EvoNews

Newsletter of EvoNet – The Network of Excellence in Evolutionary Computing

http://www.dcs.napier.ac.uk/evonet/ Issue 10, Spring 1999

EvoWorkshops

On 26-29 May EvoWorkshops'99 will present the very latest theoretical and applied research in four key areas of evolutionary computing.

Held in the superbly restored Main Aula of Göteborg University, in Sweden, the event promises to be more than the sum of its parts, offering the benefits of diversity while honing in on specialist areas of concern. For a single registration fee, delegates will be able to attend Europe's largest conference dedicated to genetic programming and three workshops reviewing the current state of the art of evolutionary computing in robotics, telecommunications, and image analysis and signal processing.

Genetic programming

EuroGP'99 builds on the success of last year's conference in Paris, providing a forum in which to discuss the latest genetic programming research developments and applications. The programme includes a tutorial by the founder of GP, John Koza; an invited talk by David Fogel, Chief Scientist with the US-based Natural Selection Inc.; and a tantalising array of accepted papers and posters (titles are available at http://www.cs.bham.ac,uk/-rmp/eebic/eurogp99).

Image analysis and signal processing

EvoIASP'99 is the first European event dedicated to the application of evolutionary computing to image analysis and signal processing – a key research area with applications in domains 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.

The workshop programme includes an invited talk by Dana Ballard (co-author of *Computer Vision*) and oral and poster presentations (titles are available at http://www.ce.unipr:it/people/cagnoni/evoiasp99.html).

Telecommunications

As the unprecedented growth of the telecommunications industry spawns new and increasingly difficult optimisation and adaptation problems, so the role of evolutionary computing in this domain is set to increase.

EuroEctel'99 is the first major international conference devoted to this critically important research and development area. The event will consist of an invited talk, oral and poster sessions with periods for discussion, and software demos and industrial stands.

'We are very pleased at the number of early bookings for EvoWorkshops'99,' comments EvoNet administrator Jennifer Willies. 'We're looking forward to a large audience at Göteborg, with a lot of discussion. The event draws four distinct research communities together, but there are many areas where the concerns of one group intersect with another and those are often the areas where the most productive ideas and collaborations are sparked.'

The standard registration fee for EvoWorkshops'99 is £125 (190 Euro); the student registration fee is £60 (90 Euro) and a limited number of student travel bursaries are also available (see page 3 of this issue of *EvoNews* for details).

To register online for EvoWorkshops'99, please use the form available at http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evoworkshops_99.html

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Attar Software

From its base in Lancashire in the North of England, Attar Software undertakes consultancy projects to build KBS applications for organisations across Europe, the USA, Canada and Japan. The company's expertise lies in knowledge engineering, data mining and in embedding these technologies into mainstream data processing applications.

In 1988 Attar Software launched its Knowledge Based System XpertRule® KBS, a DOS based product that was superseded two years later by a completely new Windows version. There are currently over 2,000 commercial users of Attar Knowledge Based Systems worldwide, not to mention numerous users of run-time KBS applications delivered using XpertRule, and upwards of 100 universities that have purchased XpertRule.

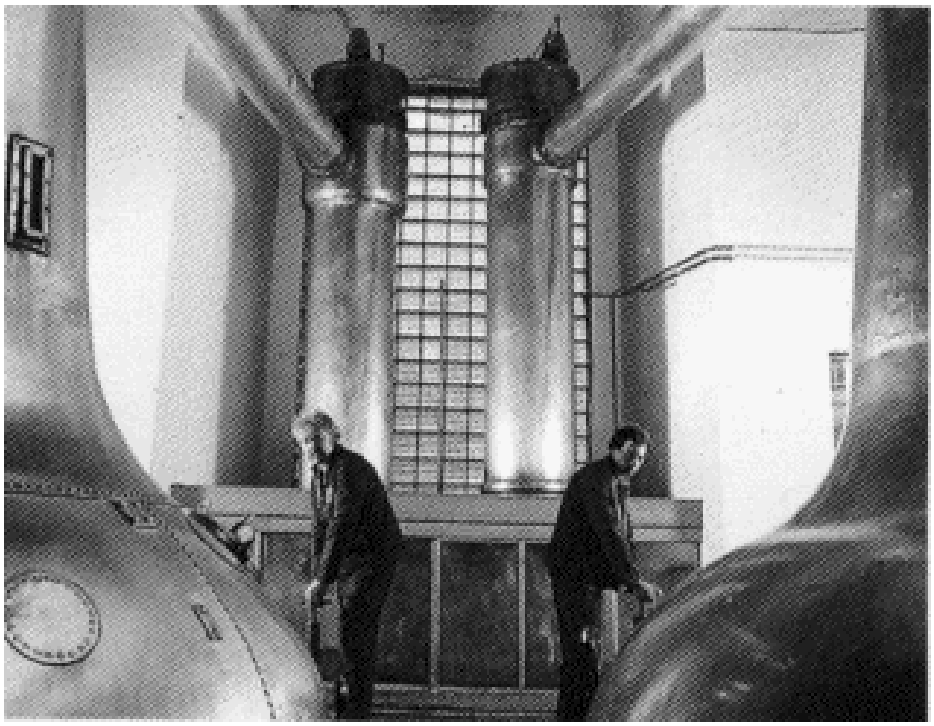
'While it's true to say that genetic algorithms are just part of our business, they are not a small part,' comments David Isherwood, one of the company's directors. Although many projects cannot be publicised due to client confidentiality, he is able to point to two examples from the early 'nineties where Attar developed major GA based systems that are still very much in use today.

Whisky production

In 1993 the company developed a GA-based application that would dramatically improve the operational efficiency of the world's largest whisky producer.

United Distillers produces some 60 blended whisky brands, including Bell's, Dewar's White Label and Johnnie Walker Black Label. 'Each week, 20,000 casks are moved in and out of our 49 warehouses throughout Scotland to provide the whisky needed for the blending programme,' explains Christine Wright, Inventory and Supply Manager at United Distillers.

Some idea of the scale of the problem can be gauged from United Distillers' Blackgrange site, which alone houses around 3 million casks. Operating on a large Digital VAX, the warehouse administration system and an associated bar-coding scheme provided details of the site and exact position of the whisky stock within each warehouse. In practice, however, 50% of the casks that were being moved were not required. They were simply being shifted out of the way to allow access to those identified by the selection process. With casks ranging from 200 litre barrels to 500 litre butts, it is not surprising that this wasted effort caused friction between the warehouses and staff working at Distillers House in Edinburgh.



Roll out the barrel – GA-based software has almost doubled cask handling rates at United Distillers.

The challenge, for Attar Software, was to develop an automated blend and cask selection system that would streamline warehouse operations.

The company responded by developing a Windows-based system operating XpertRule. Information held on the VAX about recipes, site constraints and the blending programme is passed to the XpertRule system, which works out the best combinations of stocks to produce the blends. This information is supplemented with positional information about the casks from the VAX. The system then optimises the selection of required casks, keeping to a minimum the number of warehouse sections from which the casks must be taken and the number of casks which need to be moved to clear the way. Other constraints to be satisfied include the current working capacity of each warehouse and any maintenance and restocking work that may be in progress. The whole process takes around 24 hours to run, normally starting on Friday and providing the complete weekly schedule back to the VAX for Monday morning.

Commercial benefits

United Distillers has seen significant commercial benefits since the system was delivered towards the end of 1994, as Commercial Director (Operations) Turnbull Hutton points out: 'The incidence of non-productive cask movements has plummeted from a high of around 50% to a negligible level of around 4%, and our cask handling rates have almost doubled.'

Not surprisingly, the system has improved relationships between Distillers House and warehouse staff.

'Not only does the lack of wasted effort allow warehouse staff to get on with their work, but it enables them to plan ahead and organise longterm maintenance programmes.

It encourages a mindset that is strategic, rather than reactive, and empowers managers to manage their own sites,' say Christine Wright.

Five full-time staff used to be employed at Distillers House to handle the blend selection. 'It was a boring and repetitive process,' says Christine Wright. 'The actual process of blend selection now involves only a few keystrokes and three hours of one person's time. The other staff can therefore be involved in more interesting work. Realistically, it is wholly impractical for people to do what the XpertRule system now achieves.'

Commercial breaks

Genetic algorithms featured in the solution to another complex logistical problem, when Attar Software was asked to develop an automatic break sequencing system to schedule advertisements for a television company.

Since January 1993, Channel 4 has been a statutory corporation dependent on advertising for 96% of its revenue and responsible for selling its own airtime. The corporation provides advertisers with access to a UK network of all the ITV regions, booked from a single point. At the same time, regional advertisers can choose to buy Channel 4's six 'macro-regions' (which correspond with the existing ITV regions) separately. The combination of two to five regions is known as a 'supermacro' and allows advertisers considerable flexibility in placing advertising copy.

