ERCIM NEWS

Special Theme:

Control and System Theory

NEXT ISSUE:
April 2000, Special Theme: Web Technologies.

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Automatic Control:
Past, Present and Future

**Vladimír Ku era, Head of
the Department of Control
Engineering, Czech
Technical University in
Prague and CRCIM,
Academy of Sciences of
the Czech Republic.**

Automatic control is a driver of technology progress and society industrialization. Control systems have a truly impressive legacy of innovation. Control engineering has made possible space travel and communication satellites, has assisted in the design of safe and efficient aircraft, ships, trains and cars, has helped in developing cleaner chemical processes while addressing environmental concerns. Automatic control constantly improves the quality of human life.

Control theory and engineering have witnessed dramatic achievements throughout this century. Recall the stability theory of Lyapunov from the beginning of the century, the conception of three-term or PID controllers in the 1910s, electronic and pneumatic feedback amplifiers in the 1920s, Nyquist and Bode charts of the 1930s, and Wiener's cybernetics of the 1940s. Then came the 1950s and Bellman's principle of optimality, Kalman filter of the 1960s, adaptive control in the 1970s, robust control in the 1980s, and the hybrid control systems of the current decade.

The milestones of this development were the introduction of negative feedback amplifiers, field adjustable PID controllers, and especially digital computers. These technologies have had a tremendous impact on control theory and its application. The origin of classical control theory dates back to the conception of negative feedback and the subsequent development of frequency domain techniques, while modern control theory coincides with the introduction of state space methods related to the use of computers in space applications.

Today, as a result of this evolution, it is possible to implement advanced control methodologies. We have smart sensors and smart actuators. The most dramatic impact of electronic processing occurs in controllers. In times past, computational demands of adaptive, optimal and robust control techniques could not be easily performed. With modern electronics, such operations are possible. Modern electronic implementations are also more immune to aging effects, system noise and disturbances.

Control theory, on the other hand, is looking for new solutions. There is a strong influence of computer science and engineering. Analytic methods are giving way to synthetic ones. A search for closed-form solutions was typical in the classical era. The modern control theory considers a problem solved when it is reduced to an equation; an algorithmic solution is left to a computer. This trend will continue. The control of complex systems, or systems of systems, will be formulated as a mathematical program. Much of the analysis will be replaced by interactive, computer-aided design procedures. The solution will have to address the issues of hierarchy, interaction and the possibility of system evolution.

The truly exciting developments in automatic control will occur where there is a confluence of application drivers and disciplinary development of the subject. Changes in control education, adjustments in research directions, and more emphasis on implementation may provide the foundations and tools to meet the challenge of the next century and keep automatic control a dynamic and fascinating field.

The Cycab presented by INRIA.

Ten Years ERCIM

Amsterdam 4-5 November 1999

ERCIM celebrated its 10th anniversary with a two days event in Amsterdam from 4-5 November 1999. Over 400 participants including representatives from ERCIM institutes and invited guests from industry and the political community attended the events.

The first day, 4 November, was targeted at researchers from ERCIM member institutes. It saw some 20 presentations by ERCIM researchers and invited speakers about research related issues and state-of-the-art presentations, covering a variety of research areas under the slogan 'ERCIM - a Virtual Laboratory for IT Research in Europe':

• Krzysztof Apt, CWI: 'Constraint Programming, or at the Crossroads of Mathematics and Computer Science'

• Bernard Lang, INRIA: 'Libre Software'

• Stelios Orphanoudakis, FORTH: 'Information Society Technologies in Healthcare'

• Dennis Tsichritzis, GMD: 'The changing art of research'

• Jan van Schuppen, CWI: 'Control and System Theory'

• Achim Sydow, GMD: 'New Perspectives of Environmental Modelling and Simulation'

• Keith Jeffery, CLRC: 'What's next in Databases'

• Fadi El Dabaghi, INRIA: 'Integrated Information System for Modelling and Management of Water Resources: Trends and Perspectives'

• Tamás Roska, SZTAKI: 'Analogic Cellular Array Computing - A new bridge between Computer Science, Computer Engineering, and Mathematics'

• David Duce, CLRC: 'W3C State of the Art'

• Pentti Kanerva, SICS: 'Stochastic Pattern Computing: A New Computing Paradigm for AI'

• Aarno Lehtola, VTT: 'Engineering multilingual services on the World Wide Web'

• Yves Robert, ENS Lyon: 'Algorithms and Tools for (distributed) Heterogeneous Computing'

• Constantine Stephanidis, FORTH: 'Designing for All in the Information Society'

• Dominique Pignon, Ecole Normale Supérieure, Paris: 'Perspectives of Development of Virtual Reality and its Public'

Gerard van Oortmerssen, President of ERCIM, and Stelios Orphanoudakis, Vice-President (right) blowing the candles on the cake.

• Jussi Karlgren, SICS: 'Non-topical factors in information access'
• Peter Kacsuk, SZTAKI: 'Metacomputing'
• Laurent Kott, INRIA: 'INRIA's Spin-off policy'
• Kristina Höök, SICS: 'Social navigation and un-orthodox views on usability'
• Jan Friso Groote, CWI: 'On the reliability of software'
• Leonello Tarabella and Marco Cardini, CNR: Demonstration of CNR's Computer Music Lab.

Abstracts of the presentations can be found at the ERCIM website at: http://www.ercim.org/10years/

Demonstrations
In conjunction with the presentations on both days, demonstrations of current research at ERCIM institutes were given:
• CYCAB – Self-service vehicles for the cities of tomorrow (INRIA)
• PERSONA – Tools for Social Navigation (SICS)
• Virtual Reality for Scientific Visualization – a demonstration of an interactive virtual environment that gives the scientist the the illusion of immersing into a virtual world (CWI).
• IMU – Integrated Publishing in Multimedia Networks (VTT)
• ERCIM Technical Reference Digital Library – a digital collection of the technical documentation produced by ERCIM scientists. (CNR)
•VEP – Visual Enabling for Precision Surgery – a computer-based three-dimensional (3D) image guidance system for neurosurgical operations (GMD)
•The SNAKE – a robot for difficult inspection tasks. (GMD)
•The AVANTI Web Browser developed in the framework of the AVANTI project that aimed to address the interaction requirements of disabled individuals using Web-based multimedia applications and services. (FORTH)
•DialWeb - this project implements an information service (a music and

concert event guide) which can be accessed through a telephone-based voice browser as well as through a conventional graphical browser. (SICS)

• A real-time, intelligent advisory system – A new SCADA system was introduced in the 120/400kV Substation of the Paks Nuclear Power Plant (SZTAKI)

• MPEG7: The new member of the MPEG family, called 'Multimedia Content Description Interface' (GMD)

A more detailed description of the demos as well as links to their websites are available at the ERCIM website at http://www.ercim.org/10years/.

Symposium

At the Symposium: 'ERCIM – leveraging World Class R&D for Business and Society' on Friday 5 November, leaders from industry gave their vision on the future of European R&D:

• Gerard van Oortmerssen, Director of CWI, President of ERCIM: 'ERCIM - The Challenge of the Next Century'

Lunch in the main hall of the Beurs van Berlage.
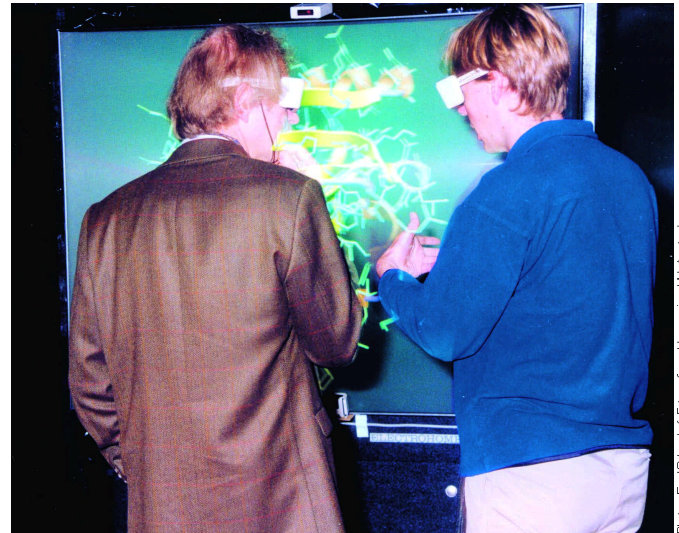
Demonstrations: an interactive virtual environment (above right), a computer-based three-dimensional image guidance system for neurosurgical operations (above); right: Ronald Melster from GMD-FIRST presents DYMOS – the daily ozon forecast for Berlin and a virtual, collaborative walk through the Guggenheim Museum for the Internet.

- Heikki Hämmäinen, Vice President Nokia Networks: 'Towards the Mobile Information Society'
- Alexander Rinnooy Kan, Executive Board ING: 'Technology and its Impact on the Financial Services Industry'
- Roger Needham, Director of Microsoft Research Europe: 'Microsoft Research - What and Why'
- Dieter Klumpp, Managing Director of Alcatel/SEL Foundation: 'INITI@TIVE D21'
- Jacques-Louis Lions, Institut de France: 'The Future of Scientific Computation'

The symposium closed with a discussion on the future of the Web and Europe's role following a statement via video by Tim Berners Lee, President of the Web Consortium, recorded at Massachusetts Institute of Technology and moderated by Dick Bulterman, Director of Oratrix Development .

The summaries of the presentations and the discussion follow on pages 8-15.

Mikael Degermark Winner of the 1999 Cor Baayen Award

Mikael Degermark, researcher at Luleå University of Technology and SICS, has been awarded the Cor Baayen Award 1999. The award, including a cheque for 5000 Euro and an award certificate, was presented to Mikael Degermark at a ceremony in Amsterdam the 4th of November, during the ERCIM 10 years anniversary celebrations. It is the fifth time the Cor Baayen prize is awarded.

The annual Cor Baayen Award for the most promising researcher in computer science and applied mathematics was created in 1995 to honour the first ERCIM President. The Cor Baayen award is open to any young researcher having completed his/her PhD-thesis in one of the fourteen 'ERCIM countries': Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Norway, Slovakia, Sweden, Switzerland, The Netherlands and the United Kingdom.

The winner of the award, Mikael Degermark, is today conducting research at the Department of Computer Science & Electrical Engineering at Luleå University of Technology and the Computer and Network Architectures Laboratory at SICS. His research focus is Internet protocols. He is also one of the founders and a board member of a router and firewall company Effnet AB.

Mikael received his doctor´s degree at Luleå University of Technology in 1997. His research provided the basis for a new standard of the Internet Engineering Task Force, for IP Header Compression (IETF RFC 2507). He is also a co-inventor of

Photo: CWI

Mikael Degermark

the Luleå-algorithm underpinning the Effnet's products. Mikael is continuing his work on wireless networks, creating new potential Internet standards in the area of mobile multimedia and ad-hoc networking, and on high-speed packet

forwarding. He has also filed a number of patents in this area.

Effnet AB, which in two years has grown to +40 employees, has offices in Luleå (HQ), Stockholm and Boston. Effnet AB went public on the Stockholm stock exchange in April 1999. The main products of Effnet are a series of routers and firewalls which were developed with the starting point in Degermarks published work on high-speed address lookups. The routers and firewalls have excellent price/performance and their algorithms are protected by several patents of which he is a co-inventor. See also his article 'Robust Header Compression enables IP Telephony to Mobile Phones' on page 36 in this issue.

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Gerard van Oortmerssen, Director of CWI, President of ERCIM

ERCIM: the Challenge of the Next Century

Our time is characterized by change, which takes place at an ever increasing speed. The most recent example is the Internet and World Wide Web. Only five years ago, few outside academia had heard about it. Now it is expected that within five more years, one billion people will be connected to the Internet, and one billion people will possess a mobile phone, probably with a web browser on it. Of course, we have to be careful with this kind of extrapolation based predictions. Technology forecasts are often falsified by history. Often, but not always. More than 50 years ago, the French Jesuit and paleontologist Pierre Theillard de Chardin predicted the emergence of a world encompassing network of conscience, which he called noosphere, as a next step, actually a discontinuity in the process of evolution of mankind. I believe we are witnesses of his vision becoming reality right now.

The digital revolution pervades all areas of our existence. It creates a new economy, in which the raw material — information — can be shared. A nice example of this is open source software or shareware, like the Linux operating system. But this phenomenon also raises new questions. For example, how can we protect our intellectual property when it's so easy to copy and distribute information? Maybe we need an entirely new system of values in the new economy.

The digital revolution also has its negative effects, which should not escape our attention. The information society is vulnerable to faulty software (millennium bug) and to people with bad intentions (computer viruses, hackers). There is the danger of a gap between the haves and the have-nots. Groups such as the elderly should have access to information as easily as anybody else. People who work long hours with keyboard and mouse frequently develop repetitive strain injury. And some people talk already about info stress, caused by the difficulty to find in the information jungle the relevant parts.

The research community, faced with all these dazzling developments which it had caused itself to a large extent, had to take action in order to deal adequately with the rapid changes. Ten years ago, after the Single European Act, the initiative to establish ERCIM was taken by Alain Bensoussan, Gerhard Seegmüller and Cor Baayen. They were at that time the directors of INRIA in France, GMD in Germany and CWI in The Netherlands. The founders were convinced that they would improve their ability to satisfy the demands of the changing environment by combining their efforts and complementing each other's fields of research. ERCIM has now 14 members, from all over Europe, including countries from Eastern Europe. The 15th member, Trinity College in Dublin, is expected to join before long.

The Working Groups are the core of ERCIM's activity. The objective of a Working Group is to build and maintain a network of ERCIM researchers in a particular scientific field. At present,

Gerard van Oortmerssen.

there are twelve Working Groups. Two successful examples are the Digital Library Initiative, which created the ERCIM technical reference digital library service and set up collaboration with the National Science Foundation in the US, and the World Wide Web Working Group, which coordinates ERCIM's activities in the further development of web technology in the framework of the World Wide Web Consortium (W3C).

ERCIM's international role is growing, also outside Europe, as can be witnessed from a recently obtained contract from the EU to identify the potential research areas, priorities and partners in South America for projects in the Information Society Technologies programme. A similar contract was obtained just now to organize workshops jointly with the National Science Foundation in the United States in order to promote US participation in the 5th Framework Programme. This means that ERCIM is now recognized by the European Commission as a point of contact for European ICT research. ERCIM faces the future with confidence, and is ready to meet the challenges of the next century.

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Heikki Hämmäinen, Vice-President Nokia Networks

Towards the Mobile Information Society

Nowadays one witnesses the use of devices like laptops for giving presentations, making overhead projectors obsolete, and of mobile 'gadgets' combining functions like watch, alarm clock, scheduler, telephone, message receiver, information retriever, etc. Concerning the emerging mobile information society, more important than technology and having a wider impact is the life-style aspect. These mobile devices are really 'taking over the soul'. The good news is that those devices are certainly doing a good job, the bad news that people become very dependent on them, in particular the younger generation, grown up with those mobile devices.

Audience listening to Heikki Hämmäinen.

Photos: Fred Schuurhof, Fotografie en Vormgeving, VU, Amsterdam.

At present the number of cellular phones is growing much more rapidly than the number of PCs. Whereas nowadays one typically attends a meeting carrying a laptop in your hand and a mobile device for other purposes in your pocket, the last ones will outnumber laptops (as these already outnumber desktops) before long. Turning to the mobile Internet, there are three services insufficiently addressed in the Internet technology so far: location-based, push-type, and personalized profile-based services. The current Internet is about virtual reality, mobile Internet is about real-time applications like information on the time schedule while going to the bus stop. Location-based services is a major new area requiring very difficult technologies, such as satellite-based GPS, triangulation-based technologies, and in-house type of uses where satellite services are not usable. Push-type of services address the real-time character of certain information. Lots of activities are going on in this area, both in the mobile and in the Internet standardization bodies, supporting this evolution. Personalization still has many open questions, mainly coming back to the difficulty of anticipating what people really want. Design of personal profiles, agents analyzing your incoming mail, etc., are being studied already for years, and such problems become even more important in real-time Internet interactions.

Fixed and mobile Web differ in the real-time and the security aspects, as well as some technical aspects, since it has turned out to be difficult to optimize www-type of activities to the mobile environment (complicated radio technology, unreliable transport mechanisms). Because cellular users gradually become Web users as well, the question rises: what are we using our pocket device and our desk/laptop for? Desktop Internet access is often used for browsing and finding information. Use in real life often requires real-time access to that information through mobile devices. It is expected that the ratio mobile/fixed use will dramatically increase as regards the number of sessions.

What will happen technically is much easier to say than how and even more when it happens. Internet will be brought into everyone's pocket by the Wireless Applications Protocol (WAP), gadgets for it have been brought into market just recently. So this happens fast, using very much the existing network infrastructure. The challenge is to optimize the traffic for Internet-type of use, and therefore GPRS (General-purpose Package Radio Service) will be developed on top of GSM networks, the first deployments being expected next year. These developments enable further fundamental steps like the 'always-connected' challenge. At present office PCs and laptops are turned on and off for Internet connection, and it takes some time before the connection is made. Mobile Internet access must be instant. The next generation Internet Protocol IPv6 will enable active addresses for every user, bringing the Internet in your pocket with instant access. It seems possible to stretch the current Internet towards these new types of use, but it is getting more and more expensive. We see that there are enough motivations for the transition to IPv6 even though it causes pain (the present Internet version 4 is 25 years old). The introduction of the third generation cellular networking environment, which is the higher speed wide-area mobile network standard, to be deployed in 2001, will change the perception of what mobile Internet is. The simultaneous evolutions: from the second to third generation cellular networks, in radio technologies, and in the actual Internet layer, form major challenges for the industry.

The transition from virtual reality to real reality Internet takes time, and the fixed tradition in WWW is very strong. Therefore we are pushing hard in the World Wide Web consortium W3C, and by participating there try to activate the mobile aspects.

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Dieter Klumpp, Managing Director Alcatel SEL Foundation

INITI@TIVE D21

The big difference between Germany and its neighbours concerning new technologies is that the neighbours ask: "how could we shape the future?", whereas we in Germany ask: "what does the future bring?". That sounds a bit defensive, and so it is regularly quite necessary to get initiatives on the way.

Photo: Fred Schuurhof, Fotografie en Vormgeving, VU, Amsterdam

Dieter Klumpp.

Germany's position in the international race is not as adequate as it should be. For example, the number of Internet nodes per inhabitant in 1998 was indexed less than 20, half of that in The Netherlands, and far behind the Scandinavian countries and, of course, the USA. Some company leaders including IBM, Hewlett Packard and Alcatel, decided to form an initiative called Initi@tive D21. A big jump is planned within a public-private-partnership: in two years time (1999-2001) a doubling of the number of Internet users (in % of the population) to 20%, catching up almost with the expectations of countries like France and the United Kingdom. The message to the government was: we are 10% of the world market in ICT, how could it then be possible to fall behind the European average?

D21 has the following objectives. First, politicians, business and industry, scientists and civil society groups should develop the best framework conditions for Germany's way to the Information Society. (Germany doesn't know centralisation, it consists of 16 Länder with independent authorities.) Second, government and public administration should become an example as pacemaking ICT users. This 'e-ministration' must be built up from the bottom in Germany. Third, education and qualification are the basic prerequisites for life, work and added value in the 'digital economy' within a knowledge society, and should be treated as such. And fourth, government and business should promote the general affordability of new ICT by enabling all actors to contribute to the framework.

A motivation campaign should lead to incorporation of more enterprises and institutions (currently over one hundred). A head office is being created in Berlin. A working programme can be found already on the Web (http://www.initiatived21.de), and quite recently a PR strategy was put into operation, with focus on 'best practice'. The first D21 plenary conference was held 22 November in Berlin.

A Board of Management, aided by an advisory committee chaired by Chancellor Gerhard Schröder, runs five working groups, with sessions every two weeks:
• regulatory framework and access to Internet
• pacemaker's role of government as ICT user
• education and qualification
• women and information technology
• business startup campaign.

Members of the Board are recruited from business circles, secretarial support from several ministries. Education and Qualification receives considerable additional governmental support (about one billion DM/year). One of the most important strategies is the Business Startup Campaign, in view of the fact that whole Germany, with 80 million people, counts the same number of ICT-startups as in Brooklyn, New York.

The Federal Government also has an Action Programme running over four years, targeting on innovation and jobs for the information society. There is collaboration with D21 to seek ways via public-private partnership to speed up ICT use. Key areas of the Programme include:
• faster dissemination of ICT in all groups of the population
• 'Internet for all' (Access and Affordability)
• modernising training (eg, '44.000 German Schools to the Net')
• stepping up research (eg, Terabit transmission, Man-Machine Interaction)
• new flexible ways of working (eg, telework)
• raising administrative efficiency (eg, e-ministration).

Of course, the USA leads the ICT field, and we as Europeans try to stay close behind. Over 40% of US households owned computers, 25% had Internet access, and 94,1% were connected by telephone at the end of 1998. However, the bright picture is clouded by data that show significant disparities continue between certain demographic groups and regions and, in many cases, the gap between these groups has grown over time (Falling Through the Net: Defining the Digital Divide by Larry Irving, National Telecommunications and Information Administration, U.S. Department of Commerce). A growing gap between the have's and the have-not's is certainly not what we want over here. We should learn from the US experience trying to avoid a digital divide from the outset.

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Roger Needham, Director of Microsoft Research Europe

Microsoft Research — What and Why

When Microsoft was not so large as it is now, it could get its technical agenda in part by looking at things that people were doing with different sorts of computers (not PCs), see what was worth doing, and say: yes, let's do that with PCs. A dozen years ago it was realized that this was not good enough. What companies like Microsoft do research for is to set their technological agenda, in order to develop the technology which people will turn into products in some years time. For this you get to have skill and experience which may be of use also in the short term. Microsoft Research has a sort of dual role: to have its eye on the far horizon, and to be enough in touch with the product activities today, to say: we can help them out. Therefore in Microsoft Research you always find some people doing short-term work with the product folk, although their overall goal remains the distant future.

Photo: Fred Schuurhof, Fotografen en Vormgeving, VU, Amsterdam.

Roger Needham.

Microsoft set up its research operation in Redmond about ten years ago, and hired Rick Rashid from Carnegie Mellon University in Pittsburgh to head it. After five years the leadership was very pleased since it turned out that, although the focus was long-term, practically every major Microsoft product had benefited from the effects of the research programme. It was decided to triple the research efforts, which amounted to hiring about three hundred people. The Microsoft Research lab in Cambridge started in July 1997 as part of this effort; my duty was "to hire the best people and have them do what they are good at". Luca Cardelli came over from the West Coast to work on programming language theory, resulting in a very strong group in that area. There is a logic-based tradition in computer science theory in Europe, which you find in the US hardly at all. Probably this is the main area of computer science where the European tradition is thoroughly distinctive.

Our business is completely people-based: the worst mistake is to take on someone who is not absolutely excellent because the area is important. We are free to choose our own areas of work, but are not uninfluenced by what is done at Redmond. For example, we don't work in graphics or in natural language understanding. We do work, however, in adaptive systems and statistical learning theory, although they have a strong crew at Redmond there. This is because we were able to get individuals who are of extreme value to the company. It is largely for this reason that research is done in the same area in several places - for example the sun never sets on Microsoft vision research. A list of what we're presently working on includes: programming languages, learning, vision, adaptive systems, networks, congestion avoidance, and performance management. Statistics runs as an intellectual thread through much of our work. In information retrieval we work on extension from text to sounds and images. We're starting work in operating systems and hardware, and putting together a group in security. We're now 45 researchers, increasing 10-15 a year.

University people considering joining us hear that we want to regard ourselves, and be regarded, as part of the intellectual scene in computer science research. We realize that most research is done by other people. It is therefore in our own interest to be open and forthcoming with others about what we do. Our university relations are very important: presently we have five people to look after our university research relations in Europe (Microsoft's Europe includes Russia, Israel, and South-Africa). We intend to extend our contacts to 40-50 of the best academic research departments in Europe, in addition to bodies like INRIA and CWI, which are not like anything in North America.

Our contacts cover a wide spectrum: from helping a university research group move their research to work on Microsoft platforms because their industrial sponsors ask for it, to paying for research and sponsoring students.

Our informal mixture between the long-term and watching out for short-term benefit would be a good recipe for universities and other research outfits. Across the world university computer science departments have come under pressure to show their relevance, and to maintain useful contacts with industry. This makes it difficult for them to undertake work which is doubtful of outcome, long-term, speculative, chancy. But that is what research is meant to be about. It ought to be possible to do both, and that is what we try to do. It is a sad state of affairs when companies such as Microsoft find themselves supporting work in universities that is longer-term than the regular funding bodies will pay for. Something here is not quite as it should be.

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Alexander Rinnooy Kan, Executive Board ING Group

Technology and its Impact on the Financial Services Industry

Technology has affected the financial services industry in two waves. An internal wave, which started in the 1960s, has led to considerable cost savings, centralization and outsourcing, technologies that have really transformed the field (data mining), and new operating procedures (risk management). A second, more fundamental external wave is caused by technology itself driving new business models. It has changed the market and the relationship with clients and competitors, and it has generated new ways to interact with both of them.

Photo: Fred Schund, Fotografie en Vormgeving, VU, Amsterdam.

Alexander Rennooy Kan.

ICT has brought enormous reduction in costs, for example by automatizing labour-intensive processes. Handling costs of transactions through Internet are up to a factor hundred less than those of a traditional branch personnel-based transaction.

Outsourcing has become a quite common phenomenon in the finance industry, for example payment systems. The recent outsourcing of R&D in particular gives the ICT research community great opportunities. Financial institutions have to deal with market risks, business risks, and even operational risks, and indeed, selling and repackaging risks is one of the core competences of the financial industry. However, we still have to find the right mathematical models, which calls for expertise in areas like stochastics, numerical analysis, partial differential equations, and optimization.

The second, external wave has fundamentally changed the way in which we distribute our services and gain access to our customers. It started in wholesale finance (abandonment of face-to-face security trading) and is now rapidly spreading into retail finance as well. Electronic money is a reality and E-finance solutions are rapidly gaining customer acceptance. The world is changing before our very eyes.

The following examples illustrate the issues coming up. First, there is an enormous problem with legacy systems. Several assumptions underlying the traditional approach turn out to be false, for example that old legacy systems should be fully replaced, and that systems are best designed in their entirety first and then constructed. Our experience is that in view of the rapidly changing environments the system should be modular. We hope to build the new systems by supplementing the old. There are ever better ways to do so because our systems are increasingly broken down into four fairly separate parts: user interface, error prevention component, database component, and core logic. At ING systems are frequently improved by just replacing the user interface.

Second, we are witnessing a dramatic decrease in the time-to-market. Traditionally the development cycle of a new product or service with a heavy IT-component is 8-9 years, whereas the market perspectives today require 2-3 years at most. This requires another business style of cooperation, including significant outsourcing. As a result the fundamental role of IT staff is changing. Computer centres will be joining external centres, becoming much less dependent on the core business. Outside professionals will increasingly build IT functionality. And finally, locally employed support groups should better cope with the needs of our business units. For a proper way to organize our renovation process we need contacts with communities such as ERCIM. A special handicap is that the service industry still lacks the tradition of industrial groups with well-established R&D contacts.

