systems.

But aren't Evolution Strategies very complex, over mathematical and inaccessible? After all, the Evolutionary Computation FAQ on the Web describes the approach as 'strong tobacco'. Schwefel disagrees.

'Of course, the self-adaptation of mutability parameters, controlling variances and covariances on-line, is a bit tricky and thus often misunderstood,' he says, but he's keen to stress that 'all evolution strategies and all evolutionary algorithms, including GA and GP, are *very* simple models of organic evolution'.

In addition to their theoretical basis, he believes that Evolution Strategies have added two key ideas to mainstream EC research: self-adaptive internal parameters and real valued variables.

'Why,' he wonders, 'look for GA variants that provide a similar performance to ES, if Evolution Strategies have already provided such performance for more than twenty years?' ■

A Step by Step Guide to Evolution Strategies

2-membered ES

(1+1)–ES This was the first ES, described in 1964 by Ingo Rechenberg. Using only a mutation operator, one parent produces one offspring with the better of the two surviving to become the parent for the next iteration.

Multi-membered ES – 'plus strategies'

With plus strategies both parents and offspring undergo selection. As a result, individuals within a population can be immortal.

(m+1)–ES When multiple (m) parents are introduced it becomes possible to use a recombination operator as well as a mutation operator. All parents have an equal probability of participating in the production of a single offspring and the least fit individual in the new population (parents and offspring) is removed before the next iteration.

(m+l)–ES m parents produce l offspring, with the m fittest of both parents and offspring going forward to the next iteration.

(1+l)–ES One parent produces l offspring, with the fittest of parent and offspring becoming the next parent.

Multi-membered ES – 'comma strategies'

In comma strategies only the offspring undergo selection, with the best m individuals of the l offspring becoming the parents in the next iteration. Just as individual mortality helps populations to adapt in nature, so a comma strategy ES that eliminates successive parent generations can adapt more readily to a changing environment.

(m,l)–ES m parents produce l offspring, of whom m individuals are selected to become the parents in the next iteration.

Mutation

The most common mutation method in ES is to mutate each gene on a chromosome by adding a number from a normal or gaussian distribution with a mean of zero (small changes in values are more likely than large changes). This reflects populations in nature, where gross characteristics such as weight or height generally follow a normal distribution.

1/5 success rule From simple functions and the (1+1)–ES Rechenberg derived the following rule of thumb: if the ratio of successful mutations to all mutations is greater than 1/5 increase the mutation variance (widen your search); if the ratio is less than 1/5 decrease the mutation variance (search more locally).

Self-learning While the 1/5 success rule implies an externally controlled search strategy, in later ESs strategy parameters are incorporated directly onto the chromosome, allowing for self adaptation of the mutation variance, and self-learning. By subjecting the control parameters themselves to mutation, recombination and selection, dynamic or 'online' control becomes possible.

Crossover

In ES this is traditionally regarded as subordinate to mutation. It is non-disruptive, with crossover points always occurring between real number parameters, not within them. Recombination by averaging of gene values is also common.

Selection

Selection for survival is completely deterministic, while selection for reproduction is probabilistic.

EvoWorkshops'99

A single registration fee will allow delegates to attend four state of the art workshops on evolutionary computing this May.

EvoWorkshops'99 brings the expertise of four EvoNet working groups together under one roof. By combining specialist strands within evolutionary computing, the event is able to focus on both practical and theoretical issues, and cater for academics and industrialists alike.

EvoWorkshops'99 will take place on 26–29 May at Göteborg University in Sweden. An exhibition of software demos, product displays and industrial stands will be held concurrently.

26 May **EuroGP'99**: The Second European Workshop on Genetic Programming

27 May **EuroGP'99** (day 2)
EvoEcTel'99: The First European Workshop on Evolutionary Computation in Telecommunications

28 May **EvoRobot'99:** The Second European Workshop on Evolutionary Robotics
EvoIASP'99: The First European Workshop on Evolutionary Computation in Image Analysis and Signal Processing

29 May **EvoRobot'99** (day 2)

EvoEcTel

EvoEctel'99 is the first major international conference devoted to state of the art research on the application of evolutionary computing to the telecommunications industry.

Workshop Chair David Corne believes this is an 'exiting and critically important research and development area.'