In fact, around 40% of advertising is sold regionally, half of which is made up of supermacros. On top of this, advertisers can specify that their commercials are placed first in the break, last in the break or 'top and tail' within the break.

'Advertisers are buying audience, not airtime,' comments Stephen Ottner, Systems Manager at Channel 4. 'It is a complex trading commodity.' Selling of this volatile medium is only closed off half a day in advance of transmission time – at which point the breaks must be sequenced. Where once this task was performed manually, nowadays a flat file from the mainframe-based airtime sales system passes an unordered list of spots in the break to the XpertRule Break Sequencer which uses a genetic algorithm to ensure that all constraints are met before the ordered information is passed back.

The result is a reduction both in the number of errors made and in staffing requirements. 'Two or three people used to be wholly committed to sequencing work, whereas now it only requires one or two,' says Ottner. 'This is an important motivation since the work is now manageable with the number of people available – they are not working just above the waterline.'

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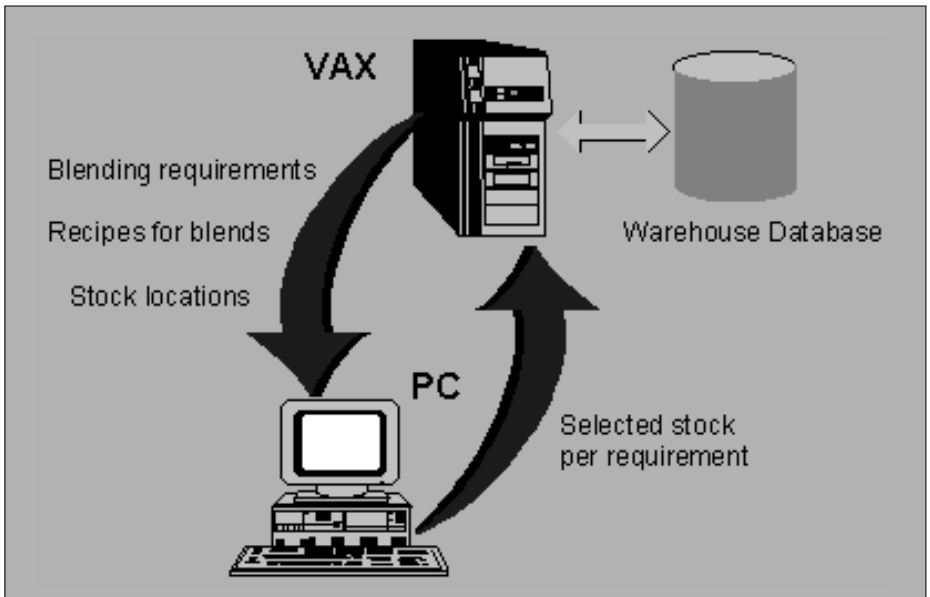

'Realistically it is wholly impractical for people to do what the XpertRule system now achieves.'

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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Genetica

Genetica - Advanced Software Architectures s.r.l. is a Milan-based software house that specialises in developing innovative solutions for Operations Research, complementing traditional methodologies with soft computing techniques in areas such as finance, business, planning, transportation, system modelling and control, scheduling and time-tabling.

Soft computing differs from conventional techniques (hard computing) in that it tolerates imprecision, uncertainty and partial truth. Its guiding principle is to exploit this tolerance to achieve tractability, robustness and a reduction of the computational resources required to solve a given problem. Also known as computational intelligence, soft computing relies on the integration of three techniques that have been used separately for several years: fuzzy logic, neural networks and evolutionary algorithms. However, rather than simply combining these three ingredients, soft computing is a discipline wherein each methodology complements the others by targeting appropriate aspects of the problem.

Given its base in the economic heart of Italy, Genetica has developed some expertise in applying soft computing methods to problems in banking and finance. On the banking side, the company is involved in the design and implementation of the GAMUT system, a financial modelling tool which uses a combination of evolutionary algorithms and fuzzy logic to predict customer behaviour.

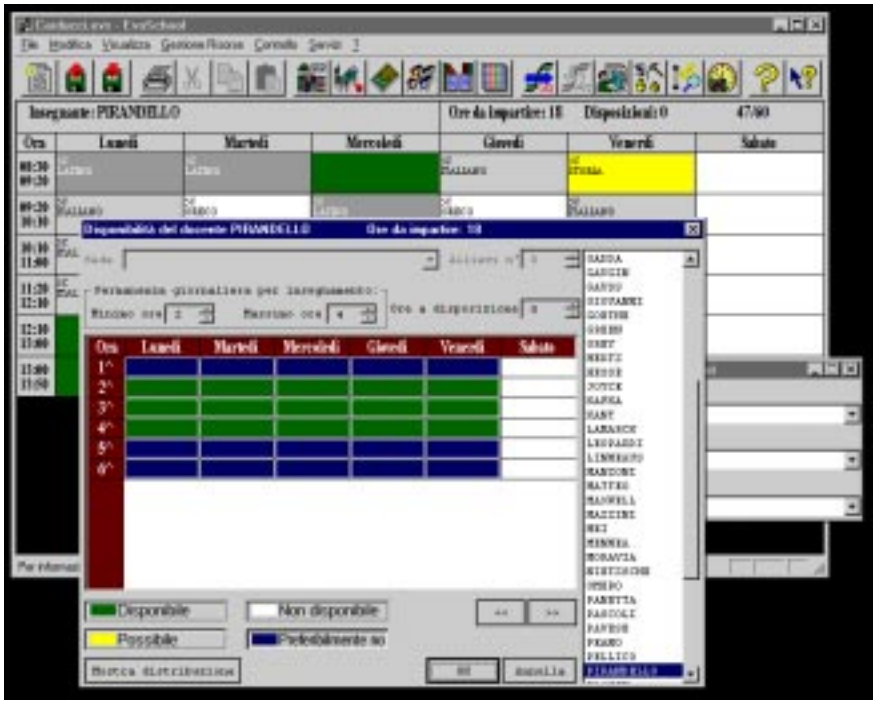
When a new customer asks for credit (for example, a credit card, or a loan to buy a house) banks face a critical decision: of course banks make profits by lending money, so they have an interest in accepting new customers; however, if the customer subsequently fails to repay the loan or repays it with a delay, the banks' profit will be eroded. To safeguard against this, banks use the vast stores of data that they maintain about their customers – data from customer credit applications and data about subsequent customer behaviour – to build a predictive model against which new customers can be evaluated. The more accurate the model, the less risk of making a mistake. Genetica's GAMUT system evolves fuzzy-rule-based models of customer behaviour to best fit the records. Because the models are expressed via linguistic rules, they can be read and understood by human decision-makers – a major advantage, this, as bankers are unlikely to give or refuse a loan solely on the advice of a black box.

On the finance side, Genetica has developed a powerful and versatile evolutionary optimisation engine for advanced multi-period asset allocation on behalf of a prominent Italian bank. The recent upsurge of interest in mutual funds and private pension plans in Italy has fuelled demand for more and more sophisticated, flexible and tailored investment products.

Institutional investors have to manage a complex cash-flow structure, and while they want to maximise returns, at the same time they must guarantee their invested wealth to meet liabilities over time. Given that the traditional asset allocation framework is limited to a one-period investment horizon, it is not adequate to model this problem. A better alternative is to adopt a dynamic approach that integrates asset and liability decisions over time, taking into account the random nature of asset returns.

Asset allocation then becomes a multi-period optimisation problem. The goal is a sequence of portfolios that maximises the probability of achieving *over time* a given set of financial objectives. The portfolio sequences are evaluated against a probabilistic representation of the future performance of a number of asset classes, the opportunity set for investment. In turn, the joint distribution of future performances of the opportunity set may be estimated using econometric forecasting methodologies.

As a result, portfolio construction can become a very complicated problem as regulatory constraints, individual investor's requirements, non-trivial indices of risk and subjective quality measures are taken into account, together



The Italian school system is subject to constant change, and consequently new constraints are continually being added to the time-tabling problem.

with multiple investment horizons, cash-flow planning and forecasting techniques based on refined econometric models. However, Genetica has successfully solved the problem by using a sampling technique to build a tree of possible scenarios for the future from a set of predictions, and an evolutionary algorithm to optimise an investment plan against the desired criteria and the possible scenarios.

The company's business is not limited to banking and finance, however. After more than three years of painstaking research, Genetica recently released its first retail product, EvoSchool. This is a software package for the automated scheduling of teaching events such as lectures. Although it was designed and developed for the Italian secondary school system, its flexibility makes it suitable for the time-tabling needs of any learning institution.

The program's main innovation is the way in which it approaches the school time-tabling problem. Unlike many traditional methods, the evolutionary algorithm within EvoSchool has made it possible to achieve surprising results.

There are several reasons why Genetica chose to integrate an evolutionary algorithm in EvoSchool. Firstly, the nature of the problem suggested an evolutionary solution. The Italian school system is subject to constant change, and consequently new constraints are continually being added to the time-tabling problem. Because evolutionary algorithms allow the easy insertion and removal of optimisation criteria and constraints, they ensure design robustness to every innovation in teaching requirements.