The third example is pervasive computing. Developments like Internet finance and (mobile) telephone finance are of crucial importance. Industry realizes that to work with these new technologies implies the need for open interoperable standards. As soon as that is realized our future customers will use mobile phones, TVs, laptops, and desktops whenever it suits them best. Things are moving here very rapidly indeed.

Looking at all these truly dazzling perspectives, it is stunning that so few people under twenty-five feel inspired by them. This ought to worry us all: ICT and mathematics clearly are increasingly important for society, but interest by students for these disciplines as well as the general public seems to decrease. The numbers for The Netherlands are dramatic: since the early nineties the number of newly enrolled students has almost halved for many of these disciplines, few female students are driven to them, and only 10% of the graduates finds a research job. We should ensure a higher intake of students in science and technology, create the right educational facilities, emphasize the fantastic career possibilities, and provide the right material incentives, also in terms of career perspectives.

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Jacques-Louis Lions, Institut de France

The Future of Scientific Computation

The main problems coming from society at large which seem to be coming or are already with us, are:
• Sustainable development of everything: environment, ...
• Global competition: optimization of everything
• Good health for everybody, and forever
• Safety of everything
What can be the role of scientific computation in these kind of questions?

For sustainable development we need simulations with a very large time horizon. Tools needed include models of the aging of materials: interfaces, corrosion, cracks. (For example, cracks are fundamental to the aging of planes.) For this you have to return to 'ab initio' computation on the molecular level (Schrödinger equations). However, then you meet the curse of dimensionality (a large number of variables, the notion stems from dynamic programming in the early fifties). In connection with simulations with a very large time horizon you find the notion of an ensemble of solutions, a trend very important in climatology. Such an ensemble consists of the results of an off-line computation repeated several times with slightly different data. Then you try to extract useful information from this set of results using statistical methods. Another recent development is validated computation of functionals of interest. For example, you have a large climatological model, but you are only interested in a tiny part, let us say the probability of having typhoons. How do you extract this information only without having to compute everything?

Certainly in the industrial world global competition requires optimization of all kinds of things. For example, real-time control of extremely complex phenomena like fusion, turbulence, and combustion, or control of sophisticated processes. Here the curse of dimensionality strikes again. Brute force is impossible (one must think of nonlinear partial differential equations in 50 variables, not unknowns). Tricks used include decomposition of spaces, neural networks, and Monte Carlo (if everything else has failed). Main trends in solution methods are: decomposition of a problem in small pieces, and arrange things so that local solutions automatically give a good global performance (this is a general trend in computer science).

In the 'Good Health' problem the challenge of challenges is the simulation of living systems: heart, liver, brain, for example to train surgeons. Here you need to have the answer of what you do (feedback) in real-time, and because there are large deformations (eg, surgery of a liver), the system is nonlinear as well. Solving such a problem in general is out of reach, but one can do something by linearization, which makes sense if the deformations are small (surgeons also make small incisions). In connection with computation also the genome problem should be mentioned here. Another fascinating problem is the production of new drugs, because it amounts to the control of Schrödinger equations. Once again these require 'ab initio' computations on the molecular level.

Jacques-Luis Lions.

Photo: Fred Schuurhof, Fotografie en Vormgeving, VU, Amsterdam.

For the safety of everything it is clear that an advanced vision of a system is needed (think of a new aeroplane), including maintenance, repairs, and waste, without risk at each step. Less obvious is to develop an advanced vision on the safety of a set of systems, such as global transportation (these systems are presently not sustainable to development). Important is here the search for feedbacks, such as anticipative functionals, which are very sensitive to change occurring in the years to come (coral growth is a good example). Finally, of course, the safety of software is a very important area.

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Discussion

The Web, Europe, and ERCIM

The ERCIM jubilee events ended with a video-recorded statement by Tim Berners-Lee, director of the World Wide Web Consortium (W3C), followed by a discussion led by Dick Bulterman (Oratr*ix* Development BV, The Netherlands). The following is a summary of the points made during the session.

The New York Times recently described the Web as a uniquely American phenomenon, although it was invented at CERN in Geneva, Switzerland. Why and how did Europe let the Web get away? Looking back may seem unproductive, but one also learns a thing or two. There are several reasons. The Internet was very much more deployed in the US, where many universities were connected, through which the Web naturally spread across the country and local telephone calls are free in the USA, which makes it less of a barrier to acceptance. The fact that the first user-friendly browser was American certainly helped. Europe had initially a strong 'not invented here' feeling towards the Internet, it wanted to wait for the ISO solutions (which didn't really come) when in fact the Internet was running fine with IP. Actually CWI, being the first non-military Internet site in Europe, had great troubles in selling the Internet. Only when the Web came along, the Internet was politically accepted in Europe. Another reason for the much faster spread of the Web in the US was the American entrepreneurial spirit (there are many start-ups) of 'do first and discuss afterwards' against the more considered European way. And, of course, there is a linguistic reason. Monolinguality helped the Web spreading faster in the US, and there was an incentive to put on a website because English is understood around the globe.

In contrast with the American monolithic culture the European diversity may be an impediment to certain developments, it also offers unique opportunities, for example using the multilingual possibilities of the Web: the native English speakers will not form the majority on the Web before long. What is most important on the Web is content, not technology, and Europe possesses the richness and diversity of contents. Also a much richer set of ideas is likely to emerge when boundaries allow people to think independently. Europe can distinguish itself in several ways in the further development of the Web. There is, for example, a lot of know-how in graphics. Europe is strong in mobile communication and can play an important role in matters like intellectual property rights (IPR) and privacy. The rapidly increasing bulk of legacy HTML in the US gives Europe (and ERCIM) the chance to take the lead in resource discovery over heterogeneous resources by connecting its pre-existing databases to the Web and put metadata in front of it (to be done by progressively improving XML and RDF).

ERCIM creates a balance between European diversity and necessary homogeneity by building bridges between different cultures and stimulating technical ideas to move freely within academia and across borders. Several ERCIM members also house a W3C office, which helped the W3C Consortium be connected into Europe. The future Web will be much more of a collaborative system (as it was always meant to be). ERCIM, being a collaborative body itself, can play an important role

Tim Berners-Lee, Director of the World Wide Web Consortium (W3C) during the video-recorded statement.

here, for example in making a very consistent user interface. ERCIM may improve its collaborative force using the Web as a tool, thus contributing to the more general task for Europe to build the new society on top of the Web. ERCIM could also play an honest broker role with respect to the 'big four' companies (essentially all American). W3C is very heavily swayed by its members, several of them having sectoral interests in the Web (databases, graphics, ...), whereas ERCIM jointly has a very wide-spread interest in the very many concepts on the Web and thus can bring integrity to it, as well as bring people together who are interested in the Web, not each in their own little niche.

New ideas are often born in an ivory tower, far away from tradition. On the other hand, the consumer requires new products to be incrementally compatible, and in order to realize a brilliant idea in the next round's software and websites it is important to find a balance between idea and compatibility. In the US there is a broad feeling that European programmes like ESPRIT introduced a level of overhead that inhibited quick focused entry into new areas. ESPRIT was worth its weight in gold in getting people who were not used to collaborating to do so. However, in introducing new technologies it is hardly possible to compete with commerce, which can act often non-bureaucratically and disposes of fairly large budgets (the budget of the Framework Programme is not more than 4% of the total research money in Europe). At the same time American companies are extremely eager to participate in the European IST Programme. In general there is a lot of interest to do research in these programmes, as the ongoing over-subscription shows. In the past the creation of the W3C consortium in Europe also received support from

Photo: Fred Schuurhof, Fotografie en Vormgeving, VU, Amsterdam.

Dick Bulterman, Oratrix, The Netherlands.

ESPRIT. When entering a new area, consortium building and submitting a proposal takes one year, followed by the project period, and only then the standardization process starts. For some things this works and for some it doesn't. In any case ideas and their time-to-market should be in balance. To be sure, work that needs to be done quickly is, also in the US, not done in governmental programmes but in the companies. One has to put activities and their funding in the right place.

The research community has certainly a role in developing standards. In general a lot of this process is political, not technical. The reason is that the very high costs of developing new software for economies of scale markets are only recaptured if you just hit the mainstream. Experience with the Web multimedia activity around the development of the language SMIL shows that companies initially show a broad willingness to accept people from the outside into the process, but as soon as something becomes a recommendation commercial interest prevails. Companies coming up with a new product see to it that it apparently conforms to standards, but a keen eye, for example in the form of more ERCIM involvement in the W3C process, is required here. In order to give technical arguments sufficient weight against company policies it is very important that researchers come to standardization meetings with something that works (product, pilot, demonstrator).

W3C is concerned about intellectual property rights: does the Web remain available for everyone if some people take for example with patents control over protocols used on the Web? W3C is supposed to control developments, but actually a few giants like Microsoft and Netscape have 'de facto' control , because they have all the resources to control market access. It is difficult to see what the future Web will be like. It did not start with someone saying 'Let's invent the Web'. It's a gradual, and global process, which happens almost by chance. There was a very strong feeling from US industry that systems like this should evolve through combative market forces. However, dividing the Web market, with its multiple technologies, between only a few players will not work, as consumer industry has shown, because of insufficient volume. This is relevant for the transition to the mobile Internet which is also hampered by the dozen odd coding formats used in the Web. (A variety of standards is on its own not a problem, not using or changing them is.) An important driving force, changing completely the technology and its use on the Web, is the expected increase with a factor twenty in bandwidth for next year, leading to 1 Megabit for everybody in five years. Of course, now everybody is speaking about video and images, but the future use of the Web will probably be something very different. The bandwidth explosion will cause a shift from the academic market. (There is some inverse similarity with the movie industry in the thirties. Movies were then completely outside academic life.) Dealing with this social phenomenon is the next challenge.

In any case the Next Generation Web should enable collaborative work to be done immediately, all participants being synchronously attached to the Web. This may, for example, reduce considerably the development time of a prototype. It's definitely going in this direction. Shared knowledge, which becomes information by association with activity, plays a crucial role in a knowledge-based economy. Paradoxically, such an economy drives on buying and selling information, thus opposing the motivation to share. In view of debates raging over ownership issues of faculty members' notes, it seems that issues like IPR play a larger role than technology in bringing about a knowledge-based economy.

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Summaries of the presentations and the discussion on pages 8-15 were edited by Henk Nieland.

Control and System Theory: Introduction

by Jan H. van Schuppen

Control is used to effectively operate machines and computers. The general public is not fully aware of the way technological products are critically dependent on feedback control for their operation. A description of several examples of control follows.

In telephone switches there is admission control for every arriving call. If there were no admission control during the periods of overload (think of TV games in which the public is asked to dial the studio), the performance would decline dramatically to a few percentages of the theoretical capacity or even to zero.

Dynamic speed limits are displayed on motorways in major urban areas of Europe to smooth the traffic flow. The control algorithms for these limits are based on a mathematical model for traffic flow and on control theory. In a juice processing plant control is used to determine the starting time and the starting conditions of all operations. Conditions to be checked include the availability of raw materials and of resources, and the proper functioning of machines (breakdowns of machines are a major problem). New procedures for air traffic control current under development in Europe and the U.S.A. are based on control theory. The mathematical model for this is based on the laws of mechanics and on the ordering of discrete operations.

Standards for levels of toxic substances are set by national agencies after experimentation with animals and with human beings. The algorithms used for estimation of concentration levels in the different organs and of parameters in the mathematical models are based on system theory and system identification. Control of waste water treatment plants is based on control theory and system identification. Predictions of weather over a horizon of several days, of air pollution concentrations, and of sea water levels at coastal areas are all based on the Kalman filter developed as part of control theory.

In the examples mentioned, control in the form of feedback is used. Sensors provide information about physical conditions or about the logical state of the system. This information is then used to adjust the input

to the engineering system such that a controlled variable will stay near a set point or will follow a reference trajectory. Control design requires the formulation of a mathematical model often in the form of a (partial) differential equation, or an automaton, or a combination of these as in a hybrid system. Control theory then provides a procedure for the construction of a control law. The control law specifies which input value to use for every state of the system.

Control theory as a scientific subject has a long history, see the keynote by Vladimír Kucera at page 3. Subjects of mathematics used in control and system theory include (partial) differential equations, functional analysis, linear algebra, numerical linear algebra, differential geometry, and algebraic geometry. Computer science subjects include automata theory, Petri nets, computation and complexity, and real-time operating systems.

The motivation for control theory shifts with the development of technology and with the needs of society. Early motivating engineering systems were: amplifiers for radios, radar detection equipment, aircraft, and aerospace vehicles. Recently control has been applied to the following technological products, areas, and services and more of this is likely to follow: cars, motorway networks, air traffic control, communication networks, manufacturing, macroeconomic control, mathematical finance, public health, the life sciences, environmental protection, weather prediction, and climate Modelling.

The research program for control and system theory in the coming decade includes the following topics. Control theory for discrete-event systems, for hybrid systems, for particular classes of nonlinear systems, for systems described by partial differential equations, and for particular classes of stochastic systems. Realization and identification is likely to

develop with algebra because of the availability of symbolic computation algorithms.

Control of nonlinear systems and of systems described by partial differential equations is likely to develop for mechanical and other physical systems. Control of discrete-event systems and of hybrid systems is motivated by the use of computers for control of engineering systems. This subject will be influenced by the developments in theoretical computer science, in particular by computation, complexity, automata theory, and algebra and coalgebra.

The papers of this Special Theme Section are structured as follows. The first four articles concern concrete engineering problems for which control and system theory are used. Papers on control theory follow next. Signal processing is based on methods from system theory and two papers describe applications. Control theory is based on system theory, in particular on realization and system identification. Several papers describe how system theory has been or may be used for engineering control and signal processing problems.

Please contact:

Jan H. van Schuppen – CWI
Tel: +31 20 592 4085
E-mail: J.H.van.Schuppen@cwi.nl

The Modelling and Control of Living Resources

by Jean-Luc Gouzé and Olivier Bernard

The aim of the research team COMORE (Modelling and Control of Renewable Resources) at INRIA Sophia-Antipolis is to apply methods from control theory (feedback control, estimation, identification, optimal control, game theory) and from the theory of dynamical systems to understand the working of the living exploited resources (renewable resources) and to manage them. COMORE is a joint project with the CNRS Villefranche-sur-Mer. The main research themes are the modelling of biological systems, the study of the properties of nonlinear dynamical biological systems, the design of robust observers, and the control of biological systems. We apply and validate our results to various fields: phytoplankton growth, fisheries and forests, wastewater treatment processes, food agro-industry.

COMORE is interested in the mathematical modelling of biological systems, more particularly of ecosystems subject to a human action (the framework is thus that of renewable resources). It is now clear that it is important to understand the working of these complex dynamical systems in order to regulate the exploitation of these resources by man. Our conceptual framework is that of Control Theory: a system, described by state variables, with inputs (action on the system), and outputs (the measurements available on the system). In our case, the system is an ecosystem, modelled by a mathematical model (generally a differential equation). Its variables are, for example, the number or the density of populations. The inputs can be the actions which one exerts on the ecosystem: eg action of the man (fishing effort, introduction of food, etc), or action of an external factor (pollution, light, etc). The outputs will be some product that one can collect from this ecosystem (harvest, capture, production of a biochemical product, etc.), or some measurements (number of individuals, concentrations, etc.).

This approach begins with the mathematical modelling of the system. This stage is fundamental and difficult, because one does not have rigorous laws as in physics. We develop techniques to identify and validate the structure of a model from a set of available noisy measurements. This approach is based on the qualitative analysis of the data (extrema, relative position,…) that we use to build a model able to reproduce the same qualitative pattern. We work also on methods dedicated to the identification of the mathematical functions that link the dynamics of a state variable to other variables. Finally we verify that the model satisfies some biological constraints: for example the concentrations must remain positive. A fundamental problem is that of the validation, or invalidation, of these models: how to accept, with a certain precision, a model by comparing it with experimental noisy data ? The traditional approach, which consists of identifying the parameters of the model by minimizing a criterion of variation between the outputs of the model and the data, is often inefficient. We are developing new methods more pertinent for the biologists.

From a model, that synthesises the behaviour of such a complex nonlinear biological system, we can study its properties and understand the way it works. One seeks to study the qualitative behaviour of the system, the existence of equilibria, their stability, the existence of periodic solutions. These qualitative questions are fundamental because they tell us whether or not the system is viable (the model does not predict the extinction of any species, etc). Specific problems are posed by the biological origin of the models: functions or parameters are uncertain, or unknown; what can we say on the behaviour of the model? Often, the models have a strong structure belonging to a general class of systems, for which one develops adapted techniques: for example the well-known models of Lotka-Volterra in dimension n, describing the interactions between n species.

Once the dynamics of the considered living system has been understood we consider problems of regulation: how to keep a variable at a given level? This is important for example in the framework of waste water treatment where the pollution levels are imposed by laws. The main problem that we have to address is to try to control a complex system when the model is uncertain. We work mainly on a class of biological systems: the bioreactors that have a growing importance in many domains related to
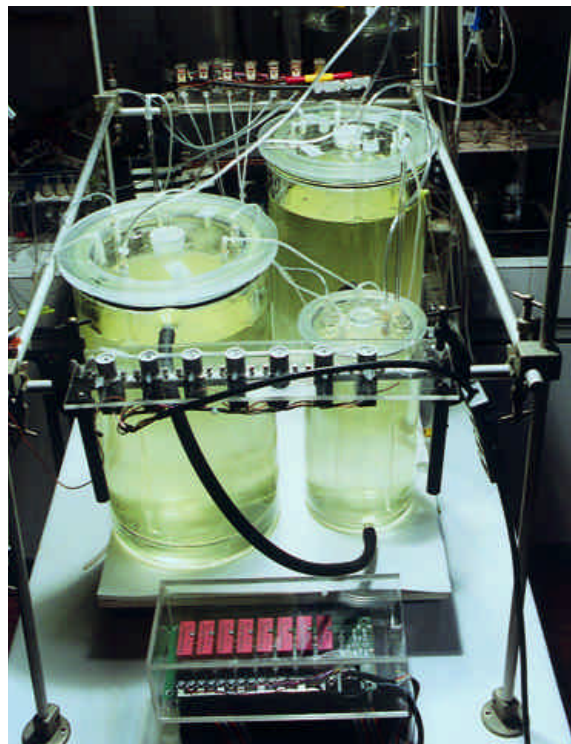
Growth of phytoplankton in the chemostat (CNRS, Villefranche sur mer, Laboratoire d'Ecologie du Plancton Marin).

the human environment: alimentary (food production), pharmaceuticals (production of medicine), environment (waste water treatment, plankton study), etc. The strong structure of these systems for which the hydraulic flow plays an important role is used in order to derive controllers.

Finally we develop observers that use the model and on-line measurements to estimate asymptotically the variables that are not measured directly. These so called 'software sensors' can help the monitoring of some systems but also replace some expensive measurements. We face with the problem of the various uncertainties that are specific to biological modelling: the model is uncertain (parameters, functions), but also the inputs can be uncertain and the outputs highly variable. We have therefore to deal with these uncertainties in the design of the observers. We developed robust observers that assume that some parameter or input belongs to a given interval. The observer estimates then asymptotically an interval for the state variables (collaboration with INRA Montpellier). The methods that we develop are validated and tested on several applications:

Growth of the Marine Plankton
We work in association with the Station Zoologique of the CNRS (Villefranche-

sur-Mer, France), which developed a chemostat (open bioreactor where algae or cells grow on a substrate) fully automated and managed by computers; this system is well adapted to the application of the methods resulting from the theory of control. Our current work consists of studying and validating models of growth for the plankton in a variable environment (light, food, etc). The growth of the plankton is the basis of all the production of the organic matter of the oceans (fishes, etc); however, the existing traditional models (Monod, Droop) are often unsatisfactory. We seek to obtain models valid during the transitory stages, away from the equilibrium.

Fisheries and forests
The scale of the problems changes here; data are rare and noisy. We consider (in collaboration with IFREMER Nantes) some important methodological problems: how to model the stock-recruitment relationship of the fish (the relationship between the number of fertile adults and eggs they produce)? How does one optimize the exploitation of fisheries or forests with respect to some criteria?

Waste Water Treatment Processes
In collaboration with the Laboratory of Environmental Biotechnology of INRA (Narbonne, France), we work on activated sludge wastewater treatment plants and on

anaerobic digesters. We build dynamical models and we design robust observers that take into account the large uncertainties encountered in this field. As an example, the amount of waste water to treat, which is an important input, is rarely measured. The software sensors are used to monitor the processes and help to detect a failure.

Food Agro-Industry
The control theory methods are helpful to optimise the production of some agricultural bioproduct, or the biomass of micro-organisms used in fermentation. We work in collaboration with the CESAME (Louvain-la-Neuve, Belgium) in order to optimise the production of vanillin by filamentous fungi. In this framework we have to take advantage from the (relative) good quality of the measurements obtained with gaseous flow rates.

Links:

COMORE website:
http://www.inria.fr/Equipes/COMORE eng.html

Please contact:

Jean-Luc Gouzé and Olivier Bernard – INRA Sophia-Antipolis
Tel: +33 4 9238 7875 / 7785
E-mail: Jean-Luc.Gouze@inria.fr, Olivier.Bernard@inria.fr

Dynamic Route Control for Motorway Networks

by Jan H. van Schuppen

Control measures have been installed on motorway networks around the main urban centres of several countries and more are planned, see Figure 1. Car drivers on motorway networks may be aided by information about traffic. Route control helps car drivers to select a route that optimizes travel time through a network. CWI has participated in a EU project for the next generation of route control.

Route control aims to provide information to network users such that each user can optimize travel costs. Provision of routing information or route directives is expected to result in an efficient use of the network capacity under all traffic conditions. Route control is likely to be primarily useful in traffic circumstances with traffic queues or with major incidents.

Currently used enroute measures of route information include: variable messages signs (VMSs), messages broadcast on radio channels, and variable direction signs. The information may have the form of lengths of traffic queues at particular locations; travel time estimates or predictions for one or several routes; or variable direction signs that should be

considered as recommendations. The road user then may make a route choice.

The display of lengths of traffic queues although partly useful is often not accurate enough for the network users. The road user wants to minimize travel costs over the possible routes. In this article travel costs are identified with travel time. Travel time predictions are

Figure 1 (left): A variable message sign on the motorway network at Amsterdam. A road user is provided information about traffic queues on two possible routes to Schiphol airport.
Figure 2 (below): A map of the motorway network near Amsterdam.

useful when based on the anticipated effect of the information provided by the signs. This is not yet the case in most current traffic information systems. In the literature there is much confusion about the interaction of information provision and control.

For the next generation of route control measures variable direction signs or travel time predictions are currently considered. The direction signs are to be considered as recommendations, the network user is free to choose a route. This proposal then leads to the problem as to how to compute the variable route directives. The mathematics used in the investigation is control and system theory, in particular control of dynamic games, predictive control, control theory of nonlinear systems, and Modelling.

The route control problem is formulated as a game problem with many decision makers or agents. It will be assumed that all road users for a particular origin-destination (OD) pair can be considered as an agent in the game. Although in principle the road users make the route choice individually, the choice will be the same for all users travelling on the same OD pair. The restriction to OD traffic flows as agents corresponds to a user equilibrium as used in traffic theory.

Each decision maker, an OD traffic flow, must make a choice as to the route to use in case there are two or more routes

available. The route directive thus consists of the route choices of all OD pairs. It is further assumed that the control objective of each OD traffic flow is to minimize the travel time from origin to destination. In dynamic game problems an equilibrium must be selected. A Nash equilibrium is a route directive, for all OD traffic flows, such that if only one OD pair deviates from the route of that equilibrium by taking another route then its cost will increase. The restriction to a Nash

equilibrium seems quite reasonable considering the fact that drivers on different OD traffic flows generally do not communicate with each other.

Although there is theory available for its solution, the dynamic game problem in its full generality is neither analytically nor numerically tractable. Therefore a control law has been formulated based on a moving horizon algorithm in a discrete-time setting. At each time step a Nash

equilibrium of the route directives is searched for, while the travel times of the traffic flow for any OD pair are estimated by a predictive control algorithm.

After the theoretical part of the investigation had been concluded the national road agency asked CWI to carry out a simulation study of the proposed algorithm. A model for traffic flow has been detailed for the flow in a motorway network near Amsterdam, see Figure 2. Route control is considered only for four OD pairs denoted by the major motorways: (A2,A8), (A4,A8), (A8,A2), and (A8,A4).

A particular simulation concerns the following traffic condition. The model is simulated for 15 minutes until it reached an equilibrium state. Then an incident was simulated to occur in the sections directly south of the Coentunnel, resulting in a reduction in the number of lanes in these sections from two to one. Consequently a traffic queue started to build up on the Western part of the ring A10 through the Coentunnel. From the state of the network model at 15 minutes after the start of the incident, travel time estimates were made under all possible route directives. That route directive is a Nash equilibrium where for almost all OD traffic flows the shortest distance route is recommended except for the OD traffic flow (A8,A2) for which the variable route directive points to the alternate route via the Northern and Eastern part of the ring. Densities of traffic on the outer and the inner ring of the A10 motorway ring with this route directive are displayed in the Figures 3 and 4.