'Evolutionary computing is being increasingly used in network design, network management, protocol validation, adaptive distributed databases, call routing, datamining of telecomms databases, and many other problems within the telecoms industry.' He foresees this role increasing as a wealth of new technologies in this domain give rise to new, and very difficult, optimisation and adaptation issues.

EvoEctel'99 provides an opportunity for academic and industrial researchers to present their latest work and discuss current developments and applications. The workshop will consist of an invited talk; oral and poster sessions with periods for discussion; software demos and industrial stands.

David Corne
D.W.Corne@ reading.ac.uk
http://www.cs.reading.ac.uk/cs/research/ectelnet/euroect1.html

EvoIASP'99

Evolutionary algorithms are proving to be effective tools for the automatic design and optimisation of image analysis and signal processing systems.

IASP is a key research area for both academia and industry, with applications in areas as diverse as printing, TV, multimedia, aerial surveillance, noise suppression, quality control, satellite and space imaging, finger print analysis, medical imaging, speech and character recognition.

EvoIASP'99 is the first European event dedicated to the application of evolutionary computing to image analysis and signal processing. The workshop aims to foster collaboration and co-operation, and will provide a forum in which researchers and industrialists can present their latest findings, current developments and applications.

The programme includes: an invited talk by Dana Ballard (co-author of *Computer Vision* and author of *Introduction to Natural Computation*); oral and poster sessions with periods for discussion; software demos and industrial stands.

Stefano Cagnoni
cagnoni@ce.unipr.it
http://www.ce.unipr.it/people/cagnoni/evoiasp99.html

EuroGP'99

Building on the success of EuroGP'98 in Paris last year, EuroGP'99 will be the largest European event dedicated to genetic programming.

Genetic programming (GP) is a new branch of evolutionary computing in which the structures in the population being evolved are computer programs. The technique has been applied successfully to a great many difficult problems, including automatic design, pattern recognition, robotic control, synthesis of neural networks, symbolic regression, music and picture generation.

EuroGP'99 will allow researchers and industrialists to present their latest research and discuss current developments and applications. The workshop will include: a tutorial by the founder of GP, John Koza; an invited talk by David Fogel, Chief Scientist at Natural Selection (where evolutionary programming techniques are used to address complex, real-world problems in industry, medicine, and defence); oral and poster sessions with periods for discussion; software demos and industrial stands.

Riccardo Poli (Program co-chair)
R.Poli@cs.bham.ac.uk
http://www.cs.bham.ac.uk/~rmp/eebic/eurogp99/

For complete information about the workshops, please visit our website:
http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html

Registration Form

How to register

Participants who do not have access to the World Wide Web, should complete the form below.

Registration for the EvoWorkshops allows for attendance at any combination of the four workshops. Please help the organisers by indicating which sessions you expect to attend.

26 May 1999 ❑ EuroGP'99 (day 1)
27 May 1999 ❑ EuroGP'99 (day 2) ❑ EvoEcTel'99
28 May 1999 ❑ EvoRobot'99 (day 1) ❑ EvoIASP'99
29 May 1999 ❑ EvoRobot'99 (day 2)

Your registration fee includes one copy of a workshop proceedings. Please indicate your choice below.

❑ EuroGP ❑ EvoEcTel ❑ EvoIASP

You may also order additional proceedings (at a cost of 20GBP/ 30Euro per copy). Please indicate how many copies are required below.

❑ EuroGP ❑ EvoEcTel ❑ EvoIASP

Coffee breaks are included in the registration fee, but lunches and the social event are not included and can be paid for at the prices listed below (details of the social event together with advice on accommodation options are available at http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html). Please indicate how many lunch and social event tickets you require (prepayment is not necessary for lunches).

I require ❑ lunch tickets at 5GBP/7.5Euro each.
I require ❑ standard tickets for the social event at 20GBP/ 30Euro each.
I require ❑ student tickets for the social event at 10GBP/ 15Euro each.

Please indicate which registration category applies to you.