Secondly, these optimisation criteria and constraints are fully visible to the user, who thus has complete control of the resolution process. EvoSchool offers flexibility both in the constraint programming phase and during algorithm execution, allowing the user to control and interact with the algorithm at all stages.

Programmed time-table production and a detailed diagnosis of the planning state are among the central aspects of EvoSchool. These facilities enable the user to divide problems into smaller sub-problems and to take an active part at runtime, for example by locking one part of a time-table and letting the algorithm resolve the rest of it.

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EVOWORKSHOP TRAVEL BURSARIES AVAILABLE!

A limited number of travel bursaries are available to cover travel expenses to the EvoWorkshops in Göteborg, Sweden on 26-29 May 1999. Each award is worth up to 500 Euros, and will be paid retrospectively after original travel tickets, receipts and a short article for *EvoNews* have been submitted to the EvoNet Administrator. The deadline for applications is 14 May.

To apply you must be:

- **a registered doctoral student at an EvoNet node (you can check this by visiting http://www.dcs.napier.ac.uk/evonet/Coordinator/html/evonet_nodes. html)**
- **prepared to write a 300-400 word review of one of the workshop sessions for *EvoNews*.**

If you would like to apply, please send the following information to the EvoNet Administrator (jennifer@ dcs.napier.ac.uk):

1. **your full name, email, telephone and fax numbers**
2. **your university name and address**
3. **your supervisor's name and email address**
4. **one or two paragraphs outlining why you think you will benefit from attending the EvoWorkshops, including reference to how it would assist your research**
5. **your attendance preferences for the workshop sessions.**

Those applications that put forward the strongest arguments for attendance will be awarded travel bursaries. The judges' decision will be final.

Optimising the Outback

DAVID MAYER reports from Australia

It is often said that 'Australia rides on a sheep's back' – a reference to our heavy dependence on agricultural products. The sheer scale of farming operations here (in central and northern regions the average size of beef properties is 370,000 hectares) makes management and planning difficult. However, evolutionary algorithms are starting to provide a useful tool for producers and policy makers alike.

At first glance, a farm seems very different to the usual targets of operations research techniques, such as engineering works. However, the principles are similar – the farmer generally wants to maximise some economic measure (usually the farm's gross profit margin), given the range of prices for different types of farm produce, costs of the available managerial inputs, and also subject to various practical constraints on operations. For example, the seemingly simple task of managing a milking herd over time contains a multitude of possibilities, covering breeds used, herd size and structure, reproductive options, culling policies and herd genetic improvement, calving patterns, areas of different pasture and forage species, fertiliser and irrigation rates to each, supplementary feeds (type, amount and timing) and veterinary health practices. These must all be managed efficiently in an uncertain and changing environment, with weather, pest and disease levels, and market forces changing from year to year. Similarly, other farming systems, such as horticulture or intensive livestock rearing, each have particular features, which must be altered as necessary to maximise the farm's profitability.

As each farm is unique, there is no opportunity to have 'replicates'; nor is it feasible to carry out experimental work over a number of years. Hence, most investigations use simulation models of these agricultural systems. Once validated against the real world, the model can be integrated with the optimisation routine to rapidly identify the likely optimal management regime. One annoying feature of these agricultural models is the frequent existence of multiple optima – combinations of management options which are markedly different, yet result in similar economic outcomes. For example, a 'low inputs and low production level' strategy may have a similar bottomline profitability to 'maximal inputs and high production levels'.

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'Evolutionary algorithms appear to offer the only realistic method of screening the vast range of agricultural strategies to determine the likely best, which can then be implemented into policy decisions.'

Back in the early 1980s, when agricultural systems models started becoming available for optimisation, computing power was limited – and expensive. The most we could afford for each farm set-up was a couple of hundred individual model trials. Hill-climbing routines generally converged within this limit, but tended to give widely different answers, as they mostly converged to local optima which were well short of the system's global optimum. The Nelder-Mead simplex algorithm proved more reliable, but was still prone to this problem.

Over the past two decades, a range of optimisation methods have been trialed on these systems, and most discarded. During this time the target models have increased greatly in complexity. Whereas initially we were looking at farms with only 12 independent management options (that is, we were searching a 12-dimensional sample-space), more recent problems go up to 40, and we will soon be considering models with hundreds of input options. Faced with increasingly complex problems, simulated annealing performed quite well for a time, proving very reliable in finding the global optimum. However, given the basis of the algorithm, this method was consistently slow and, as problem sizes increased, the time requirement became prohibitive – one run had not converged after five weeks of computing time on a Sun workstation. Even at this point, its solution was still well short of that given by an evolutionary algorithm, which took only a few days to find the optimal combination.

Tabu (or taboo) search was also trialed on these models. Despite documented success in other operations research areas such as scheduling, it was not well suited to agricultural systems, as most farming options are on a continuous scale. The required dimensionality and level of discreteness tended to defeat the tabu search method, as excessively long tabu lists had to be maintained for it to work. This overhead slowed the search to such an extent that our imple-

mentation actually took longer than simulated annealing.

Early successes were achieved using a binary-coded genetic algorithm, GENESIS. Whilst occasionally converging to a local optimum, it represented a good compromise between reliability and speed on smaller and moderately sized problems. In particular, with the more complex problems it was the only method which gave acceptable solutions in realistic computing timeframes.

More recently, we have branched out and tried alternative evolutionary algorithms, such as real-value genetic algorithms and evolution strategies (both available in Genial, a general package posted on the web at http://hjem.get2net.dk/widell/genial.htm). These methods are not constrained by the requirement to map continuous options onto binary genes, and have a range of internal operations to improve performance. On the moderate sized problems we are currently researching, we have found that all evolutionary algorithms (the binary and real-value genetic algorithms, and evolution strategy) perform approximately equally. They all find the global optimum of the tested systems, although the rates of convergence tend to vary a bit. However, all are notably superior to the other optimisation methods we have tried.

Provided we survive the year-2000 bug, the next 12 months should be very interesting. We hope to extend our models from the farm-level to whole-region, and then whole-state, and at the same time expand our timeframe to multi-years. This will allow us to look at strategies for going into, and coming out of, longterm events such as droughts or changing markets. Evolutionary algorithms appear to offer the only realistic method of screening the vast range of agricultural strategies to determine the likely best, which can then be implemented into policy decisions. At the same time, these methods will also be used at farm-level, so producers can 'fine-tune' their particular operations.

The project collaborators are John Belward, Kevin Burrage, Henrik Widell and David Mayer. For more information, please contact:

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Book review

- ***Evolutionary Design by Computers***
- **Edited by Peter Bentley**
- **Morgan Kaufmann Publishers Inc.**
- **ISBN 1-55860-605-X**

Evolutionary Design By Computers **is an edited collection of chapters by leading figures in all aspects of design using evolutionary algorithms. The book has an enormously broad scope in that it covers engineering design, evolutionary art, evolutionary artificial life forms and creative evolutionary design.**

The book begins with a short foreword by Richard Dawkins. This was especially appropriate as it became clear on reading later chapters on evolutionary art and design that Dawkins' Biomorphs program (which is available on the accompanying CD) and his book *The Blind Watchmaker* were very influential in stimulating the art and design community to try using evolutionary algorithms.

The first chapter is an enormous and very detailed exposition of evolutionary algorithms and design by Peter Bentley. I am sure that this will be especially helpful to researchers new to the field of evolutionary design as it provides many detailed examples of genotypes and corresponding phenotypes for a wide range of design problems. It also gives a very complete list of references to published work.

In a book of edited chapters there is always a danger than the style might vary considerably from chapter to chapter and that some parts might be accessible to the lay reader and others only to the specialist. I felt that the majority of chapters were very clearly and not over technical. However there were also some chapters which would have been more at home in specialist research publications.

Several of the chapters were prepared or written directly by the editor using material supplied by the authors, namely 'The Mutation and Growth of Art by Computers' by Stephen Todd and William Latham, and 'Evolving Three-Dimensional Morphology and Behaviour' by Karl Sims. I found these chapters to be particularly good as indeed was the final chapter, 'From Coffee Tables to Hospitals: Generic Evolutionary Design' which described some of the editor's own research.

The book is accompanied by a CD-ROM which includes source code libraries, galleries of genetic art, evolutionary music, demos, and other relevant material. I have the benefit of having seen part of a video which shows Sims' cuboid 'life forms' fighting for possession of a trophy. It was very impressive and lifelike, and I think the CD-ROM would have been even better had some excerpts of the video been included.

In the proof copy of the book that I was given to review many of the figures were of poor quality and indeed many were missing. I know that in the published book the quality will be much higher and I think that the book will be something of a feast for the eye with the inclusion of many colour plates.

As someone who also uses evolutionary algorithms to design things (albeit digital logic circuits) I was especially interested in the final section of the book on creative evolutionary design. I feel that it is just a matter of time before computers running evolutionary algorithms will help us to discover new design principles.