A control law for route control of motorway networks has been described. Further development work is needed before the control law can be tested on the road. Mathematics research is needed for control theory of dynamic games, and on the existence, uniqueness, and search algorithms of Nash equilibria in transportation networks.
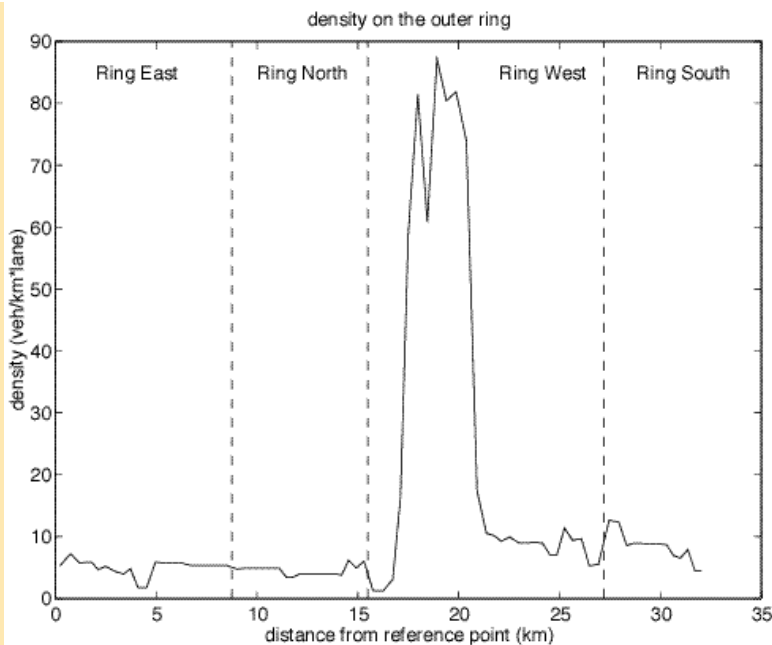

Figure 3: Density of traffic on the outer ring of the Amsterdam network in case of a traffic situation with a traffic queue.
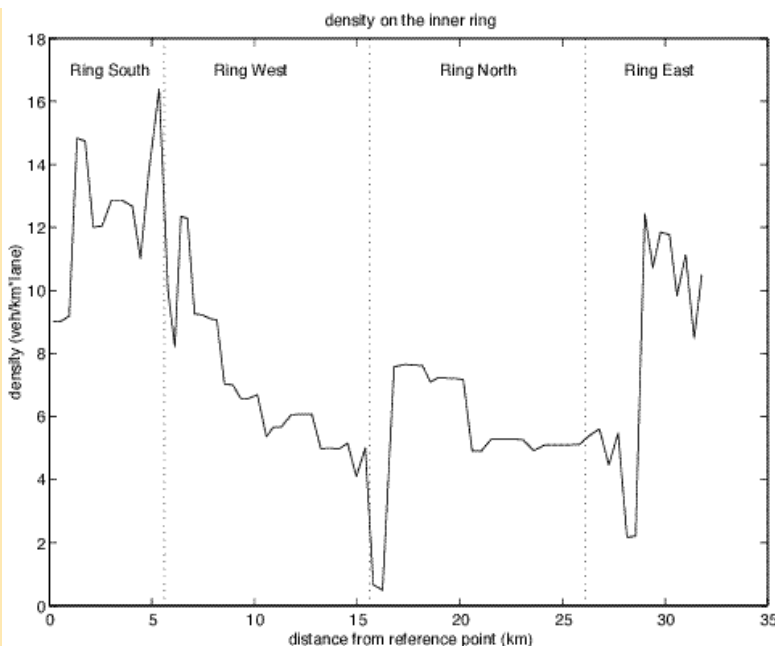

Figure 4: Density of traffic on the inner ring of the Amsterdam network in case of a traffic situation with a traffic queue.

Please contact:

Jan H. van Schuppen – CWI
Tel: +31 20 592 4085
E-mail: J.H.van.Schuppen@cwi.nl

Continuous Interaction and Manual Control

by Gavin Doherty

Under the auspices of the TMR project 'Theory and Application of Continuous Interaction Techniques' (TACIT), the author has been looking at possible applications of classical manual control theory to support the design of the 'continuous' interfaces present in modern interactive systems.

As interfaces evolve, interaction techniques increasingly involve a much more continuous form of interaction with the user, over both human-to-computer (input) computer-to-human (output) channels. Such interaction could involve gestures, speech and animation in addition to more 'conventional' interaction via mouse or keyboard. This poses a problem for the design of interactive systems as it becomes increasingly necessary to consider interactions occurring over an interval, in continuous time. This issue is the focus of the TACIT project, the aim of which is to develop theories (including mathematically based models) and methodologies for the design of interfaces in which continuous interaction techniques are used. The main TACIT partners are Department of Psychology, University of Sheffield; DFKI - Deutsches Forschungs-zentrum für Künstliche Intelligenz GmbH, Saarbrücken; Department of Industrial Engineering, University of Parma; IT Human Computer Interaction Group, University of York; ICS-FORTH; Laboratoire CLIPS-IMAG, Grenoble and CLRC. The project runs to the end of 2001.

Manual Control Theory

One body of work the project has been looking at to aid in the analysis of such interfaces is manual control theory. The theory developed out of the efforts of feedback control engineers after WWII, who required models of human performance for continuous tasks such as tracking with anti-aircraft guns. This seems to be an area worth exploring, firstly since it is generally concerned with systems which are controlled continuously by the user, although discrete time analogues of the various models exist. Secondly, it is an approach which models both system and user and hence is compatible with research efforts on 'syndetic' models, in which aspects of both system and user are specified within the same framework. Thirdly, it is an approach where continuous

mathematics is used to describe functions of time. Finally, it is a theory which has been validated with respect to experimental data and applied extensively within domains such as avionics.

The premise of manual control theory is that for certain tasks, the performance of the human operator can be well approximated by a describing function, much as an inanimate controller would be. Hence, in the literature frequency domain representations of behaviour in continuous time are applied. Two of the main classes of system modeled by the theory are compensatory and pursuit systems. A system where only the error signal is available to the human operator is a compensatory system. A system where both the target and current output are available is called a pursuit system. In many pursuit systems the user can also see a portion of the input in advance; such tasks are called preview tasks.

A simple and widely used model is the crossover model, which has two main parameters, a gain and a time delay. Even with this simple model we can investigate some quite interesting phenomena. For example consider a compensatory system with a certain delay, if we have a low gain, then the system will move only slowly towards the target, and hence will seem sluggish. Alternatively if the gain is very high, then the system is very likely to overshoot the target, requiring an adjustment in the opposite direction, which may in turn overshoot, and so on. This is known as oscillatory behaviour. Many more detailed models have also been developed; there are anthropo-morphic models which have a cognitive or physiological basis. For example the 'structural model' attempts to reflect the structure of the human, with central nervous system, neuromuscular and vestibular components. Alternatively there is the optimal control approach,

where algorithmic models which very closely match empirical data are used, but which do not have any direct relationship or explanation in terms of human neural and cognitive architecture.

Applying the Theory

With regard to potential areas of application of the theory, firstly, there is the possibility of applying the theory directly to interfaces such as those with continuous haptic interaction. Such models give us better estimates of human performance than simple HCI approaches such as the model human information processor of Card et. al., and also allow us to consider a wider range of tasks than rules such as Fitt's law for selection. It might perhaps also be useful to develop some refined models for specific technologies and scenarios, such as gestural interfaces. Secondly there is the possibility of incorporating some part of the models into formal specification techniques. Thirdly it may help in the development of signal processing models to complement cognitive models being applied in the project, such as the Interacting Cognitive Subsystems (ICS) model.

The TACIT partners will be running a workshop entitled 'Continuity in Human Computer Interaction' at CHI 2000, 2-3 April 2000.

Links:

TACIT Home Page:
http://kazan.cnuce.cnr.it/TACIT/
European Annual Manual Conference:
http://www.wbmt.tudelft.nl/mms/annualmanual/

Please contact:

Gavin Doherty – CLRC
Tel: +44 1235 44 6738
E-mail: G.J.Doherty@rl.ac.uk

Control Algorithms for Electroelastic Damping

by Maurizio Brocato and Evgeny Dudnikov

External fields may affect the mechanical properties of certain materials, which can thus be used in control devices. In the design of such devices, a control algorithm for a distributed parameter system must be used. We report here on options available during the development of an electrorheologic actuator at IEI-CNR.

The mechanical behaviour of electrorheologic fluids depends on the electric field applied. Sensors and actuators can be designed taking advantage of the properties of these fluids. The mathematical problem to be tackled is the control of a distributed parameters system, with the control acting on material elements in such a way that the parameters entering their constitutive description may be altered. The subcase we are studying is that of an elastic material with the elastic moduli depending, within limits, on the control field. The material can have varying degrees of stiffness as, for example, in an electrorheologic fluid undergoing small displacements, when an electric field is applied with varying intensity. The system under study can be controlled so that, although almost always elastic, its mechanical vibrations are damped. The damping is due to a transfer of mechanical energy into the energy of

the controller (ie, in experiments in the high voltage generator). This is possible when, under imposed strain, the material changes from a stiffer to a softer state (see ERCIM NEWS 38, p.24-25).

In a previous paper, the first author suggested the use of an extended Pontryagin's Maximum Principle, applicable to distributed parameters systems. To find optimal damping, minimum total kinetic energy was sought. The resulting optimal paths are of the type shown with thick red lines in Figures 1 and 3, on a deformation vs. rate of deformation plane: maximum or minimum stiffness must be provided respectively when the elastic energy increases or decreases. The solution represented in Figure 1 differs from that of Figure 3 because the range within which the controlled stiffness varies is wider in the second case. The bang-bang

type control functions, corresponding to the two above-mentioned solutions are shown vs. time, with thick red lines in Figures 2 and 4 respectively. This control strategy can be implemented through a feed-forward loop as follows: sense the velocity and compare it with the previous measurement; if the two samples have different signs, switch the electric field from off to on or vice versa.

If forced vibrations must be damped, the same strategy proves useful when no forcing frequency is lower than the lowest natural frequency of the system. Otherwise, more complex algorithms must be implemented.

Thus we have investigated the possibility of stabilizing the system through the method of velocity gradient developed by the group of A. Fradkov at St Petersburg. This method may be computationally easier to implement than Pontryagin's. Three classes of solutions are generally provided: differential, linear and relay control. In our case, the latter corresponds to the bang-bang solution suggested by Pontryagin's Principle. Application of the linear control algorithm to our example gives trajectories and control functions of the type shown with black thin lines in the figures. When the range of possible controls is relatively narrow, trajectories are close to the optimum, especially during the first few periods. The control function must then be updated. Feedback loops are thus required in applications.
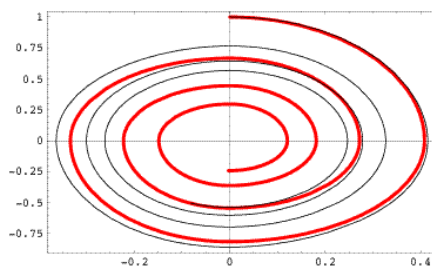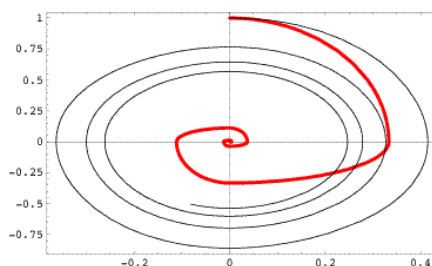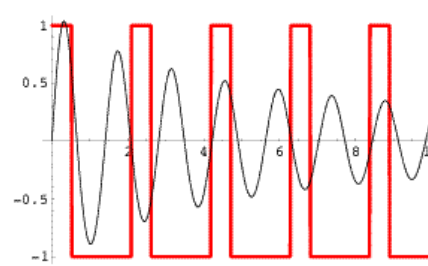
Figure 1: Phase diagrams for Pontryagin's optimal control (thick red) and velocity gradient control (thin black) in case of a narrow range of possible controls.
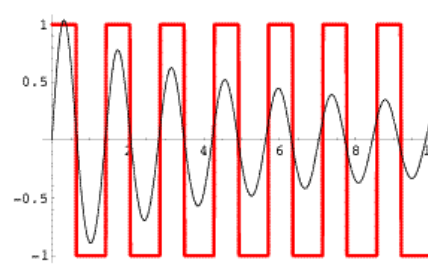
Figure 2: Control functions vs. time corresponding to the phase diagrams of Figure 1.

Figure 3: Same as Figure 1 in the case of a wide range of possible controls.

Figure 4: Control functions vs. time corresponding to the phase diagrams of Figure 3.

Please contact:

Maurizio Brocato – IEI-CNR
Tel: +39 050 593 422
E-mail: brocato@iei.pi.cnr.it

Polynomial Methods for Systems, Signals and Control

by Michael Šebek

Polynomial methods are modern design techniques for complex multi-variable systems, signals and processes based on manipulations with polynomials, polynomial matrices, and other similar objects. Invented, developed to leading world-level and applied in Europe, the methods are considered typically European.

The theoretical background of polynomial design techniques for control systems can be traced back to the late fifties. However, their frontal attack to control theory started in seventies when the first really important results were achieved. The best known result is certainly the parameterization of all controllers that stabilize a given plant, now referred to as Youla-Kucera parameterization. In the eighties, the polynomial methods were used to solve robust control problems and employed also in the field of signal processing.

Algorithms and Software

In spite of many advantages, the polynomial methods were not fully successful in industrial application until recently. Due to the original lack of really workable (that is, efficient and reliable) numerical algorithms for polynomial matrices, no software was available for polynomial methods for quite a long time. In the nineties, this gap was filled by a concerted effort of research teams from the University of Twente and UTIA, Prague, supported by the European project 'Algorithms for CAE (Computer Aided Engineering) based on modern polynomial methods in control'. This project increased interest in numerics for polynomial matrices resulting in several breakthroughs such as the first numerically stable procedures for various polynomial matrix problems or the new generation of very fast routines based on Fast Fourier Transformation. Another product of the project was the first version of the Matlab based software package called Polynomial Toolbox. The Polynomial Toolbox 1.5, a freeware publicly available via the web in 1997, appeared to be very successful: It was downloaded by more than one thousand users worldwide, one third from industry including major companies like Ericsson, Kodak and Daimler-Benz. In 1998, the former project participants founded a new company, PolyX, Ltd. aiming to further

develop and commercialize software for polynomial methods.

The EUROPOLY Network

Formerly developed as a highly theoretical tool, polynomial methods are now successfully applied in a variety of engineering fields. Their advantages are naturally recognized by numerous industries ranging from the control of human muscles through automobile industry to the design of filters for mobile phones. Current polynomial activity in Europe is coordinated through the Network of Excellence for Industrial Applications of Polynomial Methods EUROPOLY. The Network is coordinated by UTIA Prague. It consists of thirteen European companies and research groups and many external

members worldwide. The network maintains the EUROPOLY web site at http://www.utia.cas.cz/europoly/ , issues a quarterly Newsletter and organizes regular meetings and workshops.

Polynomial Toolbox 2

In spring 1999, PolyX, Ltd. launched a new version of the package. The Polynomial Toolbox 2 for Matlab 5 is object oriented, far more user friendly, much faster and more reliable. It is currently the best software available for polynomials, polynomial matrices, and their application in systems, signals and control. It features:
•over 200 macros for polynomials and polynomial matrices - Objects, overloaded operations, functions,
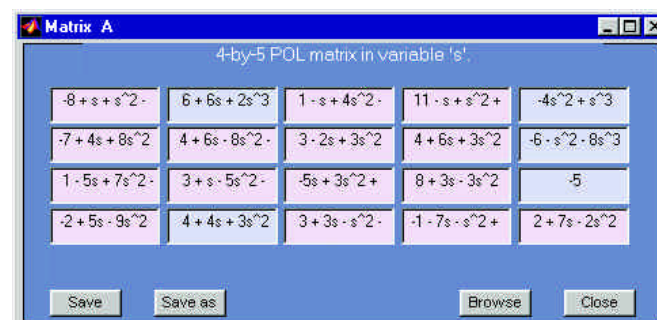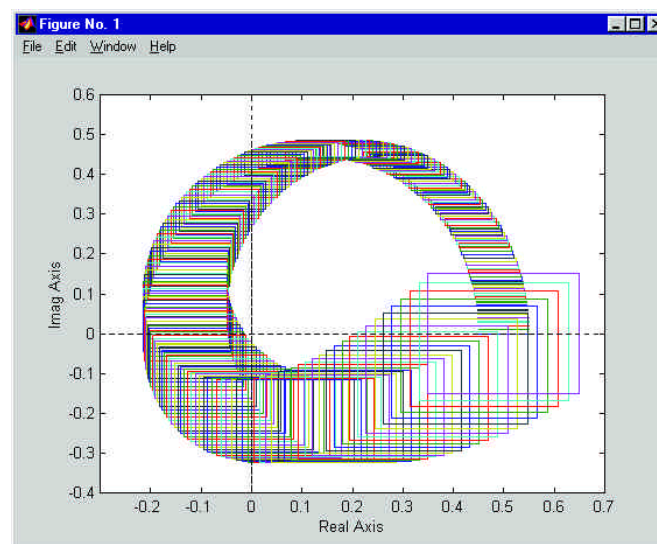
The Polynomial Toolbox 2 for Matlab.

equation solvers, graphical user interface (GUI), graphics
- new generation of numerical algorithms: easy, fast, reliable
- system and signal models based on polynomial matrix fractions
- analysis and design tools for control and filters
- classical, optimal and robust design.

The Toolbox allows the user to define, display, and handle polynomial matrices with real and complex coefficients; to use many overloaded operations and functions; to generate 2-D and 3-D colour plots of polynomial matrices; and to work with polynomial matrix fraction descriptions of linear time invariant (LTI) systems. The Toolbox can also solve various linear and quadratic polynomial matrix equations and analyze and design

control systems and filters by polynomial methods. Classical, optimal and robust design problems are solved. The Polynomial Toolbox is based on a new generation of numerical algorithms and provides a graphical user interface to edit polynomial matrices.

Users of the Polynomial Toolbox include control engineers involved in control systems analysis and design, communication engineers with an interest in filter design, and university teachers engaged in a variety of courses in linear systems, signals, and control. The Polynomial Toolbox version 2.0 is a package of as many as 200 M- files in MATLAB code but nevertheless is easy to use. It provides a Simulink block set for LTI systems described by polynomial matrix fractions and supports conversion

to and from LTI objects of the Control System Toolbox and polynomial objects defined in the Symbolic Math Toolbox. Its application areas include communications, control system design/analysis, educational instruction, general R&D, process control/monitoring and signal processing.

Optimal Control of Distributed Parameter Systems

by Jaroslav Haslinger, Michal Ko vara, and Tomá Roubí ek

Control of systems can be performed directly in open loops in such a way that a certain criterium attains its optimal value. Typical examples of such criteria are cost, consumed energy, or total time to be minimized.

The controlled system arising in engineering practice, physics, medicine, etc., often must be considered with distributed parameters, being then governed typically by partial differential equations or/and integral equations. Even more, sometimes the system may be governed by inequalities of this sort; this happens typically in various contact problems in mechanics. The variety of optimization problems governed by DPSs (distributed parameter systems) includes not only classic optimal control problems, but also optimization of the shape (so-called optimal shape design) and optimization of coefficients (so-called identification problem or material optimization).

Tools used for optimal control of DPSs varies from purely theoretical as mathematical analysis (nonlinear, (non)convex, nonsmooth analysis) and theory of nonlinear partial differential equations, through numerical as finite element methods and optimization

algorithms, to application oriented tools, including computer implementation, visualization, and a certain knowledge of the background of concrete problems in questions.

This sort of research has been performed for decades on academic ground by two of Prague's CRCIM members: The Institute of Information Theory and Automation of the Academy of Sciences and the Faculty of Mathematics and Physics of the Charles University. Before the fall of communism, this community had various collaborations with Czech steel industry, mainly through the Škoda factory. The problems covered optimal control of heating of large parts of pressure tanks of nuclear reactors, identification of parameters and shape optimal design in casting devices, etc. This collaboration, however, finished soon after 1989 during a re-structuring of the Czech heavy industry. But decay of industrial research in the Czech Republic has been far compensated by the possibility to open

new contacts with academic institutions worldwide. In Europe, Prague's DPS-optimal-control group keeps regular collaboration particularly with scientists from Germany, France and Finland. Other contacts are maintained, eg, within IFIP Working Group 7.2 'Computational Techniques in Distributed Systems'.

Presently, this (rather small) research group confines to academic problems to maintain this sort of knowledge in Czech Republic for expected future re-establishment of industrial collaborations within European community. One of fields of our current interest is shape optimization, formulated in a classical way as a design of stressed structures in mutual contact involving possibly friction effects on common surfaces. Since the state problem is modelled by a variational inequality, the optimization problem becomes non-smooth, meaning that the control-state relation is non-differentiable, in general. This fact excludes (or at least complicates) the usage of classic gradient

type methods. We are further interested in developing new computational methods in shape optimization such as fictitious domain solvers in combination with derivative free minimization methods.
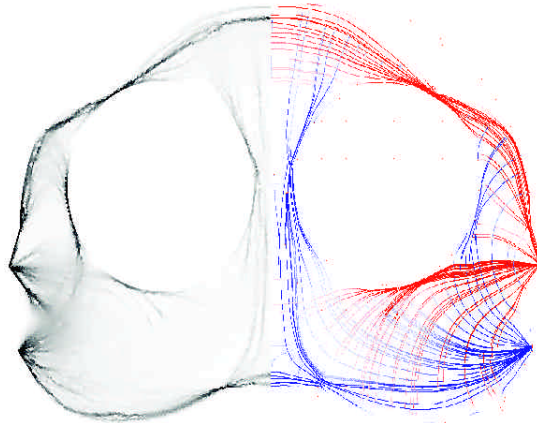
Apart from classic shape optimization, the group is also interested in optimization of material distribution and material properties. The latter is closely connected with design of advanced composite materials used, eg, in car and aircraft

Optimal design of advanced composite materials, region is fixed - left optimal orientation of fibres in the composite material right - optimal distribution of stifness of the material.

industry. Efficiency of this approach relies on fast numerical optimization methods, like interior point and barrier algorithms, that can handle systems with hundreds of thousands of unknowns. Typical application of the approach in the so-called conceptual design is presented in the figure.

Great attention is paid to optimization of fine structures arising in various physical systems due to the nonconvexity of governing potentials. This gives rise to

multiscale problems which are extremely difficult to model on computers and which represent a great challenge for numerics for next century. Yet, certain effective algorithms to model such microstructures on a 'mesoscopical' level have been developed and tested by Prague's group, while optimal control or design of such microstructures has been investigated so far rather on theoretical level. Our applications included micromagnetism in ferromagnetic materials and matrensitic microstructures in shape-memory alloys. Let us emphasize that such 'smart materials' already find broad and sophisticated applications in engineering and medicine, and their optimization will become interesting in close future.

Please contact:

Jaroslav Haslinger – CRCIM
Tel: +420 2 2191 1312
E-mail: haslin@apollo.karlov.mff.cuni.cz

Probabilistic Support of Operators

by Miroslav Kárn

The need for a completeness of advances technical solutions shifts interests of control theory to higher hierarchical levels up to the highest one humanly operated. Often, human operators supervising complex processes are left without a proper guidance and outcomes of their actions are strongly dependent on their experience and/or their mental state. This motivated a consortium (formed by the University of Reading, United Kingdom, Trinity College Dublin, Ireland, Institute of Information Theory and Automation AS, Compureg Plzeň and Kovohutě Rokycany, all Czech Republic) to put together a project that tries to create and verify industrially an adequate support of a generic nature.

A novel framework for creating of robust, fast, user-friendly advisory system has been proposed. The system supports operators of complex processes in making decisions. It guides them through high-dimensional noisy heterogeneous data spaces to successful configurations. It also warns them against dangerous configurations. Feasibility of the project was demonstrated in the 1st phase LTR Esprit project supported by European Commission within 4th Framework. Now the project will focus on reaching a full scale applicability of the tool called ProDACTool.
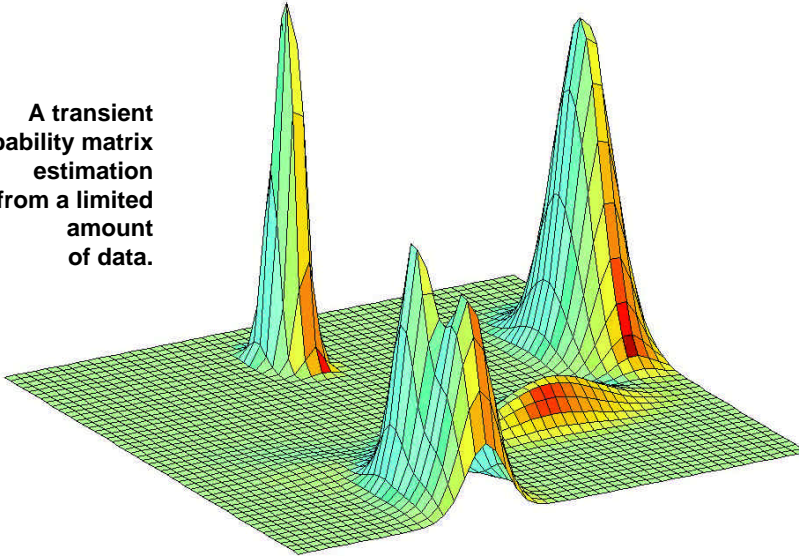
This implies addressing the following subtasks: (i) completion of the consistent novel probabilistic theory of dynamic adaptive clustering and theory of advising (ii) creating and thorough tests of the full set of robust and fast algorithms covering both experience accumulation and on-line advising to operators (iii) preparation of an adequate interaction sessions suitable for process staff (iv) implementation of the advisory systems with an intelligent graphical interface tailored to industrial environment (v) demonstration of the power of the tool on a full scale, cold-rolling mill application (vi) demonstration of the generic nature of the tool on data

taken from other sites and fields (transportation, glass industry and medicine).

The project combines all measures to built and run a probabilistic, dynamical advisory system permanently on a cold-rolling mill. The care devoted to speed, internal consistency and robustness of information processing will make the system usable for other applications. Its work-packages will address:
•Theory: extension of Bayesian decision-making to dynamic adaptive operator support; robustness analysis; design of ergonomics; adaptation of data

A transient probability matrix estimation from a limited amount of data.

preparation techniques to the addressed problem; approximation techniques for high-dimensional spaces (acceleration of MT algorithm, solution of shadows cancelling problem, stability and robustness of algorithmic kernel).
- Algorithms: robust, factorised mixture estimation dealing with mixed continuous-discrete data; parallelisation of critical steps and adaptation of robust technique of stabilised forgetting; extensive 'quality assurance' tests on simulated and real data; benchmarking with respect to available competitors; implementation to industrially applicable software environment.

- Implementation: data collection with the necessary changes of sensors and information system; data analysis; preparation of intelligent industrial graphical interface; industrial tests.
- Application: full-scale use on a cold-rolling mill and evaluation of the impact; preparation of tools for other applications (other rolling sites, transportation, glass industry and medicine).

The generic nature of the advisory system will be tightly observed by creating robust and fast implementation that can function beyond boundaries of the application considered. This will be especially reflected in the quality assurance of the implemented system (consisting of a suite of software modules). It must meet the highest standards of speed, performance efficiency and robustness. For strategic evaluations, a robust parallel design will be used.

Effectiveness of the tool is to be guaranteed via a sophisticated graphical front-end, whose logic will respect both the underlying theory and the adapted know-how on man-machine interface. The underlying theory can be characterised as an extension of dynamic Bayesian decision making under uncertainty applied to a (mixed) mixture models. The power of the decisive novel efficient estimation algorithm is illustrated on a simple search for structure of a transition probability matrix (TPM) using very limited amount of data. Figure shows the mixture fitted to matrix with 2500 entries using 1000 data. It nicely determines areas of TMP with significantly changing entries.

Please contact:

Miroslav Kárn – CRCIM
Tel: +420 2 6605 2274
E-mail: school@utia.cas.cz

Control of Discrete-Event Systems

by Jan H. van Schuppen

The use of computers for control has recently led to control theory for logical operations in addition to control theory for continuous variable systems. The long term aim of control of discrete-event systems is to develop theory and algorithms for the logic control of engineering systems by computers. The following ERCIM institutes participate in this research topic: CWI, INRIA-IRISA, and SICS.KTH.