Payment	*Standard*	*Student*
Before 31/3/99	❑ 100GBP/150Euro	❑ 45GBP/70Euro
Before 25/5/99	❑ 125GBP/190Euro	❑ 60GBP/90Euro
Onsite payment	❑ 150GBP/225Euro/ 2100SEK	❑ 70GBP/105Euro/ 980SEK

Payment can be sent separately as long as the registrant's name is clearly indicated on an accompanying payment advice. Discounts are available if payment is received by 31 March 1999. There are three options for prepayment:

- **a cheque in British Pounds (GBP) drawn from a UK bank account, made payable to Napier University**
- **a cheque in Euros drawn from a Euro bank account, made payable to Napier University**
- **credit card (VISA and MasterCard only).**

Onsite payment is also acceptable in cash (GBP, Euros or Swedish Krona) or by credit card.

To encourage participants to use our online conference registration facilities, we are giving away 3 FREE sets of EvoWorkshop proceedings to 3 randomly selected registrants. To participate, simply use the form available at http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html. When you submit your registration details electronically, your name will automatically go forward to our prize draw. Good luck!

Please fill in your contact details.

Your Title (Dr, Mr, Ms, etc)

First Name

Last Name

Organisation Name

Department Name

Address (please include town, postal code and country)

Fax

Telephone

Email

Please send your registration form and payment to:

✉ **EvoNet Office**
School of Computing
Napier University
219 Colinton Rd
Edinburgh EH10 5PF, UK

Queries can be sent to Jennifer Willies:

💻 **jennifer@dcs.napier.ac.uk**

ICES*98* Conference Report

The Second International Conference on Evolvable Systems took place at Ecole Polytechnique Federale de Lausanne in Switzerland on 24-25 September 1998.

As usual the Japanese under the guiding hand of Tetsuya Higuchi were leading the field in real-world applications. **Kajitani et al.** described their work on the implementation and application of a gate-level evolvable hardware chip with embedded reconfigurable hardware and genetic algorithms. Such a chip makes it possible to build an evolvable hardware unit which is small and light enough to put in a myoelectric artificial hand. **Tanaka et al.** described a data compression system using evolvable hardware for a digital electrophotographic (EP) printer. The authors showed in simulation that the evolvable hardware produced superior compression ratios for EP images than other standard techniques. **Murakawa et al.** showed how one could evolve the configuration of an analogue hardware chip to construct intermediate frequency filters (this could be especially useful in cellular phones). One of the great advantages of this evolvable analogue platform is that it solves the problems associated with off-value analogue components and thus enables one to meet the filter specification.

Paul Layzell won best student paper for a paper entitled 'A New Research Tool for Intrinsic Hardware Evolution'. He has constructed an evolvable motherboard which consists of a programmable array of switches with 'plug-in' daughterboards. The great advantage of this is that the basic components (transistors, resistors, logic gates, etc.) may be plugged in. No connection architecture is imposed and internal signals can be inspected freely. **Adrian Thompson** rightly won best paper for his contribution. Continuing with his work on the intrinsic evolution of circuits using an FPGA, he has built an 'Evolvatron' with which he can evolve circuits on FPGAs under a variety of conditions: silicon batch, temperature, temperature-gradient, circuit position, electronic surroundings, packaging, and power supply. With this apparatus the question of evolving robust circuits can really be investigated. Preliminary results are encouraging. **Zebulum et al.** looked at the extrinsic evolution of an operational amplifier using a string representation. The authors observed that design knowledge is assumed in the use of a simulator and one must thus be very careful when carrying out extrinsic analogue evolution. By actually building the evolved circuits, they showed that, provided these precautions are taken, one can obtain simulated designs which work well in practice.

There were some interesting papers from the US. **Stoica et al.** examined 'Evolvable Hardware for Space Applications'. They looked at intrinsic evolution using a programmable analogue neural network chip and applied it to problems in function learning and robot visuo-motor control. They also described a GP system for lossless image compression. The system was tested on a series of images of the earth and could provide better compression than industry-standard compression algorithms. **Ken Hayworth** described the state-space view of an electronic circuit and how this leads to an alternative view of circuit evolution as a vector field modelling. He has built an analogue computer and evolved a single variable transfer function.