Evolutionary Design by Computers **and its accompanying CD are likely to stimulate a great deal of interest in the creative uses of evolutionary algorithms. It provides a very good place to start for many prospective new researchers. I look forward to future developments.**

Julian Miller

From Tank to Tap

– designing and optimising water distribution systems

Water distribution systems use interconnected elements such as pipes, pumps and service reservoirs to convey treated water from one or more sources to customers spread over a wide area. Given that capital costs and ongoing maintenance and repair costs of these systems are often enormous, the need for more economic and efficient designs is pressing. DRAGAN SAVIC reports on a successful Canadian case study.

All engineers like to think that they produce good, safe designs that are operationally efficient and cost effective. However, it is rare for a designer to have the time to consider more than a handful of solutions to a problem. In the planning phase of a project there are often many alternatives to each individual component of a scheme. The number of different designs for a complete scheme can thus be extremely large, if not infinite. Even with detailed design, there are usually far too many possibilities for each to be considered and evaluated.

Design of water distribution networks is often viewed as a least-cost optimisation problem with pipe diameters being the decision variables. Pipe layout, connectivity and imposed minimum head constraints at pipe junctions (nodes) are considered known. Other elements (such as service reservoirs and pumps) and additional objectives (such as reliability, redundancy and water quality) can be included in the optimisation process. However, the problem of including additional elements, and of quantifying additional objectives for use within the optimisation process, means that researchers tend to concentrate on pipe diameters and the single objective of least cost. Even this somewhat restricted formulation of optimal network design represents a difficult problem to solve.

The optimisation problem is a non-linear, discrete combinatorial optimisation problem. In order to solve this NP-hard problem exactly it is suggested that only explicit enumeration or an implicit enumeration technique such as Dynamic Programming can guarantee the optimal solution. However, optimal pipe-network design problems of realistic size become intractable to enumeration techniques. In practice, of course, experienced design engineers will adopt rules of thumb and personal experience to avoid analysing every possible configuration. This allows them to focus on schemes that are reasonably cost-effective. With the aid of a hydraulic network solver, the designer adopts a trial and error approach to produce a few feasible solutions (networks that satisfy minimum head constraints) which can then be priced. On large, complex problems, finding just one feasible solution may take considerable effort, and it is clearly impossible to explore a wide range of alternatives using this manual technique.

Case study

Demographic projections for the Regional Municipality of York, in Ontario, Canada, predict that the population will double during the period 1996-2031. This has significant implications for the Region's water distribution infrastructure. Sources of water are primarily external to the Region with the only internal sources being groundwater and a potential supply from nearby Lake Simcoe. To service projected development, it will be necessary to extend and reinforce the water supply infrastructure through the construction of additional water mains, pumping stations and storage facilities. The number of options available to achieve a hydraulically feasible solution is vast and the potential savings associated with identifying the most cost effective infrastructure configuration are considerable.

The tool used in this study is GA*net*, the core of which is an object-oriented genetic algorithm class library. The tool was developed for distribution system optimisation; the basic optimisation process uses:

- a GA with an objective function defined on a set of decision variables (for example, pipe diameters)
- a calibrated model of the system to simulate its hydraulic behaviour and to ensure that constraints are satisfied at all times (hard constraints)
- a penalty term to penalise insufficient pressure at nodes (soft constraints).

'the phased optimal solution would cost $102,000,000 instead of the previous manual solution cost of $156,000,000 – a saving of $54,000,000'

However, extending the optimisation to include the sizing and operation of pumps and service reservoirs adds a great deal of complexity to the problem. The inclusion of pumps means that the optimisation must address not only the capital costs of pipes, pumps and tanks, but also the operating expenditure over a specified period – with all of the costs expressed at an equivalent present value. The method developed in this study had to allow for the optimal selection of pumps for installation in new or upgraded pumping stations. Therefore, the objective criterion used was to minimise the present value of the capital plus operational costs from 1996 to 2031 based on a specified discount rate.

Service reservoirs

The study also included provision for new or expanded service reservoirs. These act as buffers, filling at low demand periods of the day and emptying at peak demand periods, thereby reducing both pumping and pipeline costs. They also provide the required reserve for fire fighting and emergency conditions. Including service reservoir storage in the optimisation requires simulation of the filling and emptying of the reservoirs through the daily cycle of demand, in addition to analysis of the instantaneous peak and emergency flows.

A full simulation of the system's response to variations in demand over a day would be too time consuming to use in an optimal design program, which requires evaluation of a very large number of de-

signs. Hence only two representative periods of the day were used to evaluate the system during the optimisation, while a full 24-hour simulation was used to check the feasibility of the final designs.

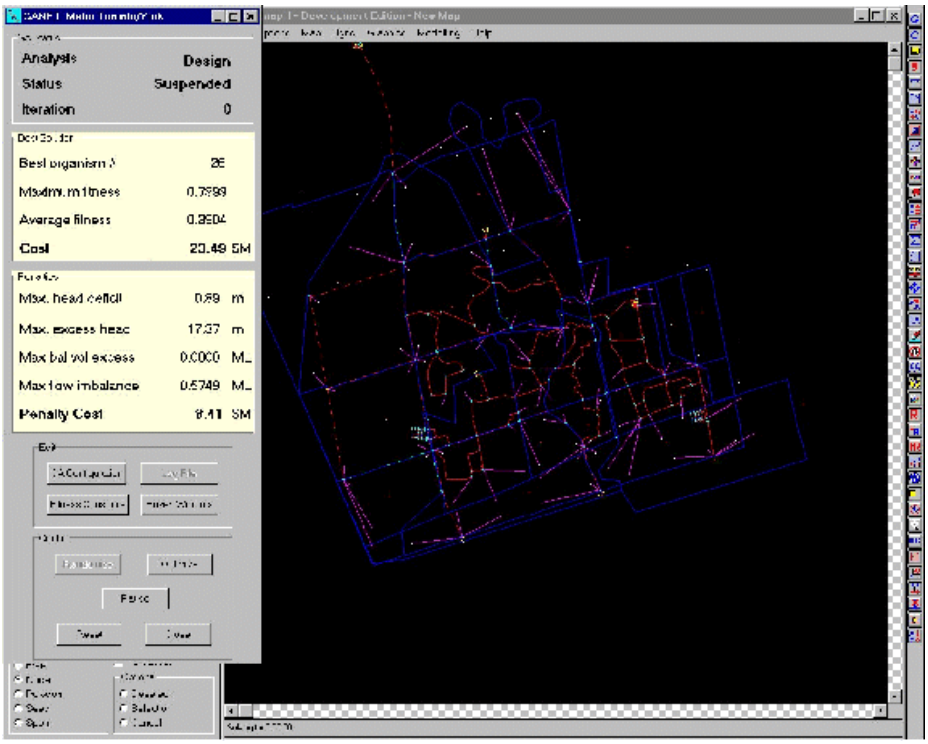
The use of two steady-state demand simulations (minimum-hour and maximum-hour demand) rather than full 24-hour simulation meant that an approximate technique had to be used to ensure consistency between storage volumes, reservoir levels and reservoir inflows and outflows. The technique was based on the assumption that for the purpose of the two steady-state simulations all new reservoirs have unlimited capacity. However, the volume of water supplied by the reservoir during high demand periods, or conversely the amount of water pumped into the reservoir during low demand periods (assuming that reservoir balancing is achieved), gives the required volume of the reservoir. During a GA run an additional penalty term was used for imbalance in the reservoir outflow and inflow.

The process outlined below shows the GA steps used to optimise a pipe network with pipe diameters, pumps to be installed and reservoir sizes as decision variables.

1. Randomly generate an initial population of network design solutions (that is: pipe diameters for new pipes and number of pumps in each pumping station).
2. Compute the cost of each network in the population.
3. Analyse each network hydraulically for the two load cases considered (those solutions that fail to satisfy the pressure or reservoir balance constraints must be penalised and a penalty cost added to their real cost to make them less attractive).
4. Generate a new population using evolution-based operators: reproduction (crossover) and mutation.
5. Repeat steps 2 to 4 to produce successive generations.

As the vehicle for optimisation, a model of all the Regional water mains, together with larger or hydraulically significant Municipal mains, was constructed using StruMap™, a Geographic Information System with a built-in hydraulic solver (http://www.strumap.co.uk/modelling.htm).

Extensive field testing of both the network and the pumping stations generated the data needed to calibrate the model. Baseline details and projected future demands were added to the calibrated model, along with potential routes for new distribution mains and potential locations for pumping stations and storage facilities. For each pressure district, a grid of possible new distribution mains was considered in potential development areas. In addition, a large number of new pipe options were specified along existing pipe routes. Also, some optional pipe routes outside the pressure zones which they service, were considered for transmission purposes. Unit construction costs relating to diameter and ground type (rural, urban or urban congested) were determined. Approximately 300 new pipes were included in the model as options for the solution. Each pipe could adopt any of 14 discrete diameters (from 300mm to 2100mm), giving a possible number of solutions of 14^{300}, or 10^{343}. With the additional options for the location and sizing of pumping and storage facilities the total number of possible designs was calculated to be approximately 10^{357}.