Control of engineering systems is implemented by computers nowadays. This then leads to problems of ordering and of sequencing of discrete operations. This may be seen in contrast with control of dynamic systems in which states take values in continuous spaces and the dynamics are described by differential equations. Examples of engineering systems for which control of discrete-event systems has been used are: communication

protocols, feature interaction in telephone networks, failure diagnosis in heating and ventilation systems, and failure diagnosis in telephone switches. Computer science terms used for the topic are embedded systems and embedded software. Control of discrete-event systems is likely to develop in cooperation with computer scientists. The common root of control theory and computer science in automaton theory facilitates communication.

Control theory makes use of models in the form of dynamic systems. For the sequencing of operations such a system is called a discrete-event system which may be an automaton, a Petri net, or a process algebra. The choice of the model class is generally based on a trade-off between the expressiveness of the language of the system and the complexity of control problems of a system in the model class. Automata and

Petri nets are most often used because of their ease of use and closeness to engineering models.

The control problem is to synthesize and to design controllers or supervisors such that the closed-loop system consisting of the system and the controller meets the specifications. The problem encompasses verification as studied in computer science. Control objectives are to guarantee safety criteria and to guarantee a minimal behaviour or liveness criteria. There is now a body of results on the existence and the design of controllers for automaton and Petri net based discrete-event systems. Control theory for automaton based discrete-event systems has been mainly developed by W.M. Wonham (University of Toronto) and his Ph.D. students. Control of infinite-string automata has been developed by J.G. Thistle (Ecole Polytechnique de Montréal) under supervision of W.M. Wonham.The research groups of S. Lafortune

(University of Michigan, Ann Arbor) and S.I. Marcus (University of Maryland, College Park) have contributed substantially to this theory and to the algorithms. Control of Petri nets has been studied by several researchers including R.K. Boel, A. Giua, and B.H. Krogh. There are several software packages available for the design of controllers.

Control of discrete-event systems for realistic engineering systems must be able to handle control problems for discrete-event systems of large sizes with moderate complexity. Several research directions follow from this aim. First, to develop hierarchical models and control theory for hierarchical systems. Inspiration sources are the publications by D. Harel on statecharts and the hierarchical systems of W.M. Wonham and K.C. Wong. Second, to develop control theory for decentralized or distributed systems. Distributed systems are often used in engineering because of the geographical distribution of

engineering systems. Third, to study special classes of discrete-event systems and the relation between discrete-event systems. The main tool in this context is universal algebra, coalgebra, and lattice theory. Computer science concepts like observational equivalence introduced by R. Milner, bisimulation equivalence between discrete-event systems, other semantics, and coalgebra introduced by J.J.M.M. Rutten are useful here. A fourth research direction is a fundamental study of expressiveness of languages of systems and of complexity. This may point the way to the selection of subclasses of systems for which the development of a realistic and substantial control theory is possible.

Please contact:

Jan H. van Schuppen – CWI
Tel. +31 20 592 4085
E-mail: J.H.van.Schuppen@cwi.nl

Research in Systems and Control Theory at SZTAKI

by József Bokor

Systems and control theory are traditional research areas at SZTAKI. Recent topics include various aspects of system identification, uncertainty modelling and robust control, stochastic systems and control, fault detection and isolation with applications to process systems, vibration monitoring and diagnostics, fault tolerant and reconfigurable control systems.

Other topics are the integrated design of process and control system structures, modelling and control of cache systems, modelling and analysis of operating procedures by coloured Petri-nets. Applications of the results appear in a 'vision in the loop' vehicle control system developed to avoid unintentional lane departure, or in the design and analysis of a new nuclear reactor protection system considered as a distributed hybrid computer control system. Most of these results are related to the activity of the Systems and Control Laboratory, in co-operation with the Combinatorial Computer Science Research Group and the Automation and Vehicle Engineering

Departments of the Technical University Budapest and with the Stochastic Systems Research Group. Some of these topics will be characterized below.

Simultaneous Identification and Control
In model-based control design, the interaction between the controller and the identified model must be taken into account. Designing the controller, the difference between the model and the plant must be considered, and the control law will influence the choice of system identification approach. The aim of the iterative design is to improve the performance properties of the controlled

system step by step. The main issue is to examine the interplay between modelling performance, control performance, and robustness, and to develop iterative schemes to solve different control engineering problems. Several closed loop identification methods are applied in the iterative schemes and it is investigated how the gray-box identification method, which takes the physical knowledge of the plant into account, fits to the iterative scheme. The cooperation between the worst-case identification process and the robust control design based on Hinf-norm is also investigated. Moreover, the iterative scheme for mixed H2/Hinf controller

design that provides disturbance rejection and robustness against uncertainties is also developed.

Fault Detection, Isolation, Fault-tolerant and Reconfigurable Control

Fault detection and isolation consist of two basic steps: robust residual generation and residual evaluation. In our approach the problem of robust residual generation for the detection and isolation of faults by using state observers is addressed. Previous results have shown that if failure modes and unknown inputs appear in the independent subspaces of the state space then geometrical methods for decoupling their effects can be used in enhancing the robustness of the detection process. Utilising the geometric view and the Lie algebra structures associated to this filtering problem, detection filters for bilinear and more general classes of non-linear plants can be derived. If perfect decoupling is not possible, a robust detection filter design problem is set up as an Hinf filtering problem where the effect of estimation weighting on filtering performance is optimised through the input diagonal scaling of the estimation. By the proper choice of the estimation weight, the objective is to provide the smallest scaled L2 gain for the disturbance input. The problem of obtaining bounds on the scaled L2 gain of the system can be solved as a convex feasibility problem.

Integrated Vehicle Control System

In the past few years the vision-based sensing of the surrounding environment has gained a strategic importance not only in military applications but also in automotive field. In co-operation with Knorr-Bremse Brake Systems Ltd., the Systems and Control Laboratory develops an experimental vision-based driving assistance system for the automatic detection of the unintentional lane departure of road vehicles. The system is tested in various road, weather and lighting conditions. Detection is the first step towards a control system aimed at keeping the vehicle within the lane bounds. Intervention is achieved by using differential braking - the unequal application of braking torque to the left and right-side wheel. Adaptive and robust control strategies are investigated for the realisation of control of this brake system.

Integrated Design of Process and Control System Structures

Process and control system structures can be described by signed directed graph (SDG) models. Computationally efficient methods are developed for integrated (joint) design of these structures for various decentralized controller design strategies (eg LQR, disturbance rejection etc.).

Modelling and Control of Cache Systems

Cache systems are hierarchical distributed computer systems communicating with various protocols. Discrete dynamic models of existing cache systems are developed, investigated and verified using measured network data. The dynamics of various cache systems is described by discrete event and Petri-net models. Discrete control strategies are developed and studied in order to increase the capacity security and reliability of these systems.

Modelling and Identification of Signals and Systems in Rational Bases

Modelling signals and systems is a central issue in various problems of signal processing, change detection or model based control design. Signals can be described eg as elements of abstract function spaces like L2 or l2, and systems are considered as operators mapping an input signal space to an output one. A usual representation of signals in Hilbert spaces is given by defining a shift operator and to construct an orthogonal decomposition. The signals are represented as infinite sums where the coefficients are obtained by projections. The well known engineering representation is related to the canonical shift on the unit elements of the space l2. Using Z-transforms, this leads to an IIR representation in polynomial basis (the powers of the complex variable z) in the Hardy space H2. FDLTI systems mapping this signal space to an output H2 space can be represented by rational functions.

The role of choosing the shift operator (or alternatively to choose a basis) in the signal spaces and to investigate its effect on the properties of input/output operators associated to these bases opened a vigorous research some years ago. A very active and inspiring role has been played by the Delft team of P.M.J. van den Hof moreover by B. Walberg and B. Ninness and coworkers, see their Preconference Workshop on the IFAC Congress in Beijing. The Systems and Control Laboratory joined this research by investigating the construction of uniformly bounded operators associated to the Blaschke shift on H2. The form of these operators has been extended to approximate operators in the Hinf norm, too. These results can be used to identify models either under H2 or Hinf norm criteria when using rational bases instead of the polynomial one. This approach has a number of advantages when solving a large family of detection and identification problems. A generalization of the Ho-Kalman realization method has been elaborated too, to provide state space models for control system design.

Research and Education Centre in Adaptive Systems

by Miroslav Kárn

In the eighties, adaptive control and adaptive signal processing, and also briefly adaptive systems, made very fashionable research areas. Nowadays, any further development of particular techniques is performed mostly under other labels, like intelligent or predictive control (due to the fashion and policy of grant agencies). At the same time, the close connection to the classical statistical decision making, coined by A.A. Feldbaum in the sixties, has been revived. The available computer power, progress in solution of various particular tasks as well as better understanding of the addressed problems have opened new perspectives in adaptive systems understanding.

Decision making under uncertainty is quite a multi-disciplinary research branch both with respect to theory and application. As stated above, adaptive systems can be viewed as its engineering version with a stress on sequential problems. Their efficient research and teaching have to cross boundaries of traditional fields as well as artificial institutional boundaries. Various research institutes and universities dealt with then and they naturally focuse on the problems related to that particular institution (technology, economy, medicine,...) and as such are more applied in their perspective. This observation has led to the establishment of the Research and Education Centre in Adaptive Systems (RECiAS). It is supported by the

Grant Agency of the Czech Republic. It intends to serve as an informal mediator in tailoring the research and education capacity to the problem at hand and to the student to be educated.

RECiAS, is a joint initiative of the Department of Adaptive Systems at UTIA and co-operating universities (Czech Technical University, Prague, Charles University, University of West Bohemia, Plzeň, Reading University), research institutes (Computer and Automation Institute, Budapest) and application oriented partners (Compureg, Plzeň, Glass Service, Vsetín). The principal aim of this Centre is to support education of top experts in the field of Adaptive Systems.

RECiAS offers a new teaching framework with the following main priorities:
- learning by doing research and development is the dominant approach adopted
- crossing boundaries between departments, universities and research institutes are intentionally crossed both with respect to student acquisition; their specialised lectures as well as their supervisor.

The centre serves for (pre-dominantly postgraduate) education of theoreticians and practitioners and will be counted successful only if it produces top experts. This aim manifests itself in:
- completion of the existing teaching means by lecture notes unifying the underlying theory, experimental laboratory, demo examples and sets of typical real data
- incorporation of students into running newly proposed research projects so that reviews, research reports, diploma and PhD theses will be created (areas: fault detection, decision support in the case of nuclear accident, biomedicine oriented modelling, estimation of relationships in a complex transportation systems, etc.)
- incorporation of students into running and newly proposed applied projects (early warning system RODOS, data processing in nuclear medicine, radon dynamics, fast prototyping of parallel systems, control design of rolling systems, operator support, traffic control, etc).

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An Example of a Problem

Accumulation kinetics of 131I used for thyroid cancer treatment exhibited unacceptable discrepancies between the estimation (diagnostic) and application (therapeutic) phase. A careful Bayesian analysis showed that under-modelling is responsible for this. The decision making of medical doctors on applied therapeutic activity will be substantially simplified by this result. The figure shows data (*) measured since the application of 131I, their fit (o) when the classical mono-exponential model, characterised by the time constant

Activity of pacient: * data o tTef x tAlt -- dTef -. dAlt
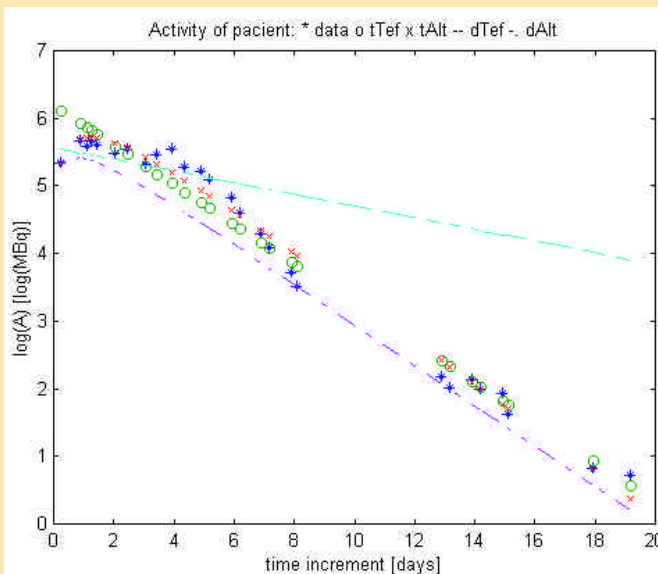
(tTef), is used and fit (x) by an alternative model (tAlt). The line ñ shows predictive ability of the former model (dTef) when data from the accumulation beginning are available (the period coincides with the length of diagnostics). The improvements of predictions (-.) for the alternative (dAlt) is obvious.

Links:

RECiAS, partners and specifics projects: http://www.utia.cas.cz/user_data/scientific /AS_dept/RECIAS/

Please contact:

**Miroslav Kárn – CRCIM
Tel: +420 2 688 3421
E-mail: school@utia.cas.cz**

In-operation Modal Analysis and Vibration Monitoring

by Michèle Basseville

Sharp monitoring of the vibrations of mechanical structures and rotating machines, under ambient excitation and in-operation, can be achieved through an appropriate multi-sensor signal processing, based on both system theoretic and statistical methods.

In-operation vibration monitoring for complex mechanical structures and rotating machines is of key importance in many industrial areas: aeronautics (wings and other structures subject to strength), automobile (gearbox mounting with a sports car body), rail transportation, power engineering (rotating machines, core and pipes of nuclear power plants), civil engineering (large buildings subject to hurricanes or earthquakes, bridges, dams, offshore structures). Tools for the detection and the diagnosis of small changes in vibratory characteristics are particularly useful to set up a preventive maintenance policy based on the actual evolution of the state of the monitored machine or structure, as opposed to systematic a priori planning

Classical modal analysis and vibration monitoring methods for mechanical structures and rotating machines are basically concerned with processing measurements made either on testbeds, or under specific excitation or rotation speed conditions.

The object of the Eureka project 'SINOPSYS' (model based Structural monitoring using IN-OPeration SYStem identification), which is co-ordinated by LMS (Leuven Measurements Systems, Leuven, Belgium), is to develop and integrate modal analysis and vibration monitoring software devoted to the processing of measurements recorded during routine operation, without artificial excitation, nor slow down, nor shut down of the machine. Two INRIA research teams participate in SINOPSYS: Sigma2 (in co-operation with CNRS) and META2.

The main contribution of INRIA to SINOPSYS consists in an original set of algorithms for multi-sensor signal processing (eg accelerometer measurements) that produces intelligent warnings, that is to say warnings that reveal the hidden causes of the defects or damage undergone by the machine or structure. This software can be embedded and work online. Among the actual data that INRIA has to process with the software developed within SINOPSYS are the Ariane 5 test flight data.

The first step of the SINOPSYS project has been focussed on modal analysis and identification of modeshapes. The key issue is to identify the eigenstructure (eigenvalues and observed components of eigenvectors) of the state transition matrix of a linear dynamical system. This can be deduced from the observability matrix of the system, written in the modal basis. A well-known key property is the fact that this observablity matrix and the empirical Hankel matrix do have the same left kernel. Therefore, subspace methods, based on the singular value decomposition of the empirical Hankel matrix, are good candidates for modal analysis, and have been used. They have been extended to the joint processing of measurements recorded by different sensor pools. Interactive methods for the selection and the validation of the modes have also been developed.

The second step of SINOPSYS has been the development of a tool for fatigue detection, that also evaluates the importance, for each mode, of the modal deviation which is detected. The detection algorithm is based on both the above mentioned left kernel space property and a local approach relying on a central limit theorem. This detection test can be equally used for laboratory test beds with measured excitation, and for in-operation data without measuring the excitation.

The third step is the development of a tool for diagnosing the fatigues, where the goal is to explain the fatigues in terms of modifications of volumic mass or Young modulus, and to localize those modifications on the structure or machine.

For the two first steps (identification and modal test), a Scilab toolbox will be available with the next release. These monitoring and diagnosis algorithms have been generalized to models more complex than those for vibrations, and can be used for monitoring in industrial process control (gas turbine, electric or thermal plant) or for on board diagnosis (catalytic exhaust).

Vibration monitoring for complex mechanical structures and rotating machines is of key importance in many industrial areas like aeronautics.

Photo: WSK-PZL Swidnik (helicopter manufacturer), courtesy of Leuven Measurements Systems

MAGDA – Alarm Supervision in Telecommunication Networks

by Eric Fabre

MAGDA (Modélisation et Apprentissage pour une Gestion Distribuée des Alarmes) is a research project supported by the French National Research Network in Telecommunications programme RNRT (Réseau National de Recherche en Télécommunication). The challenge for the MAGDA project is twofold: 1) adapting and mixing different formalisms towards the general objective of fault diagnosis in telecommunication networks, using alarm correlation, and 2) building an experimental platform to validate this approach.

Today, there are no widely-recognized standards for tools that could help alarm correlation. Thus, it is worth mentioning some key points of this research that could be regarded as useful achievements in and of themselves:

- Validation of black-box methods: Alarm logs are easily available in practice, but tools are lacking to exploit them properly. It is important to check the relevance of data mining techniques to discover structures in these logs, in particular, frequent chronicles of events.
- Modelling methodology: It is quite easy to build a model of alarm production and fault propagation for toy examples, but the construction of a model for a real network is quite challenging, and requires some structuring and methodology. In particular, it must be object-oriented and based on generic elements that are instantiated and interconnected. This model will be described in UML. The direct use of this model (for simulation and fault diagnosis) is also an objective of MAGDA.
- Model-based diagnosis: The effectiveness of model based approaches for alarm correlation will be evaluated and compared to (possibly associated with) black-box models. Key points to check are the relevance of a formalism for concurrency of events, the relevance of a stochastic model, the influence of an incomplete knowledge of the model and the possibility to cope with a changing model (reconfiguration).
- Distributed diagnosis. As very large systems must be modelled, a centralised diagnosis algorithm handling the global state of the system is unaffordable. Therefore, a distributed diagnosis algorithm will be developed, composed of asynchronous local algorithms that supervise part of the network evolution and synchronize their results. This approach is well-suited to highly concurrent systems.
- Real case experiments will be carried out on an experimental platform composed of a real network manager connected to a simulator of a simple network. Fault scenarios will be elaborated from alarm logs collected on a true network.

All the above mentioned points are very likely to lead to innovations in alarm correlation and network monitoring. We present now only the part of the project devoted to diagnosis using discrete-event control theory.

Model-based online monitoring

We consider a telecommunication network as a network of asynchronously interacting finite-state machines. Such systems are subject to spontaneous faults, occurrences of which may trigger alarms. Also, network elements get services from other elements and, in turn, provide services to several alternative network elements. This causes both fault and alarm propagation throughout the network.

As a first idea, we have proposed modelling such a situation as follows:

- The mechanism of a spontaneous fault occurrence and alarm propagation for a given element is modelled by a Petri Net of capacity one (PN). Places of the PN capture features of interest concerning the state of the network element, eg, nominal, faulty, disabled. Having a token in a given place indicates that the associated feature is active.
- Observations are attached to transitions. Each time a transition fires, it produces an alarm message that is eventually received by the supervisor of the network (losses of messages are possible). The location of tokens and their moves are not observable.
- The interaction of network elements is modelled by common places between the PN models of each element. We consider a true-concurrency semantics for the PN: transition firings are only partially ordered in time, according to the causality structure induced by the underlying PN directed graph structure.

Alarm interpretation is then regarded as the problem of inferring, from the observation of alarms, the hidden state history of the PN. As some of the events (in particular, spontaneous faults) are typically random in nature, we consider some kind of probabilistic form for our PN. To prepare for distributed diagnostics, our requirement was that stochastic independence should match concurrency, implying that if two transitions of the PN are concurrent, all interleavings of their reception by the supervisor should have equal likelihood.

We have proposed a new class of stochastic PN that satisfy the above property: Partially Stochastic Petri Nets (PSPN). The well known Hidden Markov Models (HMM) theory has been extended to them. HMM are stochastic automata for which is it desired to infer the most likely hidden state (or transition) sequence from an observed sequence of transition signatures. This machinery is very popular in pattern recognition and in speech recognition. The basic algorithm is the so-called Viterbi algorithm, which computes on-line the most likely state history. In our PSPN framework, transitions are associated with 'tiles' that describe local state changes. The Viterbi algorithm then reconstructs hidden trajectories by concatenating tiles that match the observations. Therefore it is renamed the 'Viterbi puzzle'.
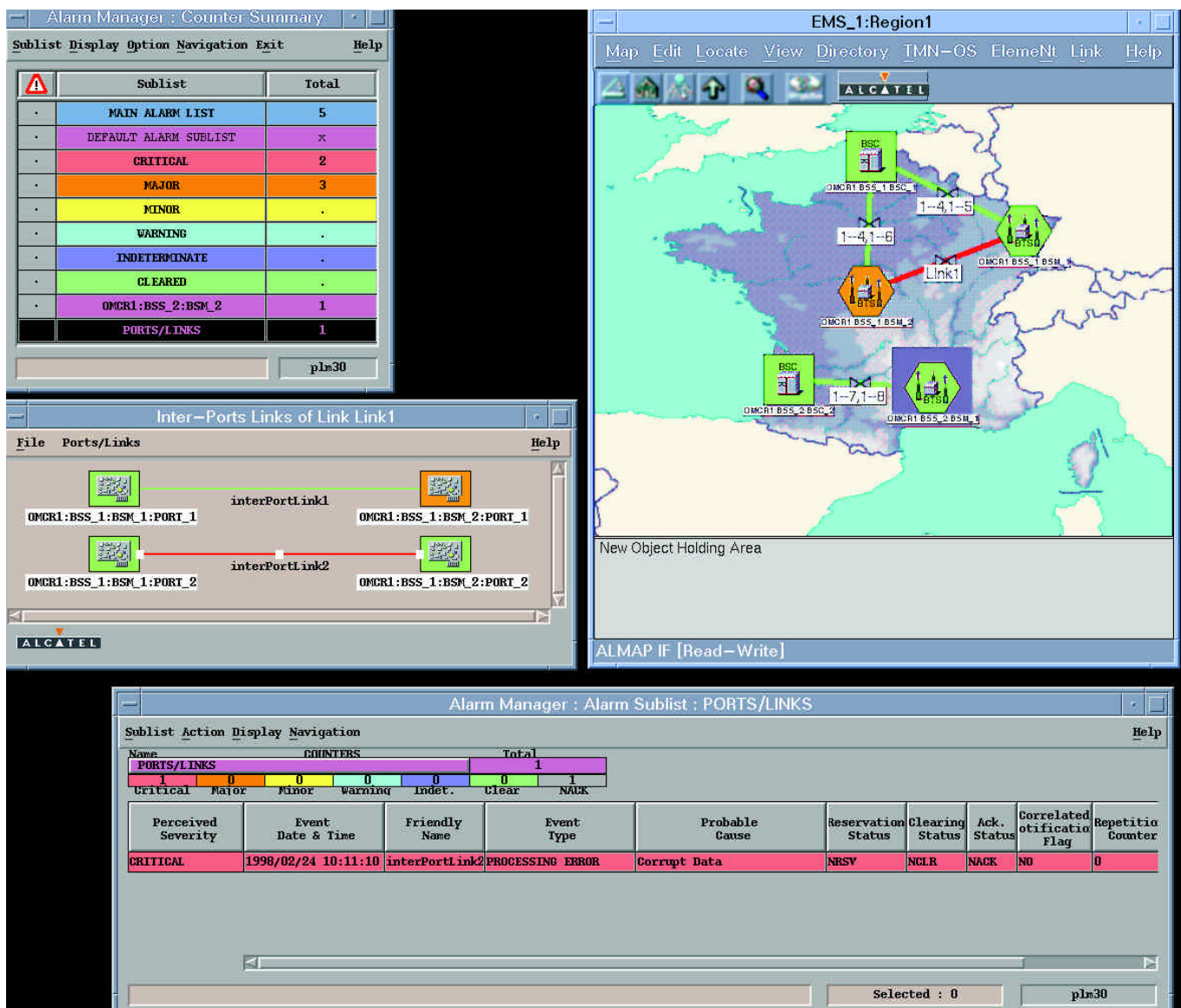
ALMAP, the Alcatel Management Platform.

The following topics require further development for MAGDA and are currently under investigation:

- developing of a theory of distributed, asynchronous deployment of the Viterbi puzzle, which means that the puzzle is now played in co-operation by several players, where each has its own partial set of tiles
- extending this theory to dynamically-evolving models of PN. This is necessary since some network elements are only logical, not physical, and thus are subject to reconfiguration. Our aim is to directly generalise Viterbi puzzles to puzzles with a dynamically-evolving set of tiles
- extending the theory further to accommodate situations where the model may be incomplete, i.e. it is not guaranteed that the observed alarm

sequence can be produced by the hypothesised model
- modelling: the process of deriving the PN model from available information is itself a challenge, as this must be automated as part of the deployment and configuration of the fault management system
- deployment of the algorithm: as the MAGDA deployment architecture will rely on OMG-CORBA model, our first objective is to use this model as a target model for the deployment of our abstract distributed 'Viterbi puzzle'.

Currently, the 'Viterbi puzzle' group at IRISA is comprised of three permanent researchers (Albert Benveniste, Eric Fabre, and Claude Jard) and two post-doctoral fellows (Mark Smith from MIT and AT&T Labs Research and Laurie

Ricker from Queen's University in Canada). Laurie Ricker is supported by the ERCIM PhD fellowship programme. After this project, she will continue her research activity at CWI with Jan van Schuppen.

The MAGDA project is a collaboration between two academic research centres (IRISA/INRIA Rennes and LIPN Paris) and three industrial companies (France-Télécom/CNET, Alcatel/CRC and ILOG).

Links:

Magda web site: http://magda.elibel.tm.fr/

Please contact:

Eric Fabre – INRIA/IRISA
Tel:+ 33 2 9984 7326
E-mail: Eric.Fabre@irisa.fr

Subspace Identification Algorithms and Stochastic Realization

by Jan H. van Schuppen

Feedback control is used in engineering systems to guarantee stability and to optimize performance. Control design is based on a model of an engineering system in the form of a dynamic system. The determination of a dynamic system from data is based on system identification and on realization theory. Results of realization theory form also the theoretical basis of control theory. Research on realization and system identification is carried out at the ERCIM Institutes: CNR.ISB, CWI, INRIA-IRISA, INRIA-Sophia-Antipolis, SICS-KTH and SZTAKI.

Kalman filters are used for prediction of, eg, water levels, economic goods, and air polution concentrations. Controllers for linear systems are used for control of, eg, electric motors, air planes, and of chemical processes. The design of Kalman filters and of linear controllers depends on the availability of a dynamic system for the dynamic phenomenon concerned. In system identification algorithms are derived and studied to determine from a time series a dynamic system. System identification algorithms for single-input-single-output linear systems have been available in the System Identification Toolbox of MATLAB for quite a while. However, for multi-input-multi-output linear systems such algorithms were not available until recently. The most effective algorithms now available are based on research initiated by R.E. Kalman in the 1960's and the 1970's.