Unfortunately it is not possible within the scope of this report to discuss the contributions in more detail and I should emphasise that my choice of papers to discuss is entirely personal. I found the conference very stimulating and a good place to develop new ideas. The next conference, ICES2000, takes place at Napier University in September 2000. I think it will be very interesting to see how the research is further developed. The field of evolvable hardware is growing and I look forward to new surprises… *watch this space.*

Julian Miller

FOGA-*5* Conference Report

The 1998 Foundations of Genetic Algorithms (FOGA-5) workshop was the fifth biennial meeting in this series of workshops. Unlike the previous meetings, which had always been in the USA in summer, this one was held in Europe and in the autumn. In breaking with this tradition, the support of EvoNet was a strong factor.

One of the strengths of the FOGA format is the emphasis on having a relaxed and pleasant atmosphere where arguments can be developed at the right pace, and where creative discussion and debate can continue (one might almost say 'rage'!) in a sustained and reflective way over the course of the meeting. This needs a special sort of environment, and thanks to Gusz Eiben, we found an ideal venue – a small castle-hotel in Leiden, just 25 miles from Amsterdam.

FOGA was initially conceived as a way of exploring and focusing on theoretical issues relating to genetic algorithms, evolution strategies, and the field of evolutionary computation in general. As well as the 18 papers presented, we had an invited talk from Emile Aarts (of Philips and Eindhoven University), which gave a splendid start to the proceedings.

While we had hoped for more papers from other fields in the evolutionary computation family – genetic programming, for example – most of the 44 papers submitted were about GAs. Following a double-blind reviewing process, 18 papers were selected. They demonstrate clearly that there is a wide variety of different perspectives from which people approach the task of thinking theoretically about GAs.

There were many ways these papers could have been classified, but it was clear that they fell into four main groupings. The first of these had to do with GA dynamics. The second group dealt with genetic operators (most papers considered them in their relationship to schemata). An area of increasing interest over the past five years has been the characterisation of the landscapes over which an algorithm is searching. There were three papers in this group. The final group consisted of studies of the interaction between different parameters or strategies used for controlling the course of a genetic search.

The proceedings will be published in 1999 by Morgan Kaufmann, and anyone interested in foundational questions will find much food for thought. We hope that this workshop will have helped the community, both in Europe and overseas, to further the field of theoretical studies in evolutionary computation. While (as more than one contributor remarked) the question of how GAs work is in general one that still awaits an answer, progress is being made. At any rate, we are having a lot of fun trying to answer it!

Colin Reeves and Wolfgang Banzhaf

Book Review

- ***Genetic Programming: An Introduction***
- **By Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone**
- **Copublished by Morgan Kaufmann Publishers, Inc. and dpunkt.verlag, 1998**
- **ISBN 3-920993-58-6/1-55860-510-X**

This book provides a thorough and wide-ranging review of the automatic induction of computer programs by evolutionary means. Aimed at everyone, from complete novice to professional, it includes a navigation diagram to guide readers from different backgrounds through its twelve chapters with the minimum of wasted reading. This user-friendliness is present throughout: the book is very easy to read and laid out in a logical way.

The opening chapters provide background. The first three consider GP as machine learning and introduce relevant biological, computer science and mathematical ideas. The fourth chapter briefly describes the main flavours of evolutionary algorithm, including GP itself.

The four central chapters of the book contain much of the meat. If you thought that Genetic Programming started and ended with Koza's LISP parse trees, then Chapter 5 is where you get a pleasant surprise: after introducing the terminology and challenges of GP representations, three common representations (tree, linear and graph) are described and GP operations to manipulate them shown. After reading this chapter you are ready to start doing GP yourself.

Chapter 6 gives a solid and balanced treatment of the crossover operator in GP, including suggestions for reducing some of its negative effects. Chapter 7 shows how the variable length representations typical of GP lead to some interesting emergent features including the evolution of large lengths of 'junk DNA' (code which does nothing) as a GP run progresses. It is suggested that these evolve to protect good solutions from the disruptive effects of crossover. Chapter 8 is packed with excellent practical tips on how to use statistics to improve your effectiveness. Subjects covered include significance tests, feature extraction and overfitting. It was disappointing that space was not allowed to give a few worked examples here.

The final third of the book examines representation and operator issues in GP in greater detail and in a more open-ended way. Plenty of practical tips and tricks are supplied and areas where more research needs to be done are pointed out.

I read Chapter 12, Applications of Genetic Programming, first. If you use other evolutionary techniques, but don't think that automatic program induction is of relevance to your application, this chapter may change your mind: 200 pieces of work in robotics, signal processing, data mining, biotechnology, electronics, pattern recognition and several other areas are listed. The thumbnail summaries of 15 of them make fascinating and inspiring reading. If you only buy one book this year make it this one!