'The total number of possible designs was calculated to be approximately 10^{357}.'

Three existing pumping stations were considered for possible upgrading, with another 13 new pumping station locations considered, with, for some stations, up to 16 new pumps to be included as options. In addition to pipes and pumps, there were five possible new ground level reservoirs and four new elevated tanks considered in the system.

Results

The optimisation plan produced using GA*net* proposed adding 85 new watermains to the existing 750 watermains in the system. Six new pumping stations were proposed and three existing pumping stations were identified for expansion with a total of 42 new pumps. The plan also recommended that three pumping stations be decommissioned. Seven new ground reservoirs and elevated tanks were proposed with two existing elevated tanks identified for decommissioning.

The capital cost of these works for the ultimate planning horizon of 2031 is $194,420,000 (1997 Dollars) based on the unit costing data developed for the study. Whilst no directly comparable cost for a manual solution was available for the ultimate planning horizon of 2031, the phased optimal solution for 2011 would cost $102,000,000 instead of the previous manual solution cost of $156,000,000 – a saving of $54,000,000 or 35%.

For further information, please contact:

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☎ +44 1392 263637 (voice)
+44 1392 217965 (fax)

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Mechanistic models

EvoNews talks to Professor David Goldberg

One can only assume that, despite John Holland's presence on the premises, the University of Michigan wasn't using genetic algorithms to tackle its time-tabling problems when David Goldberg arrived there to do his PhD in 1980. With his civil engineering credentials under one arm and Hofstadter's *Goedel, Escher and Bach* under the other, Goldberg was all set to apply artificial intelligence to a gas pipeline problem when a scheduling slip-up meant the standard computer science AI course he'd signed up for was cancelled and he was forced to make do with Holland's 'Introduction to Adaptive Systems' instead.

'At the time, I had never heard of GAs and didn't know who John Holland was,' Goldberg admits. 'I sat through his class for the first few weeks and was puzzled by all this biology he was talking about. After all, what does that stuff have to do with adaptive systems? Of course, after a while I realised that it had everything to do with it.'

So rather than applying classical AI methodologies to his pipeline problem, Goldberg turned to GAs and classifier systems.

'I couldn't articulate what attracted me so much to Holland's work, but later when I was writing my thesis it struck me that genetic algorithms were trying to talk to us about a mechanistic theory of the innovative and possibly creative, and I used those words as metaphors to give an intuition how such simple operators might do something useful together.'

'... it struck me that genetic algorithms were trying to talk to us about a mechanistic theory of the innovative and possibly creative, and I used those words as metaphors to give an intuition how such simple operators might do something useful together'

In terms of career moves, converting to the evolutionary paradigm in the early 1980s was the academic equivalent of joining an obscure and somewhat scandalous religious cult. 'GAs couldn't have been more disreputable,' Goldberg recalls. His first submissions to the *Journal of Hydraulic Engineering* were laughed out of the review pipeline and although he later got the work published, the experience taught him a healthy scepticism towards the academic establishment.

Now a Professor of General Engineering at the University of Illinois, and firmly ensconced within the establishment himself, he attributes his success 'partially to being outside the mainstream of computer science as an engineer with "odd" credentials. I believe that my colleagues in CS have had a tougher time of it because they had to go head to head with people who "knew better." '

However, membership of the pariah band of genetic algorithmists had its advantages, as Goldberg discovered when he attended the first ever ICGA at Pittsburgh in 1985.

'It is hard to describe to newcomers who now confront a literature with thousands of references and conferences with 250 and 300 people how nice it was to be able to read a couple hundred papers and "know" the field, and how pleasant it was to have drinks with half a dozen people and know that you had the best researchers sitting around the table.'

Despite his evident nostalgia, some of the credit for the field's subsequent rapid growth must go to Goldberg himself. It's worth remembering that before he returned to academia, he worked not only as a project engineer but also as a marketing manager. A persuasive wordsmith, he has been the genetic algorithm's most ardent champion, chief populariser and author of its first textbook.

Nowadays, though, he tends to talk in terms of GEAs rather than GAs.

'I prefer the term genetic and evolutionary computation,' he says, 'because it acknowledges the contributions of those who have laboured under the separate terms "genetic" and "evolutionary" equally.

'Yes there has been convergence in the field about the importance of various operators, and indeed we are all selectionists. Having said that, the categories identify important traditions and emphases, and I don't believe that we should move too quickly to sweep them under the rug. After all, as a group we believe passionately in the importance of useful diversity for maintaining and prolonging a genetic-evolutionary search process. Maintaining demes of those with different traditions will delay a convergence which may be premature.'

Nevertheless he believes that the great debate over the relative merits of cross-over and mutation has been framed incorrectly. 'It is not GP vs EP or ES vs GA that should fill our thoughts,' he observes, 'but rather, how do we bring the best of all of these traditions to work together to give us good answers in reasonable time.

'Researchers in both modes of GEC are coming to similar conclusions. Specifically both camps are starting to understand the need for operator adaptation or self adaptation and the need to replace crossover versus mutation thinking with crossover plus mutation thinking. These ideas are starting to come together and the resulting algorithms are truly remarkable in their robust capability.' David Goldberg has extremely high aspirations for the GEA and it's quite clear that he considers the approach to be a long way from achieving its full potential. But ask him whether he thinks proof of concept has been achieved and he's momentarily stunned by the naivety of the question.

s of the mysterious

For Goldberg, any slurs on the practical merits of GAs are well and truly trounced by the numerous fielded systems 'that solve real problems better than other methods'.

As he points out, 'in business the bottom line is the bottom line'.

'Companies that have developed GA technology have been sold for 10s of millions of US dollars, so wealth is being created, problems are being solved, and as a new generation of competent and efficient GEAs comes into common usage the picture will only get brighter.'

From a range of practical, economic considerations, he plucks two that he believes will help clinch the GEA's future success. 'Organisations invest hugely in solution techniques that help to simulate their problems,' he says. 'GEAs respect that investment and allow you to interface it easily to the search engine, whereas many optimisation and operations research techniques require you to bend the problem to the method, which is expensive in user time.

'Also, OR and optimisation require you to learn new methods for new problems – which assumes that you have a staff with the time to devote to such things. An investment in learning GEA technology, however, can transfer from one problem to another very different one. So, as GEAs become more competent and efficient, companies will be increasingly compelled to take up these efficiencies in simulation and method economy.

'Ultimately,' he maintains, 'all realms of endeavour will be affected by GEAs… Any area where we might benefit from the creation of that which has never been will benefit from our efforts.'

It's a grandiose claim. But since his earliest intuition that genetic algorithms might shed light on the mechanisms behind innovation and creativity, David Goldberg has had his sights set on something extremely ambitious indeed: a computational theory of the creative.

'I think we have achieved computational innovation, but I believe computational creativity is a tougher nut to crack'

In a recent technical report, *The Race, the Hurdle and the Sweet Spot* (http://www-illigal.ge.uiuc.edu), he starts by distinguishing between design tasks that lend themselves to rote computation and those that don't, and ends by undermining his own categories, suggesting that the processes surrounded by the most mystery – innovation and creativity – are yielding to computational modelling and mechanistic understanding.

He believes that GEAs can be thought of as a form of *computational innovation and creativity* and he likens the two processes of selection plus mutation and selection plus recombination to different facets of human innovation.

'Simply put, I believe that selection plus mutation gives us the kind of continual improvement or *kaizen* that is frequently discussed in the literature of total quality management, and that selection plus recombination gives us discontinuous improvement, a kind of cross-fertilising innovation.'

Given their source in the human mind, the idea that innovation and creativity might be the product of evolutionary mechanisms isn't so new. Scarcely a decade after the publication of *On the Origin of Species* the American psychologist William James was describing thought in terms of Darwin's model. And the recent resurgence of interest in Richard Dawkin's 1970s meme theory focuses closely on the human mind as a breeding ground for ideas.

Dawkin's memes are communicable items of information that inhabit the human mind as genes inhabit our bodies. They are the ideas, techniques, stories, snatches of song and sayings that, given our genius for imitation, pass from human to human either individually or in vast memeplexes such as Catholicism or calculus. Like genes they evolve, being subject to mutation (copying errors) and selection.

For Dawkins, Dennet, Blackmore and their followers, memes are not a metaphor, but a real world phenomenon, a secondary replicating system that piggybacks on the primary replicating system of the gene pool. But meme theory has surprisingly little to say about creativity; there doesn't appear to be a model for the spontaneous creation of startling new memes. And yet there's no doubt that humans are creative, so how do we do it?

This is something Goldberg wants to address: 'I think we have achieved compu-

Continued on page 12.