The prediction algorithm that is now known as the Kalman filter was published in 1960. It provides predictions of a stochastic process described by a Gaussian system, a linear system driven by a Gaussian distributed sequence of independent random variables. After its initial success, Kalman proposed in 1964 a fundamental study of representations of stochastic systems. Stochastic realization theory for Gaussian systems was developed mainly by P. Faurre, G. Ruckebusch, A. Lindquist, and G. Picci in the period 1967-1985. H. Akaike, stimulated by Kalman, and inspired by stochastic realization theory, has formulated system identification algorithms for Gaussian systems during the 1970's. W. Larimore in R.K. Mehra's company Scientific Systems Inc., further developed the system identification algorithm, which became known as the `subspace identification algorithm'

because of the interpretation provided in terms of stochastic realization theory. B. de Moor and P. van Overschee improved the numerical properties of the subspace identification algorithms by the use of singular-value decomposition during the 1990's and developed generalizations. Since then several variants of the subspace identification algorithm have been published, for example by A. Lindquist and G. Picci. In hindsight the research process seems to have been excessively long.

Consider a finite time series. From the data an estimate is formed of its covariance function. The time series is partitioned into a finite future and a finite past series. A canonical variable decomposition is then applied to these series. The relation between the future and the past series is then approximated, the low order approximant only contains the significant canonical variables. The resulting state at anytime is then obtained as a linear function of the finite past series. Finally a regression operation of a future state and the output on a past state is used to compute the matrices of a Gaussian system. The output of this system is the approximant of the considered time series. Variants of the algorithm differ in the choice of basis for the space generated by the time series and in the approximation step. Numericallly reliable algorithms are based on the singular value decomposition.

The subspace identification algorithm for multi-input-multi-output Gaussian systems is now available in the MATLAB Toolbox System Identification. This computer program package is available in a large number of companies, agencies, and universities. Students in control and signal processing are trained in its use. The algorithms are effective and rather robust. There is a small difference

between the approximant of a subspace identification algorithm and that of a maximum likelihoud algorithm and an explanation for this is still subject of study.

The view that stochastic realization theory is useful for system identification, is now well established. This has stimulated further research on stochastic realization theory for other classes of stochastic systems. Stochastic realization of finite stochastic systems, also called hidden Markov models, has been carried out but the problem is far from satisfactorily solved. Stochastic realization in the abstract setting of -algebras has also been considered. System identification of stochastic systems will lead to further research in stochastic realization theory.

The effectiveness of control theory is mainly due to the availability of realistic models of dynamic systems for the phenonema concerned. System identification algorithms are the main tool to construct such dynamic systems. The effectiveness of the currently available algorithms for system identification of multi-input-multi-output Gaussian systems is amazing. These algorithms are based on stochastic realization theory for Gaussian systems and on realization theory for finite-dimensional linear systems. The development of these theories was stimulated by R.E. Kalman. The results of realization theory and the application of subspace identification algorithms form an example of what has been called the 'unreasonable effectiveness' of mathematics.

Please contact:

Jan H. van Schuppen – CWI
Tel: +31 20 592 4085
E-mail: J.H.van.Schuppen@cwi.nl

Stochastic Systems and Recursive Estimation

by László Gerencsér

This article summarizes results achieved in the area of recursive estimation of stochastic systems by the author in the past decade. The main objective of this work was to develop a rigorous foundation of the theory of recursive estimation.

The spectacular success story of stochastic systems in the sixties and seventies had been interrupted by the emergence of worst case approaches to control and identification. Another less obvious reason for the loss of momentum was a series of unresolved technical difficulties. The book of Ljung and Söderström about system identification in 1981 was instrumental in bringing attention to the enormous flexibility of recursive identification. The blueprint of a new theory of recursive estimation has also been given in this book, but it took almost a decade to develop a practically useful rigorous methodology. As it stands now there are two basic approaches in Europe: one based on Markov-processes, presented in the book of Benveniste, Metivier and Priouret, and a second one based on a rigorous development of the ODE (Ordinary Differential Equation) method. The power of the second approach is that it allows the handling of enforced boundedness and is applicable for time-varying systems.

In what follows we provide a short survey of results obtained via the theory of L-mixing processes, and give a glimpse of related works and further potentials. The basic technology behind the modern theory of recursive identification is the notion of exponentially stable processes introduced by Lennart Ljung on the one hand and Jorma Rissanen and Peter E. Caines on the other hand. A systematic investigation and generalization of this notion has lead to the concept of L-mixing processes (Stochastics, 1989). The usefulness of this concept is due to certain invariance properties. Furthermore, we have powerful moment inequalities for weighted integrals, multiple integrals of Volterra-type, and for exponential moments. The new techniques have been used extensively by Andrew Heunis.

On-line prediction error estimators were traditionally derived from off-line estimators using approximations. It was conjectured by Gábor Tusnády that the difference between the two estimators is negligible compared to the standard deviation. This had in fact been proved in 1993 in my paper published in Systems and Control Letters. This paper gives the most precise and convenient characterization of recursive prediction error estimators. The harder part of the analysis is given in my paper, published in SIAM Journal on Control and Optimization, 1992, which provides a rigorous foundation of a practically useful ODE-method.

A major challenge to the theory of system-identification was the emergence of the theory of stochastic complexity developed mainly by Jorma Rissanen. More generally, the study of the interaction of uncertainty and performance became a widely investigated subject. Using the new theory of recursive identification the pathwise performance of an on-line computable adaptive predictor for ARMA-processes was analyzed in my paper in the Journal of Statistical Planning and Inference, 1994.

More recently we have considered the problem of interaction of identification and control. On the technical level, we ask about the effect of statistical uncertainty, due to identification, on control performance. The level of external excitation is an interesting design variable. A key element of the analysis is understanding closed loop recursive identification, and the interaction seems to be unmanageable complex. It turns out that the rigorous theory of recursive estimation provides the appropriate tools to solve this problem. For details see my paper with Zsuzsanna Vágó in Journal of Mathematical Systems, Estimation and Control, 1998. For other aspects of this problem, see the article by József Bokor on SZTAKI's Systems and Control Laboratory on page 27 in this issue.

The asymptotic theory of recursive identification and stochastic realization theory have also been used to develop a general approach to the design and analysis of risk-sensitive identification methods in a joint work with György Michaletzky and Zsuzsanna Vágó, thus extending the works of Jan H. van Schuppen and Anton Stoorvogel.

Standard recursive estimation methods are generalizations of the classical Robbins-Monroe procedure. However, in direct adaptive control we need Kiefer-Wolfowitz-type procedures, that are designed for function minimization under noise. A remarkable progress in this direction is the development of a randomized version of the latter procedure by James C. Spall. This so-called simultaneous perturbation stochastic approximation (SPSA) method, had been the subject of my paper in the IEEE Transactions on Automatic Control, 1999, where the extension of the ODE method is given. The analysis is also applicable to discrete-variable stochastic optimization problems. The latter is a joint work with Stacy Hill and Zsuzsanna Vágó.

Estimation of Hidden-Markov processes is another recent research interest. The prime example is the estimation of Gaussian ARMA-processes under quantized observation representing low-accuracy sensors (a joint work with Francois LeGland and György Michaletzky). Surprisingly, no computationally viable procedure is known today. Some simpler benchmark problems have been studied in cooperation with Lorenzo Finesso and Ildikó Kmecs.

Further topics in recursive identification, that we considered earlier are: rate of convergence for the LMS method of adaptive filtering; fixed gain recursive estimation; real-time change-detection. Continuous-time Modelling seems to be as attractive as ever (a joint work with

Arun Bagchi). An emerging area is the real-time analysis of financial time-series. In particular, the estimation of cointegrated processes is on the agenda. Another pending project is the application of stochastic realization theory to choose appropriate parameterizations for

recursive system-identification. Some of the basic problems have been formulated in the book of György Michaletzky, József Bokor and Péter Várlaki, 1998.

Please contact:

László Gerencsér – SZTAKI
Tel : +36 1 4665 644
E-mail: gerencser@sztaki.hu

Stochastic Realization and Identification

by Andrea Gombani

One of the research themes of the Systems Theory Group at LADSEB is Stochastic Realization and its main object is to construct finite dimensional representations of an infinite (or, in practice, very long) sequence of random variables, called stochastic processes. Although the subject definitely belongs to the realm of fundamental research, laying on the border between mathematics and theoretical engineering, in recent years it has lead to a surprising variety of applications in identification, signal processing, physics and finance.

The research in this field was triggered, like most of systems theory, by Kalman in the early sixties; at LADSEB the group was started in the early seventies by Giorgio Picci. The main aim of the research has been to condense the information contained in very long random signals (for example a time series of economic data, or the disturbance affecting data over a telephone line) into a small number of variables (called state). This representation is quite important since it enables the use of powerful existing techniques (like filtering and control) to analyse and handle the signals.

More precisely, if y(t) is a linear gaussian stochastic process, any Markov process x(t) which makes the past and future of y conditionally independent is called a state of the process. If the state has dimension as small as possible, it is called minimal realization. The problem then is to characterize all minimal realizations. There exist several ways to do this: by the set of solutions of a Riccati equation, using splitting subspaces in a Hilbert space of random variables or coinvariant subspaces in a Hardy space of analytic functions on the disk or the left half-plane.

Therefore the tools are essentially mathematical and they encompass theory of stochastic processes, linear algebra and, above all, functional analysis. In fact, it

is through the use of Hardy spaces and functional models in this setup, that the major steps forward have been made. Most of the research work has been carried out jointly with the Electrical Engineering Department of the University of Padua (with which LADSEB has a longstanding cooperation) and the Division of Optimization and Systems Theory of the Royal Institute of Technology (KTH), Stockholm (also affiliated to ERCIM through SICS) and, more recently, with the Mathematics Department of the Ben Gurion University (BGU), Beer-Sheva, Israel.

A main motivation for research in this field has been the need to understand some fundamental issues in stochastic system theory. Some early applications have been in time series analysis and signal processing. However, in recent years there has been a growing number of applications of this theory in a number of different areas. These include the use in subspace methods for systems identification (again with KTH), leading to the development of new algorithms for identification of linear systems; geometric control theory (with BGU), also leading to new algorithms, this time regarding the disturbance decoupling problem; the Modelling of surface acoustic wave filters for channel selection in the GSM mobile phones (under development with the MIAOU project at INRIA); factor

analysis and compartmental systems (partly in cooperation with CWI); the volatility in the term structure of interest rates, like options on bonds (joint work with the Finance Department of the Stockholm Business School). In this last application, an algorithm for pricing illiquid options (eg those which have a thin market or no market at all, eg new options) in terms of the prices of liquid ones (i.e. those treated on the market in large volumes) is currently being tested.

This research is done within the Systems Theory Group at LADSEB (see also Complexity of Hidden Markov Models, by Lorenzo Finesso, in this issue); this Group participates in the ERCIM Working Group on Control and Systems and in two EU networks (ERNSI and DYNSTOCH).

Links:

http://www.ladseb.pd.cnr.it/control/control.html

Please contact:

Andrea Gombani – LADSEB-CNR
Tel: +39 049 829 5756
E-mail: gombani@ladseb.pd.cnr.it

Statistics of Hidden Markov Models

by François le Gland

Hidden Markov models (HMM) are a special case of partially observed dynamical systems, where the state of a finite Markov chain should be estimated from a sequence of noisy observations. This article gives an overview of some progress made recently in the SIGMA2 research group at INRIA Rennes / IRISA, in the identification of general HMM's and in the design of approximation methods for continuous state HMM's, which have attracted a lot of interest recently under the generic name of particle filtering.

Hidden Markov models (HMM) are widely used in speech recognition, biological sequences alignment, etc. These models are a special case of partially observed dynamical systems, where the state of a finite Markov chain should be estimated from a sequence of noisy observations.

A related problem, in which significant progress has been made recently, is to identify the model from observations. It is easy to express the log-likelihood function, the conditional least squares error and other classical statistics, in terms of the prediction filter, which is the probability distribution of the state given past observations. Similarly, the score function and the conditional least squares residual can be expressed in terms of the gradient of the prediction filter with respect to the unknown parameter.

Our main contribution has been to introduce the extended Markov chain consisting of the unobserved state, the observation, the prediction filter and its gradient, and to prove the existence of a unique invariant probability distribution for this chain, from which the law of large numbers and the central limit theorem can be proved. For a wide class of minimum contrast estimators, including the maximum likelihood estimator and the conditional least squares estimator, it is then easy to prove consistency, i.e. convergence to the set of maxima of the associated contrast function, and asymptotic normality, as the number of observations tends to infinity. We have obtained similar convergence results for the Bayesian estimator and for recursive versions of the estimators. Part of this work is the result of a co-operation with members of the ERCIM working group on Control and System Theory: Lorenzo Finesso (CNR-LADSEB), László Gerencsér (SZTAKI) and György Michaletzky (Eötvös Loránd University).

Future activities will be devoted to extending the same approach to more general models, with emphasis on:
• distributed discrete events dynamical systems, such as those introduced by Eric Fabre for fault diagnosis in telecommunication networks (see page 31 in this issue)
• hidden Markov models with continuous state space.

Extension to continuous state space immediately raises the question of computing the prediction filter, even approximately. An attractive answer to this question has been proposed recently, under the generic name of particle filtering, in which the prediction filter is approximated in terms of the empirical distribution of a particle system. The particles move independently according to the state equation, and whenever a new observation is available, resampling occurs in which the particles are selected according to their consistency with the observation (as measured by the likelihood function). The positive effect of the resampling step is to automatically concentrate particles in regions of interest of the state space. The method is very easy to implement, even in high dimensional problems, since it is sufficient in principle to simulate independent sample paths of the hidden dynamical system, and it allows also for parallel implementation, eg on a cluster of workstations or PC's.

Our contribution has been to propose modifications of the original method, so as to handle efficiently the (difficult) case where the state and / or observation noise are small. One approach is to regularize the empirical distribution associated with the particle system, using a kernel method.
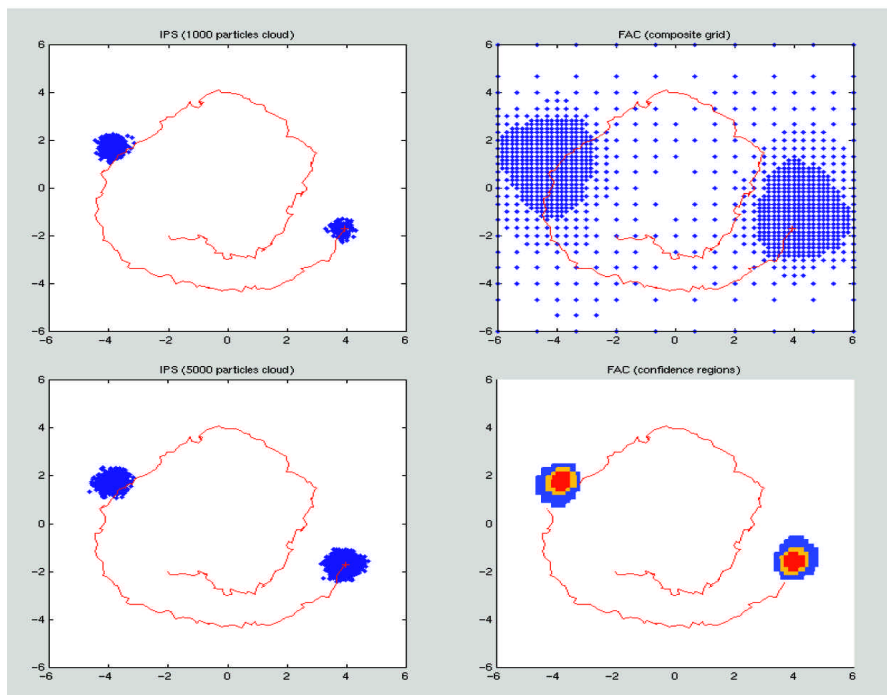
Both the particle filter (left column) and a multigrid method with locally refined adaptive grid (right column) have the ability to concentrate the computing effort in relevant regions of the state space. In terms of the programming effort however, the particle filter is much cheaper.

Another approach is based on the progressive correction principle, in which the correction step is splitted into subcorrection steps associated with a decreasing sequence of (fictitious) variance matrices for the observation noise. These improved particle methods have been applied successfully to various target tracking problems.

This work is the result of a co-operation with Christian Musso and Nadia Oudjane (ONERA/DTIM/MCT), and has benefited from the support of CNRS, through a research project co-ordinated by Pierre Del Moral (Université Paul Sabatier).

The Complexity of Hidden Markov Models

by Lorenzo Finesso

Hidden Markov Models (HMM's) are mathematical models of uncertain phenomena, well suited to describe complex dynamical behaviours. For quite some time HMM's have been mainly applied to speech recognition, but they are currently spreading to a variety of applications in the areas of digital signal processing, control, and pattern recognition. Popular as they have become, HMM's are not yet mature and still offer a wealth of challenging theoretical problems. HMM's are an ongoing research theme of the System Theory group at LADSEB-CNR.

The simplest probabilistic models of uncertain phenomena are independent processes. The salient feature of these models is their lack of memory: the present value of the process is not influenced by its past or future values. Independent processes are adequate to represent the randomness of games of chance and of equivalently simple physical phenomena, but are of limited use in describing true dynamic behaviours. One step above independent processes, in the hierarchy of probabilistic models, one finds Markov chain (MC) models. The present value of a MC depends on a finite (bounded) number of its most recent past values. If their memory size is correctly adjusted, MC's can be used to describe approximately phenomena with complex dynamical behaviour. Hidden Markov Models are at the top of this hierarchy. Roughly speaking, HMM's are processes that can be represented as functions of MC's with a finite number of states: if X(t) is a (finitely valued) MC and h(.) a given function, then Y(t) = h(X(t)) is an HMM.

The simplicity of the definition and the popularity of HMM's in applied research should not give the (wrong) impression that these are simple generalizations of MC's. In general, the transformation h of the MC X(t) destroys the Markov property and, as a result, the HMM process Y(t) can exhibit infinite memory. Only a few of the fundamental questions concerning HMM's have been solved satisfactorily. In the following, we briefly mention the problems to which researchers working at LADSEB have directly contributed.

The most basic probabilistic question is the characterization of HMM's. Is it possible to decide whether a process Y(t) is an HMM, knowing all of its finite dimensional distributions? The positive answer to this question was provided, independently, by Heller and by Furstenberg in the early sixties and later rederived, within the framework of System Theory, at LADSEB, by Picci in 1976. Another probabilistic problem is the realization of HMM's (on Realization theory, see also the articles by Gombani and van Schuppen in this number). In the context of HMM's, realization theory provides the tools to construct, for a given HMM Y(t), the parameters X(t) and h(.), such that Y(t)=h(X(t)). The minimal number of states required for the construction of X(t) is called the order of the HMM and is a measure of its complexity. Picci and van Schuppen (CWI) have shown that the realization problem for HMM's is equivalent to a problem of positive factorization of positive matrices.

Statistical inference problems for HMM's have been intensively studied since the early sixties, when Baum and his coworkers presented two related algorithms (the Forward-Backward and a form of what is today known as the EM algorithm) that helped solve the Maximum Likelihood parameter estimation problem in the case of finitely valued HMM's. At LADSEB,

we are currently working on some aspects of the parameters and order estimation problem for finite and continuous HMM's. The work in this area is in collaboration with Le Gland and Mevel (IRISA-Rennes). Order estimation problems can also be approached with the tools of Information Theory (as pioneered by Rissanen with his MDL, in the context of time series) and are of direct relevance in areas of communications theory such as data compression and source coding. Work on this problem is done jointly with Narayan (University of Maryland).

There are two less standard topics which we have found interesting and on which we are planning future work. In collaboration with Gerencsér (SZTAKI) we are studying estimation problems for quantized ARMA processes, which call for a generalization of HMM's to continuous MC's X(t). In collaboration with Spreij (University of Amsterdam) we study special classes of HMM's hoping to find good approximants of general HMM's in the sense of complexity reduction. For more information on the research of the System Theory group at LADSEB see also the article by Andrea Gombani in this number.

Robust Header Compression enables IP Telephony to Mobile Phones

by Mikael Degermark

Since early 1999, researchers at SICS and Luleå University of Technology have been working with Ericsson Research on developing a robust header compression scheme suitable for IP telephony over cellular systems such as GSM or UMTS. The research has resulted in a novel header compression scheme called ROCCO, RObust Checksum-based header COmpression, with excellent performance.

To make IP telephony over cellular radio systems an economically viable alternative to circuit-switched voice, it is an absolute requirement that the 40-octet IP/UDP/RTP headers of IP telephony packets are reduced in size to conserve bandwidth and expensive radio spectrum. Links in cellular radio systems can have bit error rates of 10% before channel coding and 1/1000 after channel coding. Add a link roundtrip time of 200 milliseconds and all earlier schemes for header compression perform badly. This has been a major obstacle to using the Internet Protocol, IP, for transmitting telephony traffic to mobile phones.

Since early 1999, researchers at SICS and Luleå University of Technology have been working with Ericsson Research on developing a robust header compression scheme suitable for IP telephony over cellular systems such as GSM or UMTS. The research has resulted in a novel header compression scheme called ROCCO, RObust Checksum-based header COmpression, with excellent performance. ROCCO is now being standardized in the IETF, Internet Engineering Task Force, the protocol development and standardization body of the Internet.

Background

With IP telephony gaining momentum and cellular telephony having several hundred million users, it seems inevitable that some future wireless telephony systems will be based on IP technology. What we today know as cellular phones may in addition to telephony and video have IP stacks, web browsers, email clients, networked games, etc. If based on IP, the telephony service will be considerably more flexible than today. The project initially concentrated on the problem of providing a good IP solution for speech, but it is understood that applications for video, games, etc, will also have to be supported. It is vital for cellular phone systems to use the radio resources efficiently in order to support a sufficient number of users per cell. Only then can deployment costs be kept low enough. It is also important to provide sufficiently high quality voice and video. In particular the voice service should be as good as what users expect from the cellular phone systems of today. A lower quality may only be accepted if costs are significantly reduced.

The radio channels used in cellular systems have very high bit error rates (BER) due to shadow fading, multipath fading, and continuous mobility. The radio signals of one user will interfere with the radio signals of other users, so with the desired number of users per cell, BERs will be high. Even after error correcting channel coding, the remaining BER can be as high as 10^{-3} (one in 1000) or even 10^{-2} (one in 100) for some users some of the time. Interleaving is used to improve the performance of the channel encoding, and together with other delays this brings the link roundtrip time to 100-200 milliseconds.

Header compression

The existing standard for compressing IP/UDP/RTP headers is CRTP, defined in [RFC-2508]. It compresses headers over a single link by maintaining a 'context', which is essentially the full version of the last header transmitted over the link, at both ends of the link and transmitting only differences between consecutive headers. In this manner, each compressed header updates the context. When a packet is lost between compressor and decompressor, the context of the decompressor is not updated properly, and decompression will fail. To deal with such problems, CRTP has a context repair mechanism which relies on signaling. Essentially, the decompressor signals the compressor that its context is out of sync, and the compressor then sends updating information. Due to the long link roundtrip time, however, several voice packets will be lost before the repair is completed. CRTP thus performs very badly when error rates are high as each lost packet is accompanied by several packets being lost due to context mismatch. The only way to avoid context-related loss appears to be to enable the decompressor to repair its context locally, i.e., without going across the link. ROCCO computes a CRC over the header before compression and transmits the CRC as the compressed header. In this manner a reliable way to detect a successful context repair is introduced. It becomes feasible to have a decompressor attempt several repairs without risking introduction of erroneous headers. As headers of voice conversations are fairly regular, the decompressor will almost always succeed in repairing the context. When there are irregularities, the compressor adds minimal extra information to the compressed header.

ROCCO exhibits excellent performance with near-trivial context related packet loss. It is an enabling technique for cellular IP telephony. The development and standardization of robust header compression schemes are now being continued in the context of the ROBHC working group of the IETF, chaired by Degermark. In addition to IP telephony, the WG will work on robust header compression for low-bandwidth video and for TCP.

Links:

ROCCO homepage:
http://www.ludd.luth.se/users/larsman/rocco/

Please contact:

Mikael Degermark – Systemteknik, Luleå University of Technology
Tel: +46 70 833 8933
E-mail: micke@cdt.luth.se, micke@sics.se

MARVINS – Mobile Augmented Reality Visual Navigational System

by Raghav Sanwal, Sepideh Chakaveh, Konstantinos Fostirpoulos and Horst Santo

A solution for museum guides or training in dangerous environments was developed at GMD Institute for Media Communication.

To acquire information has never been cheap. Moreover until recently time was not a significant element when costs of information were being calculated. Nowadays, information acquisition time factor has taken on greater significance, and consequently provided an incentive for the development of technologies to facilitate the minimum time costs. The business sector has not yet been significantly concerned with the increased monetary costs of these time saving information technologies. A perfect example is the rapid adoption of live video conferencing, despite its initially high costs.

In other fields, such as education and tourism however, the situation is quite different. Here, the information seekers are generally individuals, schools or other organisations which normally hold rather limited funds. Consequently, they have been forced to adhere to the time worn and inexpensive methods of information acquisition such as pamphlets, brochures etc. or recently supplemented by the vast resources of the Internet. Nonetheless the Internet bears an inherent drawback, i.e. its inability to be a personal, customised, on-site and subject specific interface medium contrary to a teacher or a guide.

A fairly non-expensive system named MARVINS (Mobile Augmented Reality Visible Navigation System) eliminates this drawback. MARVINS is a mobile interactive interface between the user and the Internet or other information access points which can selectively display any desired information allocated at some remote server.

Implementation

MARVINS is a simple Augmented Reality Assembly, primarily designed for mobile applications, which is implemented at a rudimentary level for test purposes. The complete system consists of a DynaSight tracking system, a Sony GlassTron, a transmitter and receiver set,

Mobile multimedia museum guide, a typical MARVINS application.

and a computer. In addition the whole assembly is tracked using the line-of-sight principles. Information (Video, Audio and Text) is relayed from a server via the transmitter-receiver to the GlassTron Head-Mount.

A tracking system is used to provide orientation and navigation possibilities. The sensitivity of DynaSight tracking system is limited by the speed of any moving target (Lock-on delay: 0.3 sec, Measurement Latency: 16-31 millisec.). This is also a function of target's relative position with respect to a three-dimensional co-ordinate plane centred midway between its two near infra-red tracking beams. The tracking system´s angular active field of cone, is some 75-degrees with respect to the origin of the co-ordinate's plane.

Using three similar tracking systems to provide accurate tracking in a four-sided room, one may reduce considerably, the limitations on the field of sensitivity of the tracking system. For larger physical areas, normally Global Positioning Satellite (GPS) technology could be used. The head mount unit used for MARVINS is a Sony Glasstron. The system renders

the eye-screen opaque for viewing displayed information, as well as transparent for viewing with the naked eye, which can be adjusted accordingly. Glasstron is also devised with Stereo headphones for audio transmission.