Gary Robertson

online

Evolutionary News from the Web

Job-shop scheduling at Volvo plant
Volvo Trucks use a genetic algorithm to schedule work on their assembly line in Dublin, Virginia.
http://207.25.71.22/TECH/science/9802/26/t_t/artificial.intelligence/

GAs for optical character recognition
Silicon Biology's GA-based 'Fermat' system outperforms other OCR programs by a factor of 50% or more.
http://www.wired.com/news/news/technology/story/11154.html

Differential evolution
From a seed population of parameter vectors, differential evolution generates offspring populations by adding the weighted difference between two population vectors to make a third vector. A Java applet demonstrating the technique has been posted on the Web.
http://www.techweb.com/se/directlink.cgi?EET19980511S0047

Optimising water distribution
In the words of one interviewee in this article from Public Works Online, genetic algorithm optimisation is 'by far the most significant advance in distribution system design... in 40 years'.
http://news.publicworks.com/feature-articles/frey.html

GAs optimise flight paths for interplanetary space probes
Researchers at the University of Illinois have devised a genetic algorithm capable of evaluating different mission scenarios.
http://spacer.com/spacecast/news/sotv-98b.html

Immortal Anomalocaris
A team at Kanagawa University in Japan has combined simulation tools and genetic algorithms to evolve the likely swimming stroke of long-extinct creatures.
http://www.newscientist.com/ns/980704/nfossil.html

GAs police the Stock Exchange
The London Stock Exchange has adopted an Intelligent Alerting System based on fuzzy logic and genetic algorithms to help identify illegal transactions by looking for patterns in trading data.
http://www.searchspace.co.uk/company/comput.htm

Siemens launch Ecanse
German Electronics giant Siemens have incorporated an unprecedented range of smart technologies in one development tool.
http://www.techweb.com/se/directlink.cgi?EET19980727S0059

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 bookmarks.

Artificial Intelligence in Medicine: Special issue on evolutionary computation in medicine

Submission deadline: 15 March 1999

Guest Editors: Eytan Ruppin, James A. Reggia and Moshe Sipper

Background

The idea of applying the biological principle of natural evolution to artificial systems, introduced more than four decades ago, has seen impressive growth in the past few years. Usually grouped under the term 'evolutionary algorithms' or 'evolutionary computation', we find the domains of genetic algorithms, evolution strategies, evolutionary programming, and genetic programming.

Central to all these different methodologies is the idea of solving problems by evolving an initially random population of possible solutions, through the application of genetic operators, such that in time increasingly fit (i.e. better) solutions emerge.

Evolutionary algorithms have been successfully applied to numerous problems from different domains, including optimisation, automatic programming, machine learning, and economics. As studies have advanced during the last several years, there has been an increasing interest in adopting them to investigate a wide range of domains in medicine, ranging from the modelling of the immune system to epidemiological studies of disease spread, population genetics and, more generally, as optimisation and classification tools for improved diagnosis and decision-making systems in medicine.

Objectives

The objective of this special issue on evolutionary computation in medicine is to report on the recent studies in this field. The main goal is to increase the AI medical community's awareness of this research. By bringing together a series of evolutionary computation papers we strive to produce a contemporary overview of the kinds of problems and solutions that this growing research field has generated, and to point to promising future avenues of research.

The papers are expected to cover one or more of the following primary themes:

- using evolutionary algorithms to study and model basic questions in medical research
- applications of evolutionary algorithms to medical diagnosis and management, with emphasis on a systematic comparison of the latter with other existing methods
- methodological issues involved in applying evolutionary computation to study problems in medicine, including obtaining sufficient data and normalising it, methods for reducing the search space dimension, choices between different evolutionary computation techniques, and testing and validating the results.

Instructions for authors

Manuscripts should be prepared in accordance with the journal submission guidelines, which are available on request, and may also be retrieved from http://www.elsevier.nl/locate/aimed. The deadline for receipt of full papers is 15 March 1999. Three copies should be sent to:

✉ Eytan Ruppin
Department of Computer Science
School of Mathematics
Tel-Aviv University
Tel-Aviv, Israel, 69978

The Journal of Scheduling

Aims and scope

The Journal of Scheduling provides a global forum for the publication of all forms of scheduling-oriented research. *JOS* covers advances in scheduling research, such as the latest techniques, applications, theoretical issues and novel approaches to problems.