MECHANISTIC MODELS OF THE MYSTERIOUS

— *Continued from page 11.*

tational innovation, but I believe computational creativity is a tougher nut to crack. First, what do we mean by creativity and how is it distinguished from innovation? An essential idea is the notion of *transfer*. Whereas innovation (the cross-fertilising kind) is juxtapositional, creativity is often related to the transfer of one domain to another with understanding of the transfer at a higher level.'

As a tentative model of creativity this seems to work, calling to mind as it does science's favourite parable, that long preserved and propagated snapshot of the eureka moment in which Archimedes ponders the question of volume as he lies in the bathtub. There's transfer for you: the bathtub meme slots into the weights and measures memeplex, everything falls into place and suddenly all sorts of new things become possible.

Similarly, for Edward Jenner a centuries old rural meme about healthy milkmaids leapt into place within the public medicine memeplex. Eureka: a smallpox vaccine. The history of science is punctuated with myths of such fortuitous transfers and mental leaps. True or not, there's little doubt that our preferred model for creativity is of something jumping virus-like across the species barrier.

For humans, thinking by analogy is ingrained; almost automatic. Pattern seekers by nature, it's inevitable that we'll take a pattern observed in one domain and impose it on another. So despite our esoteric individual concerns, and despite Pasteur's observation that chance only favours the mind prepared for it, memetically we're pretty good at creative transference. But how can we coax a computer to automatically transfer useful information between domains?

Goldberg can imagine a number of ways of doing this, 'either through the transfer of deep, whole building blocks from other fields or through the transfer of knowledge about better knowledge representation'.

Buy his argument or not, there's something inexorable about the engineering approach that makes you believe that one day the secret mechanisms of creativity will be unlocked. Besides, how can you refute his proposition that by designing more effective GEAs, step by step we will illuminate aspects of ourselves that we don't yet understand?

EC Courses

AUSTRIA

Evolutionary algorithms

http://www.apm.tuwien.ac.at/teaching/LVA/186019.html

- Primarily undergraduates, but also MSc and PhD

✉ Gunther Raidl,
Institute of Computer Graphics,
Vienna University of Technology,
Karlsplatz 13/1861,
1040 Vienna, Austria
☎ +43(1)58801/18616
💻 raidl@apm.tuwien.ac.at

DENMARK

Evolutionary algorithms and artificial life

- MSc, PhD

✉ Brian Mayoh,
Aarhus University Computer Science Department,
NyMunkegade Bldg.540, DK-8000 Aarhus C, Denmark
☎ +45 8942 3188
💻 brian@daimi.aau.dk

FRANCE

Evolutionary methods for numerical optimisation

- PhD (French name DEA, first year of PhD studies)

✉ Dr Marc Schoenauer
Ecole Polytechnique
Plateau de Saclay Palaiseau 91128
France
💻 marc.schoenauer@polytechnique.fr

Evolutionary optimisation

- Engineering graduates; the course is 1 out of 3 optional courses in the second trimester.

✉ Dr Marc Schoenauer
Ecole Polytechnique
Plateau de Saclay Palaiseau 91128
France
💻 marc.schoenauer@polytechnique.fr

GERMANY

Application of evolutionary algorithms

- MSc level (German Diplom)
The course is taught at the Institute of Computer Science (Institut fuer Informatik), University of Stuttgart

✉ Karsten Weicker
University of Tuebingen
WSI, Computer Architecture,
Koestlinstr. 6,
D-72074 Tuebingen
Germany
☎ (+49/0) 7071-29-77175
💻 weicker@informatik.uni-tuebingen.de

Evolutionary computation

- MSc

✉ Prof. Dr H. Schmeck,
Institut AIFB,
Universität Karlsruhe (TH)
D-76128 Karlsruhe,
Germany
☎ ++49 (721) 608-4242 (voice)
💻 schmeck@aifb.uni-karlsruhe.de

Evolutionary computation/ Evolutinaere algorithmen

http://LS11-www.cs.uni-dortmund.de/

- Mostly students aiming at the degree 'diploma in informatics'

✉ Prof.Dr Hans-Paul Schwefel
Department of Computer Science,
University of Dortmund,
Joseph-von-Fraunhofer-Str. 20
D-44227 Dortmund,
Germany
☎ 49 231 9700 952
💻 schwefel@LS11.informatik.uni-dortmund.de

THE NETHERLANDS

Evolutionary algorithms and intelligent automata

- MSc

✉ Dr Vladan Babovic
International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE)
PO Box 3015
2601 DA, Delft
The Netherlands
☎ +31 - 15 - 2151715

across Europe

Evolutionary algorithms

http://www.wi.leidenuniv.nl/home/gusz/eas-eng.html

- Available both as a daytime and an evening course.

✉ Dr Gusz Eiben,
Leiden Center for Natural Computation, Faculty of Mathematics and Natural Sciences,
University of Leiden,
Einsteinweg 55,
2333 CC Leiden,
The Netherlands

💻 gusz@cs.leidenuniv.nl

POLAND

Evolutionary computation and machine learning

- MSc, PhD

✉ Jaroslaw Arabas,
Warsaw University of Technology,
Faculty of Electronics,
Warsaw,
Poland

💻 J.Arabas@ipe.pw.edu.pl

Evolutionary computation

- MSc

✉ Halina Kwasnicka,
Department of Computer Science,
Wroclaw University of Technology,
Poland

💻 kwasnicka@ci.pwr.wroc.pl

SPAIN

Evolutionary computation

http://www.salleURL.edu/~josepmg/Assignatures/GA/index.html

- PhD

✉ Dr Josep M. Garrell i Guiu,
Department of Computer Science
Enginyeria i Arquitectura La Salle
Universitat Ramon Llull,
Passeig Bonanova 8,
08022-Barcelona,
Catalonia,
Spain

☎ +34 932 902 439 (voice)
+34 932 902 416 (fax)

💻 josepmg@salleURL.edu

UK

Evolutionary computing

- This is part of a Machine Learning MSc

http://www.cs.bris.ac.uk/Tools/Local/Handbook/Units/COMS70302.html

✉ Claire J. Kennedy,
Machine Learning Lab,
Department of Computer Science,
University of Bristol,
Merchant Venturers Building,
Woodland Road,
Bristol BS8 1UB, UK

☎ +44-117-9545251 (voice)
+44-117-9545208 (fax)

Research in evolutionary computation

http://www.sun.rhbnc.ac.uk/~uhap016/

- MSc, PhD

✉ Dr Stuart Flockton,
Royal Holloway,
University of London,
Physics Department,
Egham, Surrey TW20 0EX UK

☎ +44 (0)1784 443 510 (voice)
+44 (0)1784 472 794 (fax)

💻 S.Flockton@rhbnc.ac.uk

Evolutionary techniques

http://www.cs.reading.ac.uk/cs/people/dwc/teaching/et/home.html

- 3rd year undergraduates and MSc students (MSc students take a slightly harder version of the course)

✉ David Corne
Parallel Emergent & Distributed Architectures Laboratory
Dept. of Computer Science
University of Reading, PO Box 225
Reading RG6 6AY, UK

☎ +44 (0)118 931 8983

💻 D.W.Corne@reading.ac.uk

Evolutionary computing and machine learning

- Undergraduates

✉ Prof. Terence C. Fogarty
School of Computing
Napier University
219 Colinton Road
Edinburgh EH14 1DJ, UK

☎ +44 (0)131 455 4398 (voice)
+44 (0)131 455 4552 (fax)

💻 tcf@dcs.napier.ac.uk

Machine learning

- A final year unit on the Software Engineering route in BSc Computer Science and Information Management, the course consists essentially of 50% Evolutionary Computation, 50% Neural Networks.

✉ William Campbell,
Senior Lecturer,
Room F328A,
School of Computing,
University of Central England,
Birmingham B42 2SU, UK

☎ 0121 331 5291

💻 william.campbell@uce.ac.uk

Evolutionary computation

http://www.cs.bham.ac.uk/~rmp/courses/sem3a4.html

- Undergraduates

✉ Dr Riccardo Poli,
School of Computer Science,
The University of Birmingham,
Edgbaston,
Birmingham B15 2TT, UK

☎ +44-121-414-3739 (voice)
+44-121-414-4281 (fax)

💻 R.Poli@cs.bham.ac.uk

Neural and evolutionary computing

http://www.elec.gla.ac.uk/~yunli/nec4/

- Undergraduates

✉ Dr Y Li
Department of Electronics and Electrical Engineering,
University of Glasgow,
Rankine Building,
Oakfield Avenue,
Glasgow G12 8LT,
Scotland, UK

💻 Y.Li@elec.gla.ac.uk

Thanks to Xin Yao and Riccardo Poli of the University of Birmingham, who have collated information about EC courses around the world. You can find more information at their website, http://www.cs.bham.ac.uk/~rmp/eebic/ec_teaching/

CoIL – springloaded with potential synergy

In January EvoNet joined forces with three other Networks of Excellence to form CoIL – the Computational Intelligence and Learning Cluster. In partnership with NeuroNet, MLNet and ERUDIT, EvoNet will be working to promote co-operation between four distinct communities undertaking research and development in neural networks, machine learning, fuzzy logic and evolutionary computing.