The system was completed by cascading a transmitter-receiver set, operational in 1.2 GHz range. The video and audio signals generated by the server were directed to the transmitter- receiver set, which in turn forwarded the signals to be broadcasted to the head mount unit. It was found that a significant loss of clarity does not occur in either the video or audio. This would, of course, depend on the distance between the transmitter and receiver, and transmission range. The disadvantage of the Glasstron head-mount is its small viewing area, which consequently generates difficulties in reading fine scripts etc. (Dimension units 149x48x86 mm).

Further tests were carried out by adding some tracking systems. It was found that MARVINS could accurately track movements of the user's head. However, the limitation recorded here was again the field of sensitivity of the tracking system.

Apart from the lateral area of sensitivity, at distances in excess of an 8-feet radius, the information on the display did not change. It was found that the tracking readout would need to be modified to correct for distance from the viewed object. This correction would need to be incorporated into the final readout from the tracking system before the information or image were displayed. In this case, the display would reflect the actual line-of-sight.

Possible Applications

Tourism: It is likely that the tourism sector will rapidly embrace this technology. Here, tourists may be provided with such a visual display and could freely wander and receive the audio-video information remotely from a server. An incentive is the boost to tourism that such a technology can provide.

Education: It will be a while before MARVINS is seen extensively in the educational sector at large. While the prices for such units are within the budgets of holidaymakers, they would normally exceed those of schools and small universities or even are assumed redundant. Nonetheless such systems may be used in areas, such as science museums, art museums and other historic or cultural sites.

Rescue Operations, Training and Simulations: MARVINS can be used for fire fighting and other hazardous activities. It can provide a definite edge where the latest information, directions, advice may be continuously updated in real-time. MARVINS´ fairly lightweight and portability make it ideal for rescue operations. It can also be used for training and simulations, functioning as a link between the training instructor and the trainee.

Please contact:

Sepideh Chakaveh – GMD
Tel: +49 2241 14 2608
E-mail: sepideh.chakaveh@gmd.de

Challenges towards Universal Access in the Information Age

by Constantine Stephanidis

The radical technological changes in the Information Technology and Telecommunications industries have contributed towards a more information- and interaction-intensive paradigm for human-computer interaction. This trend, which is expected to continue, raises a whole new range of social, economic and technological considerations, regarding the structure and content of societal activities at the turn of the 21st century.

The term Information Society is frequently used to refer to the new socio-economic and technological paradigm likely to occur as a result of the changes that are taking place. The Information Society has the potential to improve the quality of life of citizens, the efficiency of our social and economic organisation, and to reinforce cohesion. However, as with all major technological changes, it can also introduce new barriers, if the diverse requirements of all potential users are not taken seriously into consideration, and access to computer applications and services is not guaranteed. This may lead to a 'two-tier' society of 'cans' and 'cannots', in which only a part of the population has access to the new technology, is comfortable using it and can fully enjoy the benefits.

The acceptability of the emerging Information Society to all citizens ultimately depends on its accessibility and usability. Therefore, it is important to develop high quality user interfaces, accessible and usable by a diverse user population with different abilities, skills, requirements and preferences, in a variety of contexts of use, and through a variety of different technologies. Universal Access concerns the right of all citizens to obtain and maintain access to a society-wide pool of information resources and interpersonal communication facilities, given the varieties of context. To this end, Human-Computer Interaction (HCI) plays a critical and catalytic role.

Universal access is predominantly an issue of design, namely how is it possible to design systems that permit systematic and cost-effective approaches to accommodating all users. The term universal design is used to reflect a new concept or philosophy for design that recognises, respects, values and attempts to accommodate the broadest possible range of human abilities, requirements and preferences in the design of interactive environments, products and services. Thus, it promotes a design perspective that eliminates the need for special features and fosters individualisation and end-user acceptability. Design for all does not imply a single design solution suitable for all users. Instead, it should be interpreted as an effort to design products and services in such a way so as to suit the broadest possible end-user population.

Over the years, the issue of access to computer-based applications and services has been addressed through various collaborative efforts. The traditional approach to accessibility is to adapt applications and services to the abilities and requirements of people with disabilities (see Figure 1). As a result, such an approach mainly reflects a reactive attitude, whereby Assistive Technology solutions addressed problems introduced by a previous generation of technology. Despite the undoubted value
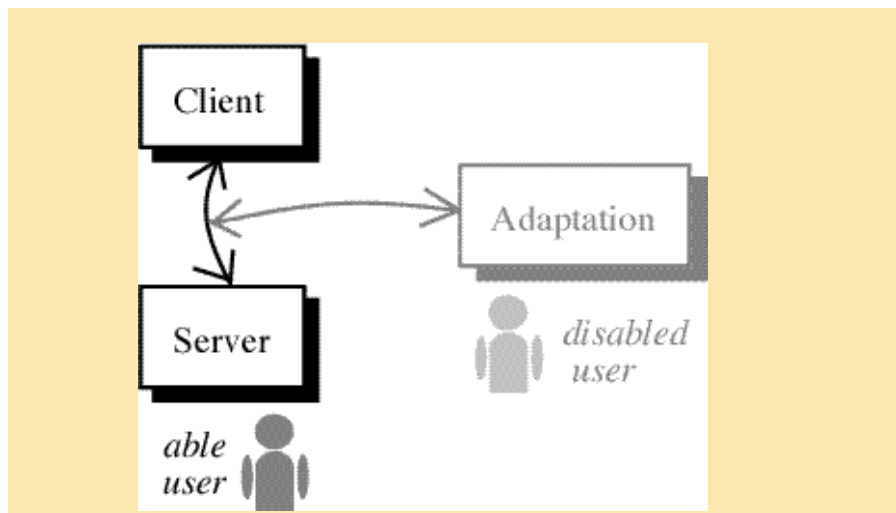
and usefulness of the adaptations-oriented approach and the accumulated body of knowledge, it clearly neglects aspects of accessibility that are particularly important in the context of the emerging Information Society.

The second and more recent approach aims to proactively account for accessibility by taking appropriate actions during the early phases of a product's life cycle. Though cost/benefit data are missing, at present, to assess the economic efficacy of proactive approaches, the attention that is being devoted to the issue is rapidly increasing. Recently, there have been a number of initiatives by mainstream actors (Microsoft, Sun, IBM,

**The general architectural model
of accessibility-oriented environment-level adaptations.**

Apple, etc) and research consortia to develop technological frameworks that provide more adequate support for accessibility and easier integration of assistive technology applications. These efforts aim to provide accessibility tools as integral components of mainstream interaction platforms and environments. Three promising alternatives are the Active Accessibility® initiative by Microsoft, JavaTM Accessibility by Sun and the Unified User Interface development platform developed in the context of the TIDE - ACCESS consortium funded by the European Commission. The FRIEND21 project in Japan has also made a very important contribution in this respect.

In addition to the above efforts, there have been several attempts, some of which are still on-going, to consolidate the existing wisdom on accessible and/or universal design in the form of best-practice principles. Such materials become increasingly available either as general and context-free guidelines or as platform- or user-specific recommendations (eg, W3C - Web Accessibility Initiative).

Universal Design is also addressed in some policy initiatives. In the recent past, the principles and practice of design for all have been progressively adopted and advocated by an increasing proportion of the research community (i.e., research consortia in the context of various RTD Programmes of the European Commission), industrial consortia, scientific and technical committees, standardisation bodies, as well as national legislation and international directives. Efforts towards universal design have met wide appreciation by an increasing proportion of the international research community, thus leading to the foundation of working groups, such as the ERCIM Working Group on User Interfaces for All.

Despite the fact that the currently available know-how has reached a level of maturity that provides evidence of technological feasibility in the area of accessible computer-based products and services, Design for All still poses many challenges in the field of HCI. The lack of consolidated theories to guide and facilitate universal access is evident from the limited input and impact that prominent HCI design strands (such as Human Factors evaluation and Cognitive Science) have had on the study of universal access. Furthermore, the situation is further complicated by the lack of practical means (tools and architectures) to guide developments towards universal access. Clearly, additional and significant research and development efforts are needed to address the challenges posed by Design for All in the HCI field. A research agenda is therefore required for providing a common and unifying frame of reference for subsequent endeavours.

A proposal for such an agenda is presented in the ERCIM ICST Report 'Designing for all in the Information Society: Challenges towards universal access in the information age'. The report analyses some of the critical issues involved, provides an overview of the current state of the art in Universal Design, and identifies and proposes specific research directions. The thematic scope of the proposed agenda is broad and complex, and is articulated around four clusters: (i) the development of environments of use; (ii) the support of communities of users; (iii) the extension of user-centred design to support new virtualities; and (iv) the establishment of suitable accompanying measures.

Evolution and Neurons in ICT and Management

by Han La Poutré

Evolutionary methods and neural networks are important computation methods inspired by essential principles in Nature, like 'survival of the fittest', evolution, learning processes, interaction, and parallelism. They provide important new possibilities for a fast and good solution of problems related to economy and management. R&D at CWI focuses on evolutionary algorithms, as well as on dynamic algorithms and neural networks. The main applications are related to management and ICT, including E-commerce, on-line process management, remote sensing classification, and economy.

Evolutionary algorithms are traditionally applied to areas like mathematical optimization and automatic programming. New application areas emerge in the ICT domain (simulation of adaptive agent systems, design of intelligent agents, profiling, electronic commerce, data mining) and the social sciences, where for example complex adaptive systems are seen as agent-based systems (economic markets, grouping and collaboration of individuals, etc.). The combination of these areas with software agents yields new research in E-commerce, as an economic sub-area.

The usage of evolutionary techniques in these areas requires substantial research into computational feasibility and complexity of the phenomena in question. Modelling and assessing the relation between computational techniques and real-world mechanisms also become very important. CWI presently has a strong interest in multi-agent systems, as they appear in economics, E-commerce, logistics and social systems. Two new projects were started in these areas. The first, Autonomous Systems of Trade Agents in E-commerce, is carried out in cooperation with the national Organisation for Applied Research (TNO), several major companies, and the Telematics Institute. It addresses the development of learning agents for E-commerce applications, including negotiation, search, logistics, profiling, and filtering. In the project Evolutionary Exploration Systems for Electronic Markets, an explorative system is developed to model and study electronic markets, based on evolutionary methods. The aim is to gain insight into the effects of new mechanisms in electronic commerce. Here CWI cooperates with the Faculty of Economics of the University of Amsterdam.

Neural Vision is an efficient tool to inspect data resulting from measurements of the quality of the road surface.

In the field of dynamic algorithms CWI is involved, jointly with Philips Research Laboratories, in the design of fast, dedicated algorithms for on-line management problems in ICT, for example multimedia (eg, scheduling and resource management problems) and telecommunication (eg, on-line assignment of bandwidth). The continuous decision making in real-time within an active system requires on-line management. Here, the problem field can include agents that negotiate about, eg, the quality of service or, more general, that make on-line decisions.

Using several kinds of neural networks, CWI developed a tool for visualization and clustering of high-dimensional data sets by means of data projection (cooperation with Nijenrode University and the Ministry of Public Works). The tool forms an important part of explorative data analysis within a decision making process. Other research into neural networks concerns their use in clustering techniques to determine which customer characteristics are important for purchasing behaviour. There is growing research interest in spiking neural networks. CWI currently focuses on classification problems, for example unsupervised classification to extract information on disaster areas from remote sensing data (in cooperation with the University of Amsterdam and the Cold Regions Research and Engineering Laboratory in the USA). It is anticipated that neural networks can become an important implementation of intelligent agents for several types of tasks.

Please contact:

Han La Poutré – CWI
Tel: +31 20 592 4082
E-mail: Han.La.Poutre@cwi.nl

Location Techniques for Cellular Phones

by Jaakko Lähteenmäki

One of the driving forces for location functions of mobile phones is the requirement by the FCC (Federal Communications Commission) in the USA: by October 2001 cellular systems shall be able to determine the location of a mobile phone in case of an emergency call. Mobile phone manufacturers and operators are now putting great effort into developing techniques to fulfil the FCC's requirement, and to facilitate implementation of other location-based services. A study on complementary location techniques optimized for urban and indoor environments was initiated at VTT Information Technology.

In addition to emergency applications, there is a wide range of other potential location applications including, for example, location-sensitive mobile Internet applications, fleet management and operators' own network planning activities.

Currently, there are two main approaches for mobile phone location: a GPS (Global Positioning System) receiver module can be integrated into the handset or the transmitted signals of the cellular system can be used for location. Both approaches are based on computing the handset coordinates with the help of geometric distances retrieved from signal delay measurements. In open areas, these methods work well, but in built-up areas the signals from satellites or base stations do not reach the mobile phone directly, which leads to seriously degraded accuracy. Indoors, it is normally even not possible to receive a sufficient number of GPS satellites or base stations for location determination.

New Location Technique

VTT Information Technology has initiated a study on complementary location techniques optimized for urban and indoor environments. The new technique, depicted in the figure below, involves a location server with a large database including the measured or predicted field-strength values of several base stations in the area of interest. The location of the mobile phone can be computed by comparing the signals received by the phone to the signal values stored in the database.

The new location technique enables various signal characteristics to be utilized. In addition to field strength, for example, the predicted and measured delays and even impulse responses between the base station and mobile phone can be stored in a signal database and used as information for the location algorithm. Furthermore, if a GPS receiver is integrated into the phone, the GPS signal information may also be used to enhance the results in cases when satellite signals can be received. It is the objective of the first phase of the study to find out by computer simulation which signal characteristics should eventually be used and to determine the expected accuracy of the method.

Implementation of the new location technique involves some software modifications of the handset in order to enable the retrieval of received signal characteristics. Sending of the signal characteristics to the location server may be done by standard communication channels, eg the SMS (Short Message Service) of the GSM. A more efficient service can be achieved when the GPRS (General Packet Radio Service) becomes available. The third-generation systems will use wideband signals, which will increase the accuracy of location. In the development and implementation of the location method, the existing competence of VTT in radiowave propagation prediction and planning tools is being utilized.
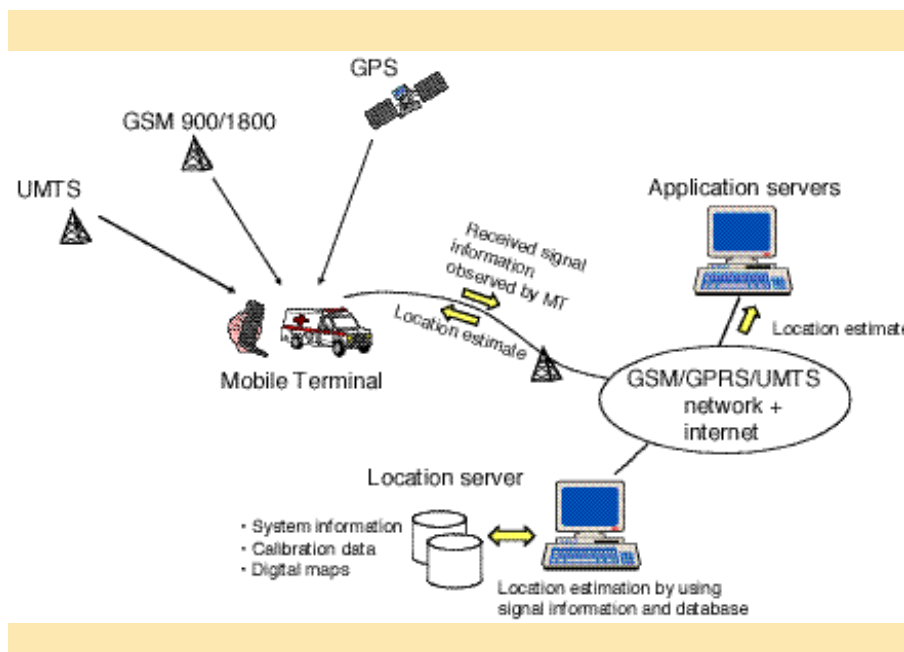
Location concept based on received signal characteristics and database information. In addition to the Mobile Terminal, the location estimate is transmitted to additional application servers

Please contact:

Jaakko Lähteenmäki – VTT Information Technology
Tel: +358 9 456 6547
E-mail: jaakko.lahteenmaki@vtt.fi

Descartes and Kepler for Spatial Data Mining

by Natalia Andrienko, Gennady Andrienko, Alexandr Savinov and Dietrich Wettschereck

Geographic Information Systems (GIS) and Knowledge Discovery in Databases (KDD) have so far been developed as two separate technologies. Recently, as organizations have accumulated huge databases with a high percentage of geographically referenced data, they begin to realize the huge potential of information hidden there. The task of applying data mining technologies to geographic information systems is therefore now becoming extremely relevant. Current results of integrating the geographic information (analysis) system Descartes and the data mining tool Kepler are very promising.

Our system Descartes provides unique features (i) for intelligent mapping support and (ii) a full spectrum of functions for interactive visual analysis of spatially referenced data (see 'Descartes system: Interactive Intelligent Cartography in Internet' by Gennady Andrienko and Natalia Andrienko in ERCIM News, July 1998). Thus, Descartes automates the generation of maps presenting user-selected data, and it supports various interactive manipulations of map displays that can help to reveal important features of the spatial distribution of data. Descartes also supports some data transformations effective for visual analysis, and supports the dynamic calculation of derived variables by means of logical queries and arithmetic operations over existing variables.

Our Kepler data mining system provides an easy-to-use, flexible, and powerful platform incorporating a number of data

Kepler and Descartes: integrating traditional data mining instruments with interactive cartographic visualization tools.

mining methods. It is an open platform by supplying a universal plug-in interface for adding new methods. Kepler supports the whole data mining process including tools for data input and format transformation, access to databases, querying, management of (intermediate) results, and graphical presentations of various kinds of data mining results (trees, rules, and groups). In great extent, both systems are designed to serve the same goal: to help to get knowledge about data but provide complementary instruments with a high potential for synergy.

Integrating the Tools - New Generation of Spatial Data Analysis

To further support the analysis of spatially referenced data we realized a first link between Kepler and Descartes, thus integrating traditional data mining instruments with interactive cartographic visualization tools. The basic idea is that an analyst can view both source data and

results of data mining processes in the form of maps and statistical graphics that convey spatial information in a natural way. The analyst can thus much easier detect spatial relationships and patterns.

Conceptually the integrated system combines three kinds of links:
• from 'geography' to 'mathematics': when visually exploring and manipulating a map, the user may detect some spatial phenomenon; he may then try to find an explanation or justification for this by applying data mining methods
• from 'mathematics' to 'geography': data mining methods produce results that are then visually presented and analyzed on maps
• dialogue between 'mathematics' and 'geography' (linked displays): graphics representing results of data mining in the usual (non-cartographic) form are viewed in parallel with maps, and dynamic highlighting visually connects

corresponding elements in both types of displays.

The integrated system has a client-server architecture. The server is implemented in C++ (Descartes) and Prolog (Kepler), the client in Java. The system is available for Windows and Unix platforms. Product version of Descartes and Kepler are available from Dialogis Software & Services GmbH.

Links:

Descartes examples to try out:
http://allanon.gmd.de/and/java/iris
Information about Kepler and Dialogis:
http://www.dialogis.de/
Homepage of the research group:
http://ais.gmd.de/KD/

Please contact:

Gennady Andrienko
and Alexandr Savinov – GMD
Tel: +49 2241 14 2486/2629
E-mail: gennady.andrienko@gmd.de,
alexandr.savinov@gmd.de

Analytical Visualization of Spatio-Temporal Data

by Natalia Andrienko, Gennady Andrienko and Peter Gatalsky

How to show in a map characteristics of spatial objects or phenomena that vary in time? This has always been a challenge for thematic cartography. At present, when people deal with maps on computer screens more often than with printed ones, there exist much more opportunities than ever for visualization of time-related spatially referenced data. A screen map may display dynamics of phenomena through changing its appearance in real time.

Research on visualization of spatio-temporal data is being conducted at GMD in Knowledge Discovery Group of the Institute of Autonomous Intelligent Systems. The primary goal of the research is to develop such visualization techniques and tools that will support exploratory analysis of spatio-temporal data. In this it is different from other works that are more focused on the use of animated maps for presentation purposes, i.e. demonstration of previously known spatio-temporal trends and patterns.

Diverse tools for data analysis are needed depending on what kind of time-dependent characteristics are to be studied: existence, spatial location, geometry (shape and size), or thematic (attribute) data. Thus, studying

development of cities, one may be interested when cities appeared or, possibly, which cities disappeared due to some disaster (existence), how the cities spread territorially (geometry), or how their population grew (attribute). For a beginning, we have focused on visualization of changes of spatial location.

Investigating movement of objects in space, an analyst may seek answers to different questions:
• what trajectories did the objects make during the whole time span considered?
• where was each object at a selected moment t?
• how did the positions of objects change from moment t1 to moment t2?

• what were the routes of the objects on the interval [t1, t2]?
• how did the movement progress with the time?

We have developed a visualization tool to support such an investigation. It offers the user various views on the data: overall view (the whole routes), instant view (positions at any selected time moment), interval view (route fragments made on the specified interval), and dynamic view (animation). Interactive exploration of data is enabled by special interaction control - time slider - which is connected to a dynamic map display. It allows the user to select time moments or intervals, move the display forth and back in time, or run animation. Animation may be
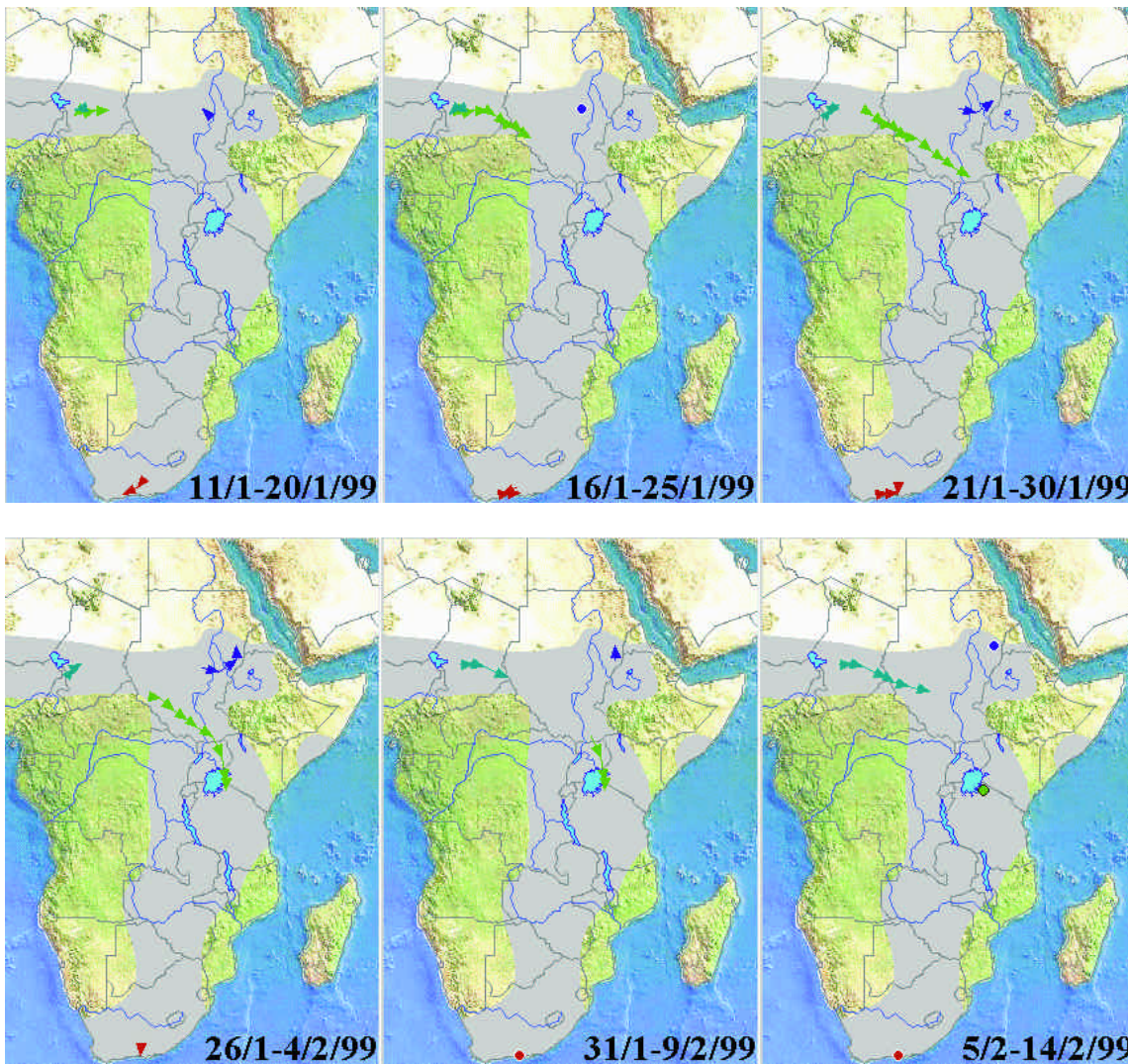
Observations of migration of four storks to Africa in a combined interval-dynamic view. Each image represents a 10-days-long successive interval. The intervals overlap; the step between them is 5 days. Though the intervals are of the same length, the length of the corresponding route fragments varies reflecting changes of speed of movement.

regulated through a number of parameters. In particular, the analyst may select whether at each moment of animation the map presents instant, interval, or overall view.

We tested our tool on an example data set containing telemetric observations of migration of four storks to Africa in autumn 1998 and back to Europe in spring 1999. In our tests we found especially interesting and useful combination of dynamic and interval views, i.e. the animation mode with interval view at each moment. In such a display object routes look like worms crawling on the map. It is not merely fascinating; these 'worms' help to study important dynamic characteristics of movement. The length of a 'worm' shows the speed of movement. Reducing of the length signalizes that the movement of the object slows down, growth of the length means that the movement becomes faster. When an object stops its movement and stays for some time in the same place, the corresponding 'worm' reduces to one point. All these observations would be

practically impossible with usual animated presentations, which simply play a sequence of images showing states (in this case positions) at successive moments of time.

The figure demonstrates the combined interval-dynamic view. The shots represent six 10-days-long successive intervals. The intervals overlap; the step between them is 5 days. Though the intervals are of the same length, the length of the corresponding route fragments varies reflecting changes of speed of movement.

We invite the readers to explore the movement of the storks as well as test our tools to support this exploration by running the Java applet that is available at http://borneo.gmd.de/descartes/java/birds/index.html.

Exploratory techniques similar to those we designed for data about spatial movement can be proposed for other types of spatio-temporal data. We developed a variation of the above-

described tool that deals with point observations, eg data about earthquakes (see example at http://borneo.gmd.de/descartes/java/show1field/eq.html) or nature observations made by schoolchildren (examples are available at the Naturdetektive project site, http://lo.san-ev.de/natdet/). At the moment we are creating interactive analytical techniques and visualizations for studying dynamics of attribute data, for example, demography or economic indices. This work will be further developed within the SPIN project (Spatial Mining for Data of Public Interest) accepted for funding in the IST Programme.