Techniques of interest include evolutionary computation, heuristic search, tabu search, logic programming, mathematical programming, expert systems, and so forth.

Scheduling domains of interest include real-time scheduling, sports scheduling, shop-floor scheduling, machine scheduling, transport scheduling, vehicle routing, employee timetabling, and educational timetabling.

The editors invite you to submit high quality scheduling-related work for publication in this new international, peer reviewed journal. Papers of both a theoretical and applied nature will be considered and prompt reviewing and publication times will be maintained.

Key features

- Incorporates theoretical, experimental and applied research.
- Covers recent computational and algorithmic advances in the field.
- Addresses the industrial need for scheduling.
- Includes surveys of techniques appropriate to particular subsets of problems.

For further information, and submission details, contact:

✉ **Edmund Burke (Editor-in-Chief), University of Nottingham, UK.**
💻 **ekb@cs.nott.ac.uk**
http://www.interscience.wiley.com/jpages/1094-6136/

The Journal of Computational Economics Special issue on evolutionary processes in economics

Submission deadline: 15 Feb 1999

Topics of interest include, but are not limited to:

- evolutionary economics (IO in Schumpeter/Nelson/Winter tradition)
- evolutionary game theory
- evolutionary computation/algorithms
- complex adaptive systems
- (bounded) rationality, learning and adaptive behaviour
- experimental economics.

An essential criterion applied to any paper will be that it has important economic, evolutionary and computational components.

For further information, please contact:

✉ **Nick Vriend, Queen Mary and Westfield College, Dept. Economics, Mile End Road, London, E1 4NS, UK**
💻 **http://www.qmw.ac.uk/~ugte173/**

ECAL99: The 5th European Conference on Artificial Life

13-17 September 1999, Swiss Federal Institute of Technology, Lausanne

Artificial Life is an interdisciplinary research enterprise aimed at understanding life-as-it-is and life-as-it-could-be, and at synthesising lifelike phenomena in chemical, electronic, software, and other artificial media. Artificial Life redefines the concepts of artificial and natural, blurring the borders between traditional disciplines and providing new insights into the origin and principles of life. Artificial Life attempts to answer questions such as: How did biological life originate from inorganic components? What are the main principles that characterise life? What are the rules of interaction between evolution and other self-organising processes? How can we synthesise machines (circuits, robots, software) that have lifelike properties?

ECAL99 will address the following broad areas: self-organisation; chemical origins of life; autocatalytic systems; prebiotic evolution; RNA systems; evolutionary chemistry; fitness landscapes; natural selection; artificial evolution; ecosystem evolution; multicellular development; natural and artificial morphogenesis; learning and development; bio-morphic and neuro-morphic engineering; artificial worlds; simulation tools; artificial organisms; synthetic actors; artificial (virtual and robotic) humanoids; intelligent autonomous robots; evolutionary robotics; applications of Alife technologies; life detectors; self-repairing hardware; evolvable hardware; emergent collective behaviours; swarm intelligence; evolution of social behaviour; evolution of communication; epistemology; artificial life and art.

Call for papers

Accepted contributions will be published in the proceedings by Springer Verlag. All submissions will be reviewed by at least two referees. Overriding criteria will be: novelty, soundness, and clarity of presentation. Contributions will be presented during a single-track session as oral presentations, spotlight presentations (short talk + poster), or posters. ***The deadline for submissions is 28 February 1999.***

Call for debates, demos and other events

ECAL99 will also host invited talks, thematic debates and public demonstrations. If you wish to organise one of these events or have other ideas, please contact Dario Floreano (Dario.Floreano@epfl.ch) before 31 May 1999.

Debates will centre around a hot topic introduced by the debate chairman, who will post a synopsis of the topic to be discussed on the ECAL website and will invite panellists to participate. Invited panellists will add their view on the topic and open the discussion to all participants. Prospective debate chairmen should submit a short abstract and a list of potential panellists.

If you wish to organise a **demonstration** with, for example, robots, computers or chemicals, please submit a short proposal describing your demo and clearly stating your requirements (please indicate if it is a commercial exhibition).