The new initiative aims to use the potential synergy of these four approaches both to extend the scope of computational intelligence and learning, and to foster technology transfer.

Although each of the four participating networks represents a different computational paradigm, fuzzy, neural, evolutionary and machine learning techniques can often be used to tackle similar problems or combined to tackle the same problem. However, the tendency remains for researchers to focus on a single preferred technique, sometimes to the exclusion of competitive or complementary techniques from other smart computing communities.

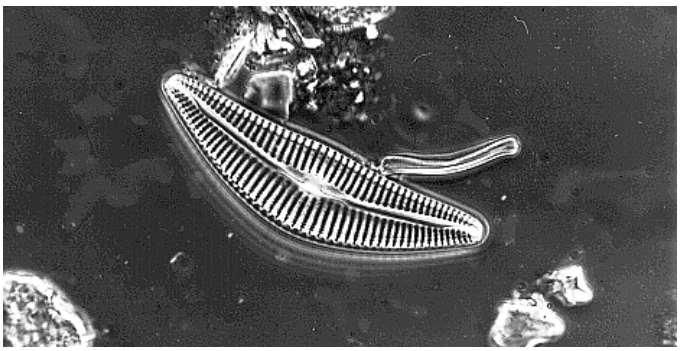
To promote communication and co-operation between members of the participating networks, over the next year CoIL will produce tutoring materials, a Cluster newsletter and technology roadmap, and organise a number of joint activities, including workshops and a competition.

For more information about Cluster activities, visit the CoIL website at http://www.dcs. napier. ac.uk/coil/

CoIL Competition

Intelligent techniques for monitoring water quality using chemical indicators and algae population

As concern mounts about the environmental impact of toxic waste from a wide variety of manufacturing processes, it is becoming increasingly clear that the more subtle changes in nutrient level and chemical balance arising from agricultural run-off and sewage treatment also have a serious, but indirect, effect on the state of our rivers and lakes.



Diatoms such as Cymbella respond very rapidly to man-made environment changes.

In temperate climates across the world summers are characterised by numerous reports of excessive summer algae growth resulting in poor water clarity, mass deaths of river fish from reduced oxygen levels and the closure of recreational water facilities on account of the toxic effects of this annual algae bloom. To reduce the impact of these man-made changes in river nutrient levels much current research centres upon identifying the crucial chemical control variables for the biological processes.

The data used in this problem comes from one such study, in which water samples were taken from sites on different European rivers over a period of approximately one year. These samples were analysed for various chemical substances including nitrogen in the form of nitrates, nitrites and ammonia, phosphate, pH, oxygen and chloride. In parallel, algae samples were collected to determine the algae population distributions. It is well known that the dynamics of the algae community is determined by the external chemical environment with one or more factors being predominant. While the chemical analysis is cheap and easily automated, biological analysis requires trained staff to carry out microscopic examination and is therefore both expensive and slow.

The competition task is to predict the algae frequency distributions on the basis of the measured concentrations of the chemical substances and some global information about the season when the sample was taken, the river size and the fluid velocity. The relationship between the chemical and biological features is complex. Typical of such real-life problems, the particular data set for the competition task contains a mixture of qualitative variables and numerical measurement values, with much of the data being incomplete.

All interested companies or institutions may take part in the competition, which will be supervised by a board of impartial referees. The board of referees will declare a winner and one runner-up for the problem. The winners will be invited, free of charge, to attend the EUFIT'99 conference to present their solutions on 14 September 1999 in Aachen, Germany.

The detailed problem description and the data is available from:

💻 **FTP Server:** ftp.mitgmbh.de
User name: anonymous
Password: email address
Name of the files: /pub/problem. zip

Alternatively a disk with the data is available on request from:

✉ ERUDIT Service Center, c/o ELITE Foundation, Promenade 9
52076 Aachen, Germany
☎ +49 2408 6969 (voice)
+49240894582 (fax)

Time-table

31 May 1999 Deadline for submission of solutions
31 July 1999 Announcement of results
14 Sept 1999 Presentation of the best solutions at EUFIT'99.

online

Useful Links for the European Commission's Fifth Framework Programme

The recently launched Fifth Framework Programme sets out the European Union's priorities for research, technological development and demonstration (RTD) activities until 2002. These priorities have been selected with the aim of increasing industrial competitiveness and improving the quality of life for European citizens.

http://www.cordis.lu/fp5/home.html
For those who are new to the European Commission's Fifth Framework Programme, this is a good starting place, giving an overview of the thematic and horizontal programmes and providing links to calls for proposals, procedure guidelines and a partner-search facility, as well as to the proposal evaluation manual and the proposal preparation tool.

http://www.cordis.lu/fp5/src/forms_a.htm#3
All the documents necessary to respond to the call for applications are available for downloading at this site. This includes proposal submission forms and guidelines for completing the forms.

http://www.cordis.lu/ist/home.html
EvoNet members who wish to submit research proposals should visit the Information Society Technologies Programme website. IST brings together and extends the ACTS, Esprit and Telematics Applications programmes into a single, integrated programme that reflects the convergence of information processing, communications and media technologies in research, technology development and demonstration under the Fifth Framework Programme. The Programme is managed by DG XIII of the European Commission with a budget of EUR 3.6 billion for 1998-2002.

http://www.cordis.lu/ist/calls/199901.htm
This site offers downloadable work programmes, guides and administrative forms for the current IST Programme Calls. The deadline for proposals in response to fixed deadline action lines included in the First Call is 16 June 1999.

http://www.cordis.lu/ist/istag.htm
This site provides information about the IST Programme Advisory Group (ISTAG) which provides the Commission with independent advice on the content and direction of research work to be carried out under the IST Programme.

http://www.cordis.lu/expert-candidature/
Applications are still open for 'experts' to evaluate proposals made under the specific programmes implemented within the Fifth Framework. This site provides more details.

http://www.cordis.lu/fp5/src/guide1.htm
The Fifth Framework Programme Guide for Proposers is divided into two parts: Part 1 contains downloadable general information common to all programmes as well as programme-specific information; Part 2 contains specific information about making proposals for each of the calls launched under the Fifth Framework Programme.

http://www.cordis.lu/fp5/src/evalman.htm
The Evaluation Manual provides the 'ground rules' or guidelines for the evaluation of proposals for European Community funded projects, taking the basic principles of quality, transparency, equality of treatment, impartiality, and efficiency and speed into consideration. It describes the basic procedures that will be followed by all the programmes under the Fifth Framework.

http://www.cordis.lu/fp5/protool/protoolinfo.html
The Commission has provided a software tool (ProTool) to help with the preparation of administrative and technical information so that it conforms to the appropriate proposal submission form. The tool can be used by the co-ordinating partner and also a separate version is available for other participants, allowing them to prepare and submit their contribution electronically to the co-ordinating partner.

To keep ONLINE up-to-date, please email evonet@dcs.napier.ac.uk with any interesting EC-related bookmarks.

EvoNet technology roadmap

EvoNet is developing a Technology Roadmap which aims to present a realistic vision of the future of evolutionary computing over the next 25 years, indicating the routes the technology is likely to follow within a context of global change.

Every Network of Excellence is asked to prepare a Technology Roadmap which outlines key research areas and identifies emerging 'bright-spark' approaches and applications in non-technical language.

EvoNet has chosen to develop a web-based map focusing on the role that evolutionary computing is likely to play in a range of future economic and social developments. The roadmap is an interactive document that will evolve over time, and will eventually be linked to a database of research interests and projects.

As a starting point, ten evolutionary computing research areas leading to ten future 'destinations' have been identified and briefly described. The intention is to develop this further and to provide links to members' research areas, giving specific examples of how research can bring about technological change.

EvoNet will help co-ordinate a range of European EA research interests across all the related fields, and it is anticipated that future research funding proposals could be evaluated within the technological context described and predicted in the EvoNet roadmap.

If you are working in a research area that is not covered by the roadmap, please send us details of your activities so that we can include them.

You can view the Roadmap Outline at: http://pc143d.dcs.napier.ac.uk /roadmap/

Please send any ideas for refining the basic categories and descriptions, or suggestions for areas that have been overlooked, to:
evonet@dcs. napier.ac.uk.

Genetic Programming and Evolvable Machines

- **Editor in Chief:** Wolfgang Banzhaf
- **Resource Review Editor:** William B. Langdon

The journal of *Genetic Programming and Evolvable Machines* is devoted to reporting innovative and significant progress in the automatic evolution of software and hardware. The artificial evolution of active components, such as programs or machines, is a rapidly developing branch of adaptive computation and adaptive engineering. It entails the development, evaluation and application of methods that mirror the process of neo-Darwinian evolution and that produce computational expressions (such as algorithms) or machines (such as mechanical or electronic devices) that actively process environmental information and transform their environment.