Links:

Homepage of the group:
http://ais.gmd.de/KD/

Please contact:

Gennady Andrienko or Peter Gatalsky
Tel: +49 2241 14 2486/2261
E-mail: gennady.andrienko@gmd.de,
peter.gatalsky@gmd.de

Software Certification: Myths and Reality

by Fabrizio Fabbrini, Mario Fusani, Vinicio Lami

Certification is treacherous stuff. People tend to have contradictory attitudes. Some want to have a full guaranty that a given product or service is reliable, others consider the term and all that it concerns as deceptive and used only for marketing purposes. And when it comes to software, professionals may be found near to hysteria, insisting that the concept should be excluded from the technological, if not the commercial, realm. Despite all this, practitioners, scientists, and even users, can coexist happily with software certification, if only they take a positive view of the concepts, actions and entities involved. The problem is that many people talk and assert their opinions on certification without really knowing what it's all about. Our aim here is to define the area of interest and show that nothing dramatic happens when software is involved.

Process of software certification.
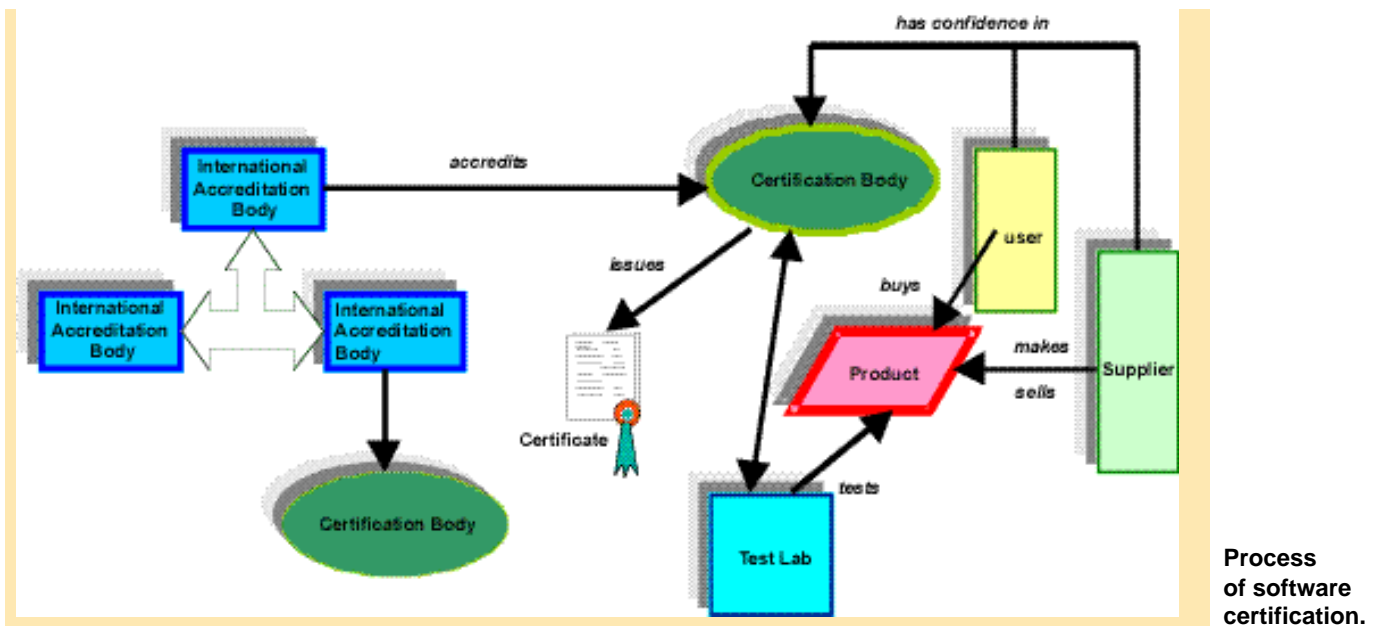
Certification can be described as an act by which an accredited third party declares that a defined entity (product, service, process, characteristic) is conform to a standard.

For sure, we could explain 'accredited third party', 'conform', 'standard', and why 'declares' is used instead of 'demonstrates' or 'guarantees', but this is not necessary to get our point over. The point is that it is not a matter of demonstrating nor guaranteeing, but of giving confidence, and this implies the involvement of some 'user' entity in the certification process. The accredited third party is needed to transfer confidence to users, but this implies other concepts such as 'third party liability' and raises questions such as: 'who accredits the accrediting organism?'. Such concepts are solved in the uncommented Figure.

And now for software. The idea that some concept of guaranty could be lurking in the word certification has actually been banished from the expression software certification as used in technical or commercial software literature. It is well known that all commercial software packages are sold (even though never advertised) together with an inseparable disclaimer by the supplier. But users do not like disclaimers; they actually want some kind of guaranty. We have spoken of confidence as a reasonable (if not full) level of certainty and as an aspect users can accept, but can we introduce guaranty in software certification? Of course we can – it just depends on what is to be guaranteed.

What can be guaranteed is hardly some functional property of the software product. We know that even functional standards for compilers, protocols and graphic kernels cannot describe exhaustive test suites. Even more disheartening is that the certification of specific functional/non-functional properties is unfeasible for general-use software products.

What can be guaranteed in software is that the supplier of a given product has performed a process that includes the proper use of defined standard practices, both general practices and practices for the specific application domain. This cannot do much more than establishing a certain level of confidence that the product suits specific user needs, but it may be all the user wants and needs. This can and should be accepted as a feasible software product certification.

It should, however, be noted that this use of certification must be distinguished from ISO 9000 or CMM certification,

which refer to the quality of a system or the capability maturity levels of an organisation. Even if a positive correlation between organisation quality and product quality can be demonstrated, in principle this correlation is weaker than in the case of complete product certification.

A Centre for Software Certification has been established at IEI-CNR which operates within the framework defined above in which certification implies above all assessing whether a product satisfies the given set of criteria adopted when developing the product. The Centre is an evolution of a former service for the validation of software programs for electronic cash registers provided on behalf of the Italian Ministry of Finances.

The activity of the centre regards product testing and quality evaluation, and software process assessment.

Please contact:

Mario Fusani – IEI-CNR
Tel: +39 050 593 512
E-mail: fusani@iei.pi.cnr.it

CLEF – Cross-Language Evaluation Forum

by Carol Peters

A Cross-Language Evaluation Forum (CLEF), an important initiative for the evaluation of multilingual information retrieval systems, is now being launched in Europe. The activity will be sponsored by the DELOS Network of Excellence for Digital Libraries and funded by the Information Societies Technology programme of the European Commission. It will be conducted in collaboration with the US National Institute of Standards and Technology (NIST) and the TREC conference series. We present the agenda and the most important deadlines for CLEF 2000.

It has been demonstrated extensively by the Text REtrieval Conference (TREC) series that the availability of evaluation procedures can contribute significantly to the improvement of system performance. For this reason, in 1997, it was decided to include cross-language system evaluation as one of the tracks at TREC. The aim was to provide developers with an infrastructure enabling them to test and tune their systems and compare the results achieved using different cross-language strategies. From 2000 the cross-language initiative for European languages will be coordinated in Europe while TREC will focus on Asian languages. This move and the inclusion of a monolingual track for the evaluation of IR systems designed for languages other than English will help to stimulate European participation and allow us to focus on a wider range of issues.

CLEF AGENDA for 2000 – Task Description

The ultimate goal for systems for multilingual information retrieval is to offer users the opportunity to query in any language and retrieve a merged and ranked set of documents that match the query in whatever language they are stored. However, information access in multiple languages also implies an understanding of the issues involved in monolingual IR for different language types and sub-types, and many of today's applications regard cross-language retrieval between selected pairs of languages. There will thus be three evaluation tracks in CLEF 2000. Interested groups can participate in any one or in all three tracks. Newcomers to the activity may well choose to begin with the monolingual track in the first year and work up to the others in later years.

Multilingual Information Retrieval

The main task of CLEF 2000 requires searching a multilingual document collection for relevant documents in English, German, French, and Italian. Similar to the CLIR track in TREC'99, the goal is to retrieve documents from all languages, rather than just a given pair, listing the results in a merged, ranked list. Although the official languages for CLEF 2000 will be English, French, German and Italian, it will also be possible to submit runs in which the document collection is queried in other languages. In this case, participants will be responsible for the translation of the query into their selected language. The results for such runs will be given separately.

Bilingual Information Retrieval

A cross-language task in which the query language can be either French, German or Italian but the target document collection is English will also be provided and the results will be judged. Many IR groups are now beginning to work on retrieval over pairs of languages and this will give them a chance to participate officially in the CLEF activity. Unofficial bilingual runs in which the query to the English document collection can be any language can also be submitted and will be evaluated.

Monolingual (non-English) Information Retrieval

It is often asserted that procedures for monolingual information retrieval are (almost) completely language independent. This is not however true; different languages present different problems. Methods that may be highly efficient for certain language typologies may not be so effective for others. Issues that have to be catered for include word order, morphology, diacritic characters, language variants. So far, most IR system evaluation has focussed on English. We will provide the opportunity for monolingual system testing and tuning and build up test suites in other European languages (beginning with French,

German and Italian in CLEF 2000) Resources.

NIST provides a complete IR system to interested participants which currently contains simplistic German and French stemmers. This is the PRISE Test Suite.

The CLEF document collections for 2000 should consist of sets of multilingual comparable newspaper documents, from the same year, for all four languages.

CLEF participants will have free access to the multilingual test suite for research purposes.

Deadlines
• Topic Release: 1 May 2000
• Receipt of results from participants: 1 July 2000
• Release of results: 15 August 2000
• Submission of paper for Working Notes: 30 August 2000
• Workshop: 21-22 Sept. 2000.

Partners
NIST, Gaithersburg MD, USA (Ellen Voorhees); University of Zurich, Switzerland (Michael Hess); Social Science Information Centre, Bonn/ University of Koblenz, Germany (Jürgen Krause); CNR, Pisa, Italy (Carol Peters); Eurospider, Switzerland (Peter Schäuble).

Links:

For further information see:
http://www.iei.pi.cnr.it/DELOS/CLEF

To be included in the CLEF mailing list, please contact:

Carol Peters – IEI-CNR
Tel: +39 050 593 429
E-mail: carol@iei.pi.cnr.it

Workshop

A two-day Workshop will be held on 21-22 September in Lisbon, Portugal, immediately after ECDL 2000, the fourth European Conference on Digital Libraries. The first day will be open to all interested participants and focussed on research related issues in Multilingual Information Access. The second day will present and discuss the results of the CLEF activity and will be restricted to active CLEF participants.

Hungarian SMEs and Academic Institutions: Some Technology Transfer Results

by György Kovács

Small and Medium size Enterprises (SMEs) became a decisive factor in recent Hungarian technology transfer activities. In this article we discuss some TT success stories 'academia to industry'.

Technology transfer was a natural and flourishing activity between academic and industrial partners during the years of 'embargo', when Western politics did not allow the delivery of high-tech equipment and technology – defined in the so-called COCOM lists – to East European countries (1960-1990). As most R&D goals were well-known and the ways to reach them were top secret, the countries were forced to have their own R&D results. Some of these were just from the narrow field of IT related manufacturing engineering: adaptive control, direct numerical control (DNC), dialog CNC, multi-axis machining, CAD/CAM/CAPP systems, Flexible Manufacturing Cells and Systems (FMC and FMS).

To reach these results a close co-operation between academia, industry and government existed. Industry and the market collapsed together at the beginning of the nineties, universities and academic research institutes survived, but became poor, and R&D support from the government decreased to 0.6% of a decreasing GDP. It is hoped that the GDP in 2002 will reach its value of 1989, and the R&D support will go up to 2% of the GDP in 2-3 years. Hungary became a full member of NATO and of several other international organisations (including ERCIM), and it hopes to join the European Union soon. Some of the positive factors of the nineties are the following:

Powerful multinational firms appeared giving jobs and demonstrating modern technologies. Several SMEs were formed; some of which are ready and are forced to invest into development to be able to survive. Joint ventures taught how to survive in the world market. European joint R&D projects became available to prove SMEs abilities. The EU Fifth Framework Programme that started in 1999 finds Hungary already in the position of a full right partner country.

Technology Transfer Success Stories
Recently the direct technology transfer from academia to industry is important but very restricted, due to financial and organisational issues. On the other hand special technology transfer solutions are provided by different types of IT related SMEs focusing on the problems and methods of transfer and implementation of R&D results. A short list of the different origins of SMEs and some representative ones are:

• spin-off SMEs of academic institutions: (i) a representative of advanced foreign firms and successful system-integrator based on the products they represent (ii) genuine R&D with implementation of the results and IT integration; the staff just continued the academic R&D they started several years earlier (iii) industrial projects as an independent SME and as SZTAKI subcontractor

•SMEs working as joint academic-private firms: joint venture of the academic research staff and some private engineers take part mostly in virtual enterprise related international projects

• SMEs based on one or two 'big' ideas: a CAD/CAM provider added to its profile the production of rapid prototypes on a Laminated Object Manufacturing 2030E machine, which they purchased with several difficulties with government support and loans. This led them to the real success.

• SMEs formed to promote products of some 'real big' firms: the merge of two existing SMEs to provide rapid technology transfer based on a successful CAD/CAM product (CATIA of IBM) formed a new SME

•SMEs based on the ruins of the socialist industry (by means or without privatisation): the software team of a machine tool factory makes software development in the field of NC/CNC programming and it sells the products with total support mostly to customers of the factory

• SMEs as parts of new, national 'big, private' enterprises: a small SME provides IT integration based on existing software products in the field of (multimedia) information systems in Hungarian and international projects.

Two further interesting technology transfer cases give partly different views, goals and solutions:

The long-term co-operation of departments of the Technical University of Budapest with industrial firms to 'sell' academic knowledge, to be involved in industrial R&D work and to assist in recruiting new engineers.

The Information and Technology Innovation Park (InfoPark) in Budapest is a private SME that started as a government initiative to establish a huge territory in Buda for effective technology transfer, by homing big and small Hungarian and multinational industries, taking advantage of the neighbourhood of the universities. This initiative has scientific, economic and even human policy advantages.

As an example of the continuing direct technology transfer from SZTAKI there is the long term co-operation in different projects with the Paks Nuclear Power Plant, providing 40% of all electrical energy in Hungary.

Most of the above information is based on the presentations and discussions of the successful technology transfer day organised in Budapest with international participation in 1999, as an accompanying programme to the International Exhibition and Fair, MACHTECH, March 5, 1999, Budapest.

Some General, Common Features
Some spin-offs started their negotiations with western partners already as members of the institute. The partners were impressed with the large, powerful, government owned and run SZTAKI. The institute had (and has) a high level infrastructure and a good scientific reputation world-wide. This led the partners to negotiate with the institute and even to contracts with representatives, resellers, partners, etc. The researchers who were involved in these types of co-operation had to decide between the research and science and bringing to the market their knowledge and experience. The successful ones decided to try to keep the 'level' and sell their knowledge. Typical to these spin-offs is that they rent the rooms and several facilities (computers, fax, copy, library) of the institute even today. This way they are independent, but still work in an unchanged environment. The new ideas for researchers of the spin-offs and for all other SME formations, which wanted to survive in the market, had to learn:
• how to find suppliers
• how to find customers
• how to design and build hardware from building blocks instead of circuits
• how to customise software instead of develop it

•how to provide the best available solutions and support
•how to add value
•how to compete with the 'big' firms and beat them
•how to co-operate with European partners in joint projects.

It was easy to find answers to most questions:
•to keep the high, academic level in R&D
•to find appropriate niches of activities
•to become system integrators
•to be there and be polite but aggressive at the market.

Conclusions
All technology transfer partners had to learn how to use the professional engineering and IT knowledge collected and accumulated during academic years. Some business knowledge had to be picked up as well. Technology transfer from academia to industry works in all examined cases keeping the high professional academic level coping with the market requirements. Another important conclusion is that the international scientific activity during academic years assisted in building up international relationships in the private business/market life.

Please contact:

György Kovács – SZTAKI
Tel: +36 1 209 6143
E-mail: Gyorgy.Kovacs@sztaki.hu

OVH Software for Self Supported Blood Pressure Monitoring

by Timo Tuomisto

VTT Information Technology is participating in the development of a software prototype, which provides assistance to manage one's blood pressure. The OVH system provides background information of reasons and effects of elevated blood pressure, and offers tools for follow-up and planning of associated actions.

Elevated blood pressure is a risk for cardiovascular diseases. The Finnish Heart Association recommends that the levels for systolic and diastolic blood pressure of adults shouldn't exceed 130 mmHg and 85 mmHg, respectively. According to this criteria, about half of the Finnish population has a reason to follow-up their blood pressure. Of those about 450 000 people suffer from elevated blood pressure.

Many of the risk factors for elevated blood pressure (except for the genetic inheritance) can be controlled by our daily habits. The risk factors include eg decreased activity, high cholesterol, salty, fatty, energetic food, and smoking. Most of these manifest themselves in the weight, i.e. in the energy balance between nutrition and activity. The software concentrates on keeping weight in tolerable limits, although it is also used to map and follow-up the other risk factors as well.

When starting the software for the first time, the user is requested to fill in basic information of himself/herself, and evaluate the current weight and height as well as nutritional and activity habits. Based on these mappings, the software indicates areas of improvement. More over it gives tools to make a weight control plan based the body mass index calculated from height and weight. An estimate of the change in energy balance needed to realise this weight loss is calculated, and the user can begin to play around to achieve this goal either by increasing the current level of activity or by reducing the total amount of energy in nutrition. The reduction of energy in nutrition can happen by reducing the amount of food, of replacing a food item by another food item containing less energy.

On basis of the plans, a weekly calendar is used to record the planned activity, as well as to remind about planned changes in other habits, especially in nutrition. Although the software includes a versatile database of the calories, fibre, cholesterol contents of food items, exact recording of all food intake was considered unrealistic, and the calculations are based on only planned changes.

Technically the OVH software consists of HTML pages and inter-operating applets. The reason to select this type of combination originated in being easily able to create and maintain the contents and look and feel of the background information, and have the ability to include sophisticated personal functionality. The applets are realised as Java Swing components, which further enhance the options for impressive look and feel. Also the chosen platform was intended to facilitate the usage of the software across the network. However, that solution for daily use proved to be unpractical and slow: The current version is run only locally, with a local object-oriented database as a backup. Measured results are optionally sent as a batch process to a remote database, which can then be monitored by a physician. The software is multilingual.

The prototype is currently under real life testing by users selected and supervised by health care professionals in Liminka Health Center, and Oulu University Hospital Dept. of Internal Medicine. These organisations have also provided the medical expertise for the project. The co-ordinator for the project has been Polar Electro Corporation. It has also implemented the contents provided by Finnish Heart Association and an expert group. The Laboratory of Human-computer Interaction and Group Technology in the University of Oulu has committed the requirement specification and preliminary evaluation. VTT Information Technology has designed and implemented the software.
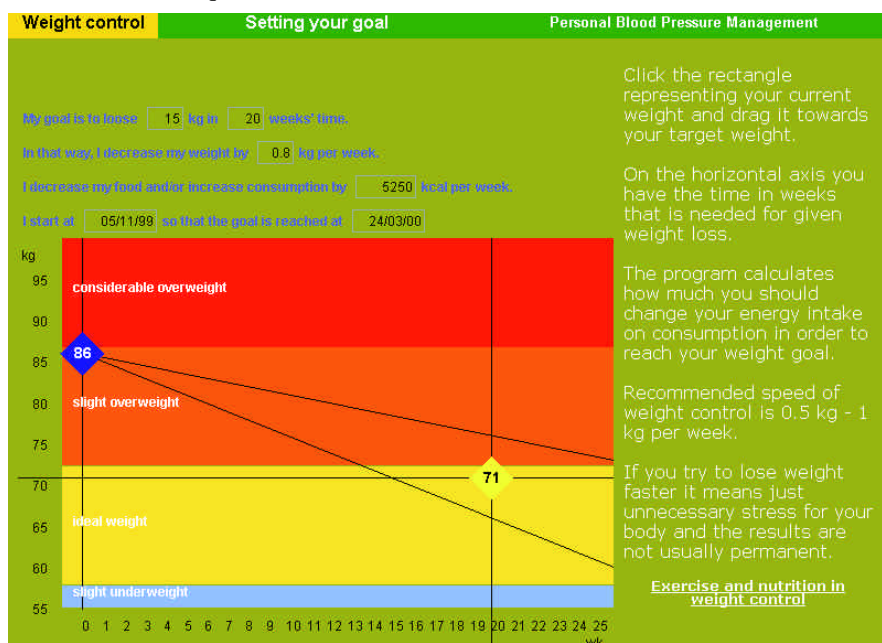
The user selects the goal for the weight. Two thirds of the HTML page is occupied by an embedded applet (on the left). Its background is adapted to the background of the HTML page containing the user instructions.
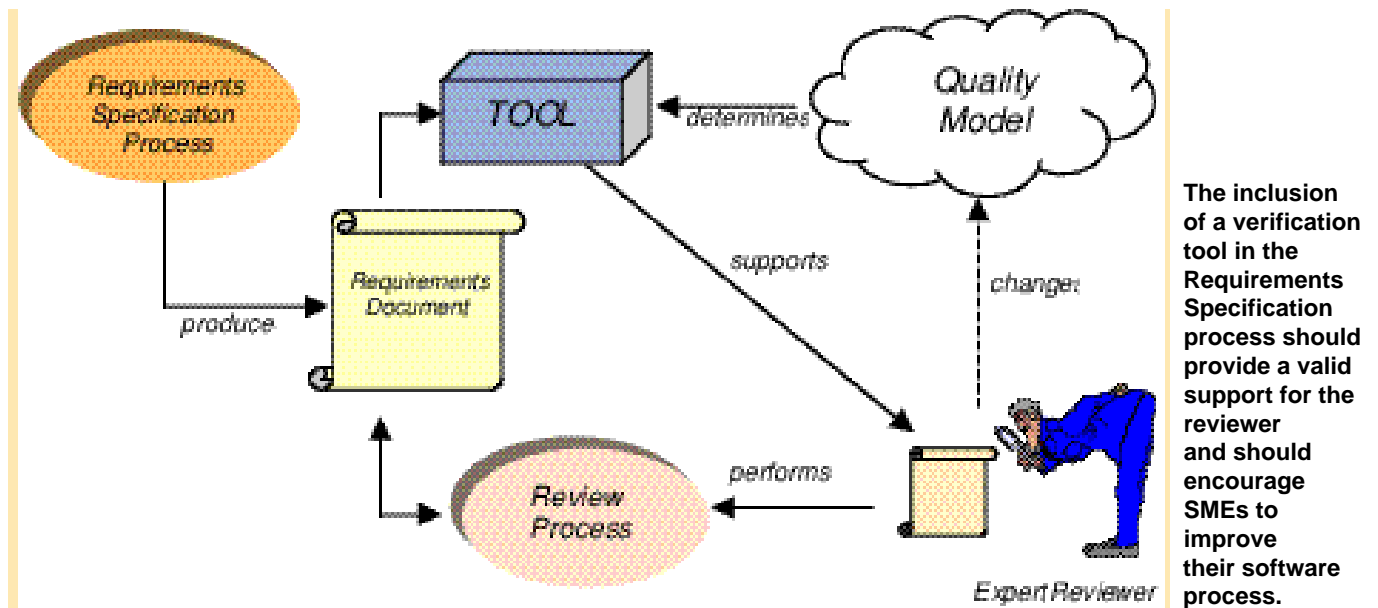
Please contact:

Timo Tuomisto – VTT Information Technology
Tel: + 358 3 316 3368
E-mail: timo.tuomisto@vtt.fi

Software Requirements Verification by Natural Language Analysis: A CNR initiative for Italian SME's

by Fabrizio Fabbrini, Mario Fusani, Stefania Gnesi, Giuseppe Lami

A project is under way at IEI-CNR with the objective of transferring technology to small and medium enterprises that helps to improve the software development process. The goal is to create an automatic tool supporting the analysis and quality evaluation of natural language software specifications.

The inclusion of a verification tool in the Requirements Specification process should provide a valid support for the reviewer and should encourage SMEs to improve their software process.

Requirements Specification is a crucial phase in the software life-cycle. However, problems in the interpretation of requirements documentation often arise as a consequence of ambiguity and incompleteness in the specifications. Providing the software engineer with tools and techniques for the early detection of such problems can help to avoid later and very expensive corrective actions. IEI-CNR has been involved for several years in research into tools for the analysis and evaluation of Natural Language (NL) software requirements.

The approach adopted has been to define a Quality Model for Software Requirements Specifications, and to develop an automatic tool for the verification of requirements in order to guarantee their compliance to this model. The quality model has been defined on the basis of selected linguistic properties of requirements documentation. These properties can be evaluated automatically by means of associated indicators and are measurable numerically. Although the model does not cover all the possible

quality properties of software requirements, it is sufficiently specific to be used (with the support of automatic tools) to verify the quality of the documentation. This quality model has been validated on real-world documents for industrial requirements in order to assess its utility.

After the validation stage, an automatic tool that assists the software requirements reviewer to detect quality problems in terms of ambiguous, incomplete and unclear sentences is now under development. Sentences in requirements documentation are parsed by means of special grammar rules in order to identify the syntactic and lexical components; specially built lexicons are used to calculate the values of the quality indicators of the model. This tool will indicate to the reviewer those requirements in which potential problems are present and identify the type of problem. The reviewer is responsible for the overall assessment of the validity of the documentation. As shown in the figure, the inclusion of this tool in the

Requirements Specification process should provide a valid support for the reviewer and should encourage SMEs to improve their software process.

Final Delos Workshop
on Future Directions in the Digital Libraries Domain

by Carol Peters

Thirty two participants, including delegates from nine ERCIM institutions, attended the final workshop of the DELOS Working Group on Digital Libraries, hosted by CNR in Pisa, 25-26 November. The main goal of the workshop was to bring representatives of major applications together with members of the research community, in order to discuss the impact of digital library (DL) technology in a number of different domains and to identify those areas where efforts should be concentrated in the near future. This is particularly relevant in view of the fact that the activities of DELOS will be continued and extended in a Network of Excellence (NoE), a thematic network on digital libraries funded by the European Commission.

The six talks on the first morning of the two-day workshop presented perspectives from the worlds of electronic publishing, television, music, geographic information systems and health care.

The first speaker, Michael Mabe of Elsevier, United Kingdom, affirmed that going digital has profound consequences for all members of the information chain in the scientific journal community. The main purpose of such journals is to serve their authors rather than their readers, although these are usually the same people. The conflict between author and reader modes of thinking creates most of the challenges faced by publishers in their desire to meet the needs of users and librarians, Some if not all have been partially solved, but in a world where paper and digital have simultaneous existence clear outcomes have yet to appear. It is not evident that more technology is necessarily the answer - human factors remain paramount.