If you have any ideas for additional events, please contact the conference organisers as soon as possible.

✉ ECAL99 Secretariat, LAMI-DI-EPFL, CH-1015 Lausanne, Switzerland
💻 ecal99@epfl.ch
http://www.epfl.ch/ecal99

Announcing the Second EvoNet Summer School Theoretical Aspects of Evolutionary Computing

1–7 September 1999, University of Antwerp, Antwerp, Belgium

The Second EvoNet Summer School will consist of a workshop followed by a two-day lecture programme.

The workshop (1–7 September)
The workshop is aimed at researchers doing theoretical work in the field of evolutionary computing. It will be held in a very informal atmosphere to encourage the sharing of ideas and promote future collaboration.

Participants are invited to submit a working paper. This need not be a completed body of work; instead it is intended to stimulate discussion and ideas. Participants will present their working paper at the workshop. Also attending the workshop will be four invited speakers from a variety of related fields, such as population genetics, statistics and statistical physics.

Deadline for submission of working papers: 15 April 1999

Contact and further information
✉ Bart Naudts, Department of Mathematics and Computer Science, University of Antwerp, RUCA, Groenenborgerlaan 171, B-2020 Antwerpen
☎ +32 3 218 0405 (voice)
+32 3 218 0204 (fax)
💻 bnaudts@ruca.ua.ac.be
http://islab.ruca.ua.ac.be/summerschool

Provisional lecture programme (6–7 September)
Invited speakers and selected workshop attendees will present a broad overview of current theoretical techniques and results in the field of evolutionary computing.

Monday
- Introduction to evolutionary computing
- Algorithms and ad-hoc theoretical techniques
- Statistical physics approach
- Short lectures by workshop participants

Tuesday
- Markov chain approach
- Short lectures by workshop participants

Topics for short lectures include:
- predictive measures of problem difficulty
- analysis of genetic operators
- fitness landscape modifications
- practical relevance of EC-theory.

The summer school is organised by EvoNet, and also sponsored by the Foundation for European Evolutionary Computation Conferences, Leiden Institute of Advanced Computer Science, and the Doctoral Study Programme Science-Pharmacy of the University of Antwerp.

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

17–19 February 1999

CIMCA'99: International Conference on Computational Intelligence for Modelling, Control and Automation, Vienna, Austria

Contact
cimca99@fcit.monash.edu.au
http://www-gscit.fcit.monash.edu.au/conferences/cimca99/

25–26 February 1999

CP-AI-OR 99: Workshop on Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimisation Problems, University of Ferrara, Italy

Contact
cp-ai-or99@deis.unibo.it
http://www.deis.unibo.it/Events/cp-ai-or99.html

12–14 April 1999

IMEM 99: Special Track on Applications of Evolutionary Computation in Environmental and Ecological Modelling, at the International Marine Environmental Modelling Conference, Lillehammer, Norway

Contact
http://www.sintef.no/units/chem/environment/sem99-web/mainpage.htm

19 April 1999

Optimise IT: Natural Strategies for Industrial Optimisation, Amsterdam

Contact
http://www.dcs.napier.ac.uk/evonet/Coordinator/html/optimise_it_99.html

EVONET EVENT

19–21 April 1999

PAAM99: The Fourth International Conference and Exhibition on The Practical Application of Intelligent Agents and Multi-Agent Technology, London, UK

Contact
http://www.practical-applications.co.uk/PAAM99

26–27 May 1999

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

EVONET EVENT

Contact
R.Poli@bham.ac.uk
http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html

27 May 1999

EvoECTel'99: European Workshop on Evolutionary Computing and Telecommunications, Göteborg, Sweden

Contact
ectel-chair@dcs.napier.ac.uk
http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html

EVONET EVENT

28 May 1999

EvoIASP'99: European Workshop on Evolutionary Image and Signal Processing, Göteborg, Sweden

EVONET EVENT

Contact
evoiasp-chair@dcs.napier.ac.uk
http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html

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

23–25 June 1999

TAINN'99: The Eighth Turkish Symposium on Artificial Intelligence and Neural Networks, Istanbul, Turkey