In addition to its main topics, the journal covers related topics such as evolutionary algorithms with variable-size genomes, alternate methods of program induction, approaches to engineering systems development based on embryology, morphogenesis or other techniques inspired by adaptive natural systems.

Methods

■ Genetic Programming ■ Variable-size evolutionary algorithms ■ Induction of algorithms and symbolic expressions by iterative and non-deterministic search ■ Evolutionary design and optimisation of electronic circuits and mechanical devices ■ On-line adaptation of hardware and software ■ Evolutionary robotics ■ DNA computing ■ Co-evolutionary techniques ■ Meta-learning ■ Hybrid systems ■ Cellular and developmental approaches

Task domains

■ Algorithm evolution ■ Agents ■ Architecture ■ Art and animation ■ Classification and pattern recognition ■ Computer graphics ■ Computing ■ Circuit design ■ Data mining ■ Distributed problem solving ■ Engineering design applications ■ Games ■ Hardware and software testing and verification ■ Image and signal processing ■ Interactive evolution ■ Molecular biology applications ■ Music ■ Natural language processing ■ Network routing ■ Optimisation ■ Process control ■ Robotics and motor control ■ Self-repair ■ Self-reproduction of software and hardware ■ Self-programming ■ System modeling.

Both theoretical papers (preferably including computer simulations) and application papers are welcome. Papers describing hardware implementations are strongly encouraged. Papers in the areas of artificial life, molecular computing and any other emergent computation technique will be considered as well. (All manuscripts are subject to review).

Submission procedures

To submit a paper to ***Genetic Programming and Evolvable Machines***, prospective authors should submit five copies of their complete manuscript to:

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781-871-7507 (fax)
💻 scott.delman@wkap.com

International Journal of Mathematical Algorithms (IJMA) — Special Issue on Evolutionary Computing with Applications in Manufacturing

IJMA is concerned with research at the interface of computer science and mathematics. The journal focuses on applicable mathematics such as operational research, discrete mathematics, number theory and logic where the research reported contains a significant computing science component.

Published papers will have a strong mathematical foundation and will be concerned with the exploitation of recent advances in computing, generally with a view to solving problems of a practical nature. Papers on evolutionary computing are welcome and a special issue on Evolutionary Computing with Applications in Manufacturing is planned for early 2000.

Please send three copies of your manuscript to:

✉ Professor V.J. Rayward-Smith
School of Information Systems
University of East Anglia,
Norwich NR4 7TJ
United Kingdom

Deadline for submissions: 1 June 1999

Natural Computing

NEW BOOK SERIES

Aims and scope

Natural Computing is a general term referring to computing inspired by nature. Research in natural computing is concerned with the theoretical and empirical understanding of computing gleaned from processes and structures in nature. For instance, evolutionary algorithms are inspired by the biological concepts of mutation, recombination and natural selection, while artificial neural nets are inspired by the highly interconnected neural structures in the brain and central nervous system. Evolutionary algorithms and neural nets are presently implemented on conventional computers. However, research in DNA computing and quantum computing involves not only new concepts and paradigms but also their implementation in totally new kinds of hardware. For example, the biological hardware, or bioware, used in DNA computing consists mainly of DNA molecules and enzymes.

Natural Computing is one of the most exciting developments in computer science, and there is a growing consensus that it will become a major field in computer science in the next century. Springer-Verlag is therefore launching the Natural Computing Series as a prestigious hardbound series. This series will include monographs, textbooks and state-of-the-art collections covering the whole spectrum of Natural Computing and ranging from theory to applications.

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Submissions

Book manuscripts may be submitted either to one of the series editors or to Dr Hans Wossner, Computer Science Editor at Springer-Verlag (woessner@springer.de).

Knowledge and Information Systems

An International Journal

Aims and scope

Knowledge and Information Systems (KAIS) provides an international forum for researchers and professionals to share their knowledge and report new advances on all topics related to knowledge systems and advanced information systems. This quarterly peer-reviewed journal publishes state-of-the-art research reports on emerging topics in KAIS, reviews of important techniques in related areas, and application papers of interest to a general readership.

The journal focuses on knowledge systems and advanced information systems, including their theoretical foundations, infrastructure and enabling technologies. We solicit submissions of original research, and experience and vision papers that address this theme.

We publish critical review papers in each issue of the journal to discuss the state of the art in particular areas, as well as state-of-the-art research reports. Accepted papers are grouped for publication so that individual issues focus on a small number of theme areas. In addition to archival papers, the journal also publishes significant on-going research in the form of short papers (limited to 3000 words), and very short papers on visions and directions (no more than 1000 words, excluding bibliography).

Special issues devoted to relevant conferences are welcome. Good papers with high quality reviews from relevant conferences can be accepted after the expansion and revision is verified by an Associate Editor of the Editorial Board. Conference organisers are invited to contact the Executive Editor for further information.

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Information for authors

Authors are invited to submit complete and original papers, which have not been published elsewhere and are not currently under consideration for another journal or conference. Manuscripts must include an abstract and a list of keywords, and should be limited to 8000 words (3000 words for short papers).

The journal emphasises timely processing of submissions and minimal backlogs in publication time. We review papers and advise authors of their paper status with a target turnaround time of 3 months (4 to 6 weeks for short papers). We strongly encourage electronic submissions in the form of postscript files. Authors can submit a postscript file of their manuscript, including figures and tables, by ftp to the following site:

ftp kais.mines.edu
login as anonymous
cd pub/kais/incoming
put FileName.ps

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The journal is published quarterly, with the first volume published in early 1999 by Springer-Verlag.

For more information, please visit the Knowledge and Information Systems website at http://kais.mines.edu/~kais/

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

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

EVONET EVENT

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

30 May–3 June 1999

EUROGEN'99: Short Course on Evolutionary Algorithms in Engineering and Computer Science, University of Jyväskylä, Jyväskylä, Finland

Contact
eurogen99@mit.jyu.fi
http://www.mit.jyu.fi/tapahtumia/eurogen99/

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

24–26 June 1999

CEF'99: Fifth International Conference of the Society for Computational Economics (Special Session on Evolutionary Computation in Economics and Finance), Massachusetts, USA

Contact
chchen@nccu.edu.tw
http://econo.nccu.edu.tw/ai/conference/CEF99.htm

1–2 July 1999

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

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

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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31 July–2 August 1999

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

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

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

13–16 September 1999

EUFIT'99: 7th European Conference on Intelligent Techniques and Soft Computing, Aachen, Germany

Contact
events@mitgmbh.de
http://www.mitgmbh.de/eufit

13–17 September 1999

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

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

18 September 1999

EWLR-8: European Workshop on Learning Robots 1999, Lausanne, Switzerland
Deadline for papers: 1 May 1999

Contact
jlw@cs.bham.ac.uk
http://www.cs.bham.ac.uk/~jlw/ewlr/

26–27 May 1999

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

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

28 May 1999

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

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

14–18 June 1999

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

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

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

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/

18–22 July 1999

AAAI'99: 16th National Conference on Artificial Intelligence (submissions from the neural/evolutionary/fuzzy communities are solicited), Orlando, Florida

Contact
rsun@cs.ua.edu
http://www.aaai.org/Conferences/National/1999/aaai99-call.html

19–21 July 1999

EH'99 Workshop: First NASA/DOD Workshop on Evolvable Hardware, Jet Propulsion Laboratory, Pasadena, California

Contact
adrian.stoica@jpl.nasa.gov
http://cism.jpl.nasa.gov/events/nasa_eh/

31 August–3 September 1999

ECC: European Control Conference, Karlsruhe, Germany

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

1–3 September 1999

AICS-99: 10th Annual Irish Conference on Artificial Intelligence and Cognitive Science, Cork, Ireland

Deadline for submissions: 21 May 1999

Contact
aics99@cs.ucc.ie
http://www.cs.ucc.ie/aics99

1–7 September 1999

Second EvoNet Summer School: Theoretical Aspects of Evolutionary Computing, University of Antwerp, Belgium

Contact
bnaudts@ruca.ua.ac.be
http://islab.ruca.ua.ac.be/summerschool

3–5 November 1999

EA'99: Artificial Evolution 99, Dunkerque, France
Deadline for papers: 15 May 1999

Contact
EA99@lil.univ-littoral.fr
http://www-lil.univ-littoral.fr/EA99

7–10 November 1999

ANNIE'99: Smart Engineering System Design: Neural Networks, Fuzzy Logic, Complex Systems, Evolutionary Programming and Data Mining, Missouri, USA
Deadline for papers: 14 May 1999

Contact
dagli@umr.edu
http://www.umr.edu/~annie

17–18 April 2000

ICES 2000: Third International Conference on Evolvable Systems: From Biology to Hardware, Edinburgh, UK
Deadline for papers: 15 November 1999

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