Deadline: 1 February 1999

Contact
http://www.cmpe.boun.edu.tr/~tainn99/

1–2 July 1999

Soft Computing'99: Workshop on Recent Advances in Soft Computing, De Montfort University, Leicester, UK

Deadline for abstracts: 31 January 1999

Contact
rij@dmu.ac.uk
http://www.cms.dmu.ac.uk/~rij/rasc99cfp.html

3–6 August 1999

11th Mini-EURO Conference on Artificial Intelligence in Transportation Systems and Science, Espoo, Finland

Contact
jarkko.niittymaki@hut.fi
http://www.hut.fi/Units/Transportation/EURO99.html

9–11 August 1999

IDA'99: International Symposium on Intelligent Data Analysis, Amsterdam, The Netherlands

Deadline: 1 February 1999

Contact
ida99@wi.leidenuniv.nl
http://www.wi.leidenuniv.nl/~ida99/

31 August–3 September 1999

ECC: European Control Conference, Karlsruhe, Germany

Contact
p.m.frank@uni-duisburg.de
http://ecc99.uni-duisburg.de/

22–24 March 1999

SIGOPT (DMV): International Conference on Optimisation, University of Trier, Germany

Deadline for abstracts: 31 January 1999

Contact
sigopt99@uni-trier.de
http://sigopt99.uni-trier.de

6–9 April 1999

ICANNGA'99: Fourth International Conference on Artificial Neural Networks and Genetic Algorithms, Portoroz, Slovenia

Contact
icannga@fri.uni-lj.si
http://cherry.fri.uni-lj.si/icannga99.html

6–9 April 1999

AISB Symposium on Creative Evolutionary Systems, Edinburgh, UK

Contact
P.Bentley@cs.ucl.ac.uk
http://www.cs.reading.ac.uk/cs/research/ces/index.html

3–5 May 1999

FLAIRS'99: 12th Annual Florida Artificial Intelligence International Research Symposium Special Track on Evolutionary Computation, Orlando, Florida, USA

Contact
matt@cse.fau.edu
http://erau.db.erau.edu/~towhid/flairs99.html

25–27 May 1999

Fuzzy Days 6: International Conference on Computational Intelligence, Dortmund, Germany

Contact
fd6@ls1.cs.uni-dortmund.de
http://ls1-www.informatik.uni-dortmund.de/fd6/

25–28 May 1999

Eurofuse-SIC'99: Joint Eurofuse-SIC99 Conference on Soft and Intelligent Computing, Budapest, Hungary

Contact
trivent@mail.elender.hu
http://www.elender.hu/~trivent/sic_euro.html

28–29 May 1999

EvoRobot'99: Second European Workshop on Evolutionary Robotics, Göteborg, Sweden

Contact
evorob-chair@dcs.napier.ac.uk
http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html

EVONET EVENT

31 May–3 June 1999

IEA/AIE'99: 12th International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Cairo, Egypt

Contact
ma04@swt.edu
http://mason.gmu.edu/~iimam/ieaaie99/ieaaie99.html

1–4 June 1999

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

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

6–9 July 1999

CEC'99: Congress on Evolutionary Computation, Washington DC, USA

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

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14–17 July 1999

GECCO'99: Genetic and Evolutionary Computation Conference, Orlando, Florida, USA

Contact
deg@uiuc.edu
http://www-illigal.ge.uiuc.edu/gecco/

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31 July–2 August 1999

CIA'99: Cooperative Information Agents, Uppsala/Stockholm, Sweden

Deadline: 5 March 1999

Contact
onn@cs.cmu.edu
http://www.informatik.tu-chemnitz.de/~klusch/cia99.html

1–3 September 1999

SOR'99: Symposium on Operations Research, Magdeburg, Germany

Contact
SOR99@ww.uni-magdeburg.de
http://www.uni-magdeburg.de/SOR99/eng/index.html

13–17 September 1999

ECAL'99: 5th European Conference on Artificial Life, Lausanne, Switzerland

Deadline: 28 February 1999

Contact
ecal99@eplf.ch
http://www.epfl.ch/ecal99/

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13–15 September 2000

ICES 2000: Third International Conference on Evolvable Systems: From Biology to Hardware, Edinburgh, UK

Contact
j.miller@dcs.napier.ac.uk
http://www.dcs.napier.ac.uk/evol/ices2000.htm

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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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