Johannes Kraus, of the Austrian Broadcasting Company (ORF) and also representing the International Federation of Television Archives (FIAT/IFTA), discussed issues involved in the segmentation and representation of video in television, and the needs for image processing with respect to both input (annotation) and output (retrieval). His conclusion was that the integration of information systems in an integrated digital workflow is crucial in order to pave the way to new forms of collaboration and content presentation using video-embedded metadata.

Ingeborg Solvberg, of the Norwegian Technical University (NTNU) and

The lions of Delos.

representing SINTEF, described challenges faced by traditional library communities in the digital library world. Important tasks are the building and sharing of collections at the local, national and international levels, and the integration of digital documents from libraries, archives and museums. In order to ease access to information and to increase precision in the IR process, new models and metadata must be developed. The value of controlled vocabularies and the use of thesauri were described. Examples from the Alexandria DL project at the University of California - Santa Barbara, and the operational California Digital Library (CDL) were given. Matthias Hemmje, IPSI-GMD, gave an overview of a number of projects at GMD using digital library technology.

Werner Deutsch, from the Acoustics Research Lab. in Vienna of the Austrian Academy of Sciences, focused on music and music information in libraries and sound archives. Main challenges being faced by music libraries and archives regard digitisation and preservation, and

the provision of music services over the Internet. Semiautomatic segmentation and content description are evaluated in a demonstrator system implemented by the European project HARMONICA (http://www.kfs.oeaw.ac.at). This session was concluded by Erich Leisch from the Institute of Computer Science, FORTH, who described the success of ongoing health care projects in Crete that adopt digital library technologies.

The afternoon sessions focussed on DL technologies. Jim Davis, a visiting scientist at CWI, introduced two new internet protocols (WebDAV and DASL) now being developed by the Internet Engineering Force (IETF) and outlined their potential areas of application in digital libraries. Norber Fuhr, University of Dortmund, Germany, discussed open research issues in resource indexing and discovery. In order to cope with the diversity of information, users, uses, systems and communication protocols in distributed digital libraries, problems regarding organizational, system, content, and human-computer interface aspects

must be solved. Thomas Baker of GMD reported on the DELOS EU-NSF Working Group on Metadata and on several related projects that have since emerged. These include a distributed registry of Dublin-Core-related schemas in multiple languages; HARMONY, an international project on metadata interoperability; and SCHEMAS, a forum for designers of interoperable metadata vocabularies.

The final presentation, by Carol Peters, IEI-CNR, Pisa, discussed the state-of-the-art and current trends in multilingual information access. She gave an overview of the results and recommendations that emerged from the DELOS EU-NSF Working Group on this topic and from an ACM DL/SIGIR Workshop held in Berkeley, August 1999, on Multilingual Information Discovery and Access. Important challenges now facing this area are to begin to explore the issues introduced by multilingual information access in media other than character-

coded text, i.e. how do we manage and query image, audio and video data in multiple languages, and to move from bilingual (pairwise) retrieval to truly multilingual systems.

Probably the main conclusion to be drawn from this confrontation between the application and research communities was the need for the developers of new technologies to study very closely the requirements of the users. Innovative proposals will not be adopted if they do not satisfy basic expectations. For this reason, communication and exchange of ideas between the two groups is crucial.

The encouragement of international collaboration in the DL domain has been a main priority for DELOS and will be one of the core activities of the future NoE. The second day of the meeting began with two presentations describing DL initiatives in Asia and South America. Jerome Yen of the Chinese University of Hong Kong discussed the building of a digital

framework to support cultural exchange between East and West. He described two projects now under way at his university: Multi-lingual Informedia, in collaboration with the University of Carnegie Mellon, US, and the CyberLibrary. Gabriela Ortúzar of the University of Chile presented the digital archives and digital library activities of her university.

The Workshop ended with a preparatory discussion aimed at identifying the main activities to be conducted within the framework of the DELOS NoE, which is scheduled to kick-off at the beginning of 2000. The proceedings of the Workshop will be published by ERCIM in the DELOS Workshop series and will be available shortly on-line at the DELOS Web site: http://iei.pi.cnr.it/DELOS/.

Please contact:

**Costantino Thanos – IEI-CNR
DELOS Coordinator
Tel: +39 050 593 492
E-mail: thanos@iei.pi.cnr.it**

12th ERCIM Database Workshop

by Brian Read

The Tenth Anniversary meeting provided the opportunity for a number of ERCIM Working Groups to meet. One that did so was the Database Research Group, one of the longest standing. CWI (Arno Siebes) and CLRC-RAL (Brian Read) organised a couple of sessions of presentations on current database activity. Two contributions addressed database performance, but the main emphasis during the workshop was on aspects of data mining.

Stefan Manegold (CWI) presented work on techniques within the Monet main memory database system to exploit high level caching to counter the cost of the main memory bottleneck - memory access times are falling behind the relentless increase in CPU speed. The other performance paper was from Peter Bosch who described recent work done at Twente on 'Clockwise'. The problem tackled is how to schedule real time deadlines for a mix of conventional and bulky (video streams) data on the same disc, given that disc service times are not known.

An important aspect of data mining, namely data preparation, was covered in

a joint paper from LGU (London Guildhall University) and RAL. It was presented by Paul Jermyn who described work in progress to develop an approach to data cleaning based on the concept of 'Clean Views' in which alternative sets of data preparation operations are well defined and supported by the system. From CWI, Robert Castello spoke about the development (with Arno Siebes) of graphical models can help guide insight during data mining, while Menzo Windhouwer explained how multimedia objects are indexed in the Acoi system.

In a more general discussion, Brian Read (RAL) tackled the extent to which conventional knowledge discovery in

databases as used on business data can usefully be applied to science. Pattern matching algorithms can be very useful for analysing large data volumes, but it is arguable if data mining alone can yield scientific 'truth'.

Overall it was an enjoyable Workshop and it explored some common interests. Plans were initiated for some joint work in the data mining area.

Please contact:

**Brian Read – CLRC
Tel: +44 1235 44 6492
E-mail: b.j.read@rl.ac.uk**

International Workshop on Fundamental Structural Properties in Image and Pattern Analysis 1999

by Dmitry Chetverikov and Tamás Szirányi

The International Workshop on Fundamental Structural Properties in Image and Pattern Analysis, FSPIPA'99, organized by SZTAKI, was held in Budapest, Hungary, on September 6-7, 1999, in conjunction with the 8th International Conference on Computer Analysis of Images and Patterns (Ljubljana, Slovenia).

The workshop provided a forum for discussing the interrelations between image structures and the real world that digital images describe, by addressing major problems and results related to the role of symmetry, self-similarity, anisotropy, regularity and structural complexity in computer vision and human perception.

After careful selection, 14 regular papers were accepted for presentation by the Programme Committee (Alfred Bruckstein, Israel; Dmitry Chetverikov, Hungary; Xavier Descombes, France; Touradj Ebrahimi, Switzerland, Luc Florack, The Netherlands; Walter Kropatsch, Austria; Tony Lindeberg, Sweden; Gerald Sommer, Germany and Tamás Szirányi,Hungary).

These regular contributions, as well as two of the three invited papers appeared as full-length papers in the workshop proceedings, published by the Oesterreichische Computer Gesellschaft (OCG, The Austrian Computer Society) under the title 'Fundamental Structural Properties in Image and Pattern Analysis 1999', edited by Dmity Chetverikov and Tamás Szirányi, in the series 'Schrifttenreihe der OCG', Band 130, ISBN 3-85403-130-0.

The studies were devoted to various theoretical and practical aspects of symmetry, anisotropy, regularity, self-similarity, scale-space, closure and other fundamental structural features of the visual world.

In his invited talk entitled 'Automatic Scale Selection for Interpreting Visual Data', Tony Lindeberg from the Royal Institute of Technology, Stockholm, pointed out that a fundamental property of visual objects is the property of being
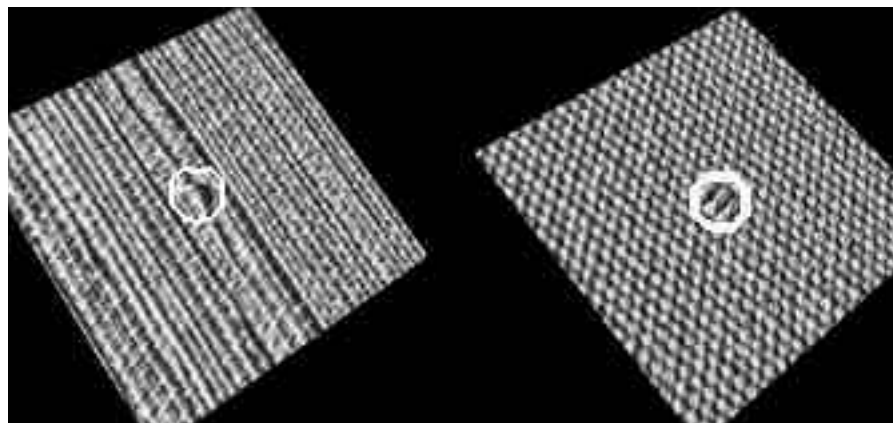
Invariant detection of structural defects using pattern regularity.

distinct over certain ranges of scale. Hagit Zabrodsky Hel-Or, Haifa University, devoted her invited lecture to symmetry as another basic structural property of two- and three-dimensional shapes and objects. Dietmar Saupe, University of Leipzig, gave an invited talk on image model in fractal coding. The property of self-similarity was investigated by Alfred Bruckstein, Technion, Haifa, who discussed the self-similar image sampling schemes.

A distinct group of regular contributions was devoted to the classical problems of visual object decomposition into structurally meaningful parts, on one hand, and grouping of structural elements into objects, on the other. In particular, it was pointed out that closure, that is, the property of being closed, is a basic structural property of visual entities perceived as distinct objects.

The participants of FSPIPA'99 shared the opinion that the workshop was a small but highly professional, useful and friendly, purely scientific event free of commercial spirit.

FSPIPA'99 was sponsored by the ERCIM, the International Association for Pattern Recognition (IAPR), the Hungarian National Committee for Technological Development (OMFB), the Hungarian Academy of Sciences, and the Hungarian Association for Image Analysis and Pattern Recognition. Their support is acknowledged with sincere gratitude. In particular, the support of the main sponsor, ERCIM, made possible the invitation of the three distinguished invited speakers. SZTAKI has greatly contributed by providing all facilities. We would like to thank Péter Inzelt, Director of SZTAKI, for his help.

Links:

FSPIPA'99 workshop web page:
http://visual.ipan.sztaki.hu/FSPIPA99/

Please contact:

Dmitry Chetverikov – SZTAKI
Tel: +36 1 209 5355
E-mail: csetverikov@sztaki.hu

5th ERCIM Workshop on 'User Interfaces for All'

by Constantine Stephanidis, Alfred Kobsa and Michael Pieper

The 5th Workshop of the ERCIM Working Group 'User Interfaces for All' took place at the International Conference and Research Centre For Computer Science in the Castle of Dagstuhl, Germany, 28 November to 1st December 1999. The Workshop was organised by GMD, with Prof. Alfred Kobsa acting as the Programme Chair and Dr. Michael Pieper as the local organisation Chair.

The Workshop aimed to consolidate recent work, and to stimulate further discussion, on the state of the art in the field of User Interfaces for All. The emphasis of this year's Workshop was on theories, methodologies, techniques and tools that contribute to the development of User-Tailored Information Environments. The Workshop attracted considerable interest, with 47 participants from 15 countries around the world.

There were two invited speakers: Dr. Jon Gunderson, Coordinator of Assistive Communication and Information Technology Accessibility in the Division of Rehabilitation - Education Services, and Adjunct Assistant Professor of Mechanical and Industrial Engineering, and Community Health at the University of Illinois at Urbana/Champaign, USA, who focussed on Universal Design as a critical factor toward Web accessibility in his capacity as chair of the W3C-Web Accessibility Initiative User Agent Working Group, and Dr. Hans-Heinrich Bothe, Associate Professor at the Department of Technology and Science at Orebro University, Sweden, who focussed on the application of assistive technologies, multimedia and robotics in communication between hard of hearing/ deaf people and able-bodied people. The paper presentations and the discussions during the workshop covered a variety of related topics, including user requirements, information filtering and presentation, evaluation, design principles and guidelines, assistive technologies, and adaptivity and adaptability.

Following a peer review process, the Workshop's proceedings have included 13 long papers and six short papers. Additionally, six posters were presented during the interactive poster session at the Workshop. The proceedings of the Workshop will be electronically available via the Web site of the ERCIM Working Group 'User Interfaces for All' at: http://www.ics. forth.gr/ercim-wg-ui4all.

In the morning of December the 1st, 1999, an open meeting of the ERCIM UI4ALL Working Group was held at the same location. Following an overview and discussion of recent activities, the group focused on the planning of future activities, and in particular collaborative project work. The 6th ERCIM Workshop on 'User Interfaces for All' is planned to take place in Florence, Italy, 26-28 October 2000, and the Programme Chair and local organiser will be Dr. Pier Luigi Emiliani, Director of CNR-IROE.

Please contact:

**Constantine Stephanidis – FORTH-ICS
Chair, ERCIM Working Group
'User Interfaces for All
Tel: +30 81 39 17 41
E-mail: cs@ics.forth.gr**

Workshop on Interactive Learning Environments for Children

**Glyfada, Athens, Greece,
1-3 March, 2000**

Deadline for paper submission:
1 February 2000

A one-day workshop on 'Interactive Learning Environments for Children' is organised by the ERCIM Working Group 'User Interfaces for ALL' in the context of the i3 Spring Days 2000, aiming to facilitate the exchange of knowledge and experience between researchers and practitioners in the fields of Universal Access and Intelligent Information Interfaces (i3).

User Interfaces for All advocates the proactive realisation of the Design for All principle in the field of Human-Computer Interaction. The i3 community on the other hand, has attained in recent years a considerable amount of work targeted to young children, one of the most challenging categories of 'non-average' users. Combining education and leisure activities, supporting novel paradigms of teaching, creating environments that foster collaboration and knowledge sharing, are only some examples of issues that have received attention and led to innovation in the field to date.

The goals of this Workshop are to consolidate recent work, and to stimulate further discussion, on the state of the art in user interfaces that are intended for use by children. The emphasis of the Workshop will be on theories, methodologies, techniques and tools which contribute to the development of interactive systems that are fun and engaging, support a multitude of learning activities, are usable by, and appropriate for children, foster social interaction, support the developmental process, and can cater for the individual requirements and preferences of each child.

Further information:

**http://www.dfki.de/imedia/workshops/i3
spring00/w7/i3SD2000-call.html.**

Please contact:

**Constantine Stephanidis – FORTH-ICS
Tel: +30 81 39 17 41
E-mail: cs@ics.forth.gr**

WISE'2000 – The First International Conference on Web Information Systems Engineering

Hong Kong, 19-20 June, 2000

With advances in Internet and World Wide Web technologies, research on the design, implementation and management of Web-based information systems have become increasingly important. The purpose of the WISE'2000 conference is to bring research scientists and industrial practitioners together to exchange their most recent research results and discuss new system developments. Both research papers and industrial papers on general web-based information and database systems are invited.

Further information:
http://www.cs.cityu.edu.hk/~wise2000/

5th ERCIM Workshop on Formal Methods for Industrial Critical Systems

Berlin, 3-4 April 2000

The aim of the FMICS workshops is to provide a forum mainly intended for researchers who are interested in the development and application of formal methods in industry. In particular, these workshops should bring together scientists that are active in the area of formal methods and interested in exchanging their experiences in the industrial usage of these methods. They also aim at the promotion of research and development for the improvement of formal methods and tools for industrial applications.

Topics include, but are not restricted to:
• tools for the design and development of formal descriptions
• verification and validation of complex, distributed, real-time systems and embedded systems
• FDT based conformance, interoperability and performance testing
• case studies and project reports on FDT related projects with industrial

participation (eg safety critical systems, mobile systems, object-based distributed systems)
• application of FDTs in standardization and industrial forums.

Deadline for paper submission: January 14th, 2000.

Further information:
http://www.fokus.gmd.de/tip/fmics/

International Olympiad in Informatics: the Source of Talented Young People for the Universities and Research Community

IOI, the International Olympiad in Informatics is an annual competition in computing science for senior pupils at secondary schools all over the world. An International Committee supervises the IOI. For the olympiad competition, the contenstants must be less than 19 years old and must have been enrolled in a school during the 1999 school year.

The 11th International Olympiad in Informatics – IOI'99 took place in Antalya-Belek, Turkey from 9-16 October 1999. The goal of the competition was to solve the problems selected by the International Jury by using a computer and a programming language, such as Pascal or C/C++ . The problems were provided in written form in English and in the native languages of the students. Every team consisted of 4 student contentants, 1 delegation leader and 1 deputy leader. The delegation leader represented his/her country in the General Assembly of the Olympiad and the deputy leader was responsible for the participants from his/her country. The first three winners were: Hong Chen (China), Mathijs Vogelzang (The Netherlands), Roman Pasthoukov (Russia).

IOI2000 will be hosted by China in Beijing on September 23-30, 2000.

Further information:
http://olympiads.win.tue.nl/ioi/

ERCIM NEWS

ERCIM News is the in-house magazine of ERCIM. Published quarterly, the newsletter reports on joint actions of the ercim partners, and aims to reflect the contribution made by ercim to the European Community in Information Technology. Through short articles and news items, it provides a forum for the exchange of information between the institutes and also with the wider scientific community. ERCIM News has a circulation of 7000 copies.

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MFCS 2000 – 25th International Symposium on Mathematical Foundations of Computer Science

### Bratislava, Slovak Republic, 28 August-1 September 2000

The symposium is organized by the Slovak Society for Computer Science and the Comenius University, in cooperation with other institutions in Slovakia. It is supported by the European Association for Theoretical Computer Science, the European Research Consortium for Informatics and Mathematics, and the Slovak Research Consortium for Informatics and Mathematics.

The series of MFCS symposia, organized alternately in the Czech Republic, Poland and Slovakia since 1972, has a long and well-established tradition. The MFCS symposia encourage high-quality research in all branches of theoretical computer science. Their broad scope provides an opportunity to bring together specialists who do not usually meet at specialized conferences. Papers presenting original research on theoretical aspects of computer science are solicited.

PRINCIPAL TOPICS of interest include (but are not limited to): design and analysis of algorithms (sequential, parallel, distributed, approximation, computational biology, computational geometry, graph, network, on-line, optimisation) and data structures, algorithmic learning theory, automata, grammars and formal languages, structural and computational complexity, concurrency theory, cryptography and security, databases and knowledge-based systems, foundations of programming, formal specifications and program development, models of computation, parallel and distributed computing, quantum computing, molecular computing, mobile computing, net computing, semantics and logics of programs, theoretical issues in artificial intelligence.

Further information:
http://www.mfcs.sk/
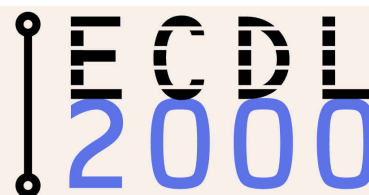
ECDL 2000

ECDL 2000 – Fourth European Conference on Research and Advanced Technology for Digital Libraries

Lisbon, Portugal, 18-20 September 2000

ECDL2000 follows the previous very successful conferences in Pisa in 1997, Heraklion in 1998 and Paris in 1999. One major goal of the ECDL series of conferences is to bring together researchers, industrial members, professionals, user communities and responsibles, promoting it as a reference forum for discussion of new emerging issues, requirements, proposals, politics and solutions. In this sense, ECDL2000 intends to contribute to bring into focus this complex scenario, promoting opportunities for the exchange of ideas and knowledge between all the different perspectives relevant for digital libraries.

Proposals for papers and panels related to digital libraries should address mainly the following topics:
• Digital Library Requirements, Models, Systems and Frameworks
• Knowledge Representation; Filtering and Dissemination; Preservation; etc.)
• Electronic Publishing and Economic Issues
• Networking and Distributing Issues
• Social Implications and Issues

Important Dates
• Deadline for All the Proposals: 1 May 2000
• Notifications of acceptance: 15 June 2000
• Camera ready versions of papers: 1 July 2000

Further information:
http://www.bn.pt/org/agenda/ecdl2000/

Fraunhofer-Gesellschaft (FhG) and GMD are to be merged under the roof of the Fraunhofer-Gesellschaft. This was agreed between the Federal Minister of Education and Research, Edelgard Bulmahn, and the chairmen of the executive and supervisory boards of the two research organizations.

Federal Minister of Education and Research, Edelgard Bulmahn: "It is the aim of the Federal Government to bring Germany to a top position in the information society throughout Europe. In this way, we contribute to the sustainable creation of new jobs. Therefore the expertise of the two organizations is to be focused and synergy effects shall be achieved by a common strategic orientation and close interlinking."

The merger will give birth to Europe's biggest research organization for information and communications technology with more than 2500 employees in this field. It is expected to strengthen and focus research on information and communications technology funded by government. The merger of the GMD and FhG is a first step towards the implementation of the Federal Government's action program 'Innovation and Jobs in the Information Society'.

INRIA released a strategic plan for the 1999-2003 period. The plan features ten objectives for conducting an ambitious research policy in the field of Information and Communication Science and Technology. The Institute's strategy is based on the close combination of scientific achievement and technology transfer. In order to meet its objectives, the Institute intends to take up five major scientific challenges: (1) mastering the digital infrastructure by knowing how to code, compute and communicate over the Internet and over heterogeneous networks; (2) designing new applications that make use of the Web and multimedia databases; (3) knowing how to produce reliable software (4) designing and mastering automatic control for complex systems (5) combining simulation and virtual reality. Through these five challenges and in closely coordinated interaction with other scientific disciplines, INRIA will focus its efforts on a few major fields of applications, primarily telecommunications, multimedia, health and biology. The full strategic plan is available at http://www.inria.fr/Strategy/.

Irish mathematician Robert Harley, a member of INRIA's Cristal research group together with a team of 195 researchers has cracked the seventh and most difficult Certicom Elliptic Curve Cryptosystem (ECC) Challenge problem to date, a 97-bit encryption system based on elliptic curves. The challenge took place in a set of about 10^{29} points on an elliptic curve chosen by Certicom. To solve the problem, the participants first computed 119,248,522,782,547 (more than 10^{14}) points using open-source software developed by Harley. Among these points, they screened 127,492 'distinguished' points and collected them on an Alpha Linux workstation at INRIA where further processing revealed two twin points. Finally Harley computed the solution using information associated with these two points, thus nailing the problem. The team struck it lucky, finding the solution in less than a third of the expected time. The distributed computation was run by 195 volunteers, on a total of 740 computers, over 40 days. Nevertheless the computing power used, around 16,000 MIPS/years, was twice as much as that used for the factorization of RSA-155 announced by Herman Te Riele of CWI and his colleagues on 26 August 1999 (see ERCIM News No. 39). This result strengthens the case of those who contend that a crypto system based on ECDL (Elliptic Curve Discrete Logarithms) is

**Robert Harley, researcher at INRIA's Cristal research team.**

stronger even when using short keys than RSA with much longer keys, although it does not prove that assertion. Rather, it indicates that at the current state of the art, the best mathematical tools and algorithms known for cracking ECDL take longer to run than the best tools known for cracking RSA. Out of the $5000 prize money, the team members will gave $4000 to the Free Software Foundation. Further information at http://cristal.inria.fr/~harley/ecdl/.

French President, Jacques Chirac visited INRIA on 28 October 1999. Chirac was given a general presentation of the institute and of two research projects on medical imaging and robotics, and on vehicles and transport systems of the future. Both projects are good examples for an insight in current scientific topics, they are interdisciplinary and resulted in technology transfers with a strong economic and social impact.

French President Jacques Chirac during his visit at INRIA.
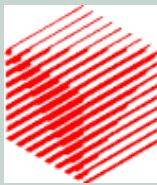
ERCIM – The European Research Consortium for Informatics and Mathematics is an organisation dedicated to the advancement of European research and development, in information technology and applied mathematics. Its national member institutions aim to foster collaborative work within the European research community and to increase co-operation with European industry.

Central Laboratory of the Research Councils
Rutherford Appleton Laboratory, Chilton, Didcot, GB-Oxon OX11 0QX, United Kingdom
Tel: +44 123582 1900, Fax: +44 1235 44 5385
http://www.cclrc.ac.uk/

Consiglio Nazionale delle Ricerche, IEI-CNR
Via S. Maria, 46, I-56126 Pisa, Italy
Tel: +39 050 593 433, Fax: +39 050 554 342
http://www.iei.pi.cnr.it/

Czech Research Consortium for Informatics and Mathematics
FI MU, Botanicka 68a, CZ-602 00 Brno, Czech Republic
Tel: +420 2 688 4669, Fax: +420 2 688 4903
http://www.utia.cas.cz/CRCIM/home.html

Centrum voor Wiskunde en Informatica
Kruislaan 413, NL-1098 SJ Amsterdam, The Netherlands
Tel: +31205929333, Fax: +31 20 592 4199
http://www.cwi.nl/

Danish Consortium for Information Technology
DANIT co/CIT, Aabogade 34, DK - 8200 Aarhus N, Denmark
Tel: +45 8942 2440, Fax: +45 8942 2443
http://www.cit.dk/ERCIM/

Foundation for Research and Technology – Hellas
Institute of Computer Science, P.O. Box 1385, GR-71110 Heraklion, Crete, Greece
Tel: +30 81 39 16 00, Fax: +30 81 39 16 01
http://www.ics.forth.gr/

GMD – Forschungszentrum Informationstechnik GmbH
Schloß Birlinghoven, D-53754 Sankt Augustin, Germany
Tel: +49 2241 14 0, Fax: +49 2241 14 2889
http://www.gmd.de/

Institut National de Recherche en Informatique et en Automatique
B.P. 105, F-78153 Le Chesnay, France
Tel: +33 1 39 63 5511, Fax: +33 1 39 63 5330
http://www.inria.fr/

Swedish Institute, of Computer Science
Box 1263, S-164 29 Kista, Sweden
Tel: +46 8 633 1500, Fax: +46 8 751 7230
http://www.sics.se/

Swiss Association for Research in Information Technology
Dept. Informatik, ETH-Zentrum, CH-8092 Zürich, Switzerland
Tel: +41 1 632 72 41, Fax: +41 1 632 11 72
http://www.sarit.ch/

Stiftelsen for Industriell og Teknisk Forskning ved Norges Tekniske Høgskole
SINTEF Telecom & Informatics, N-7034 Trondheim, Norway
Tel :+47 73 59 30 00, Fax :+47 73 59 43 02
http://www.informatics.sintef.no/

Slovak Research Consortium for Informatics and Mathematics
Dept.of Computer Science, Comenius University, Mlynska Dolina M SK-84215 Bratislava, Slowakia
Tel: +421 7 726635, Fax: +421 7 727041
http://www.srcim.sk

Magyar Tudományos Akadémia – Számítástechnikai és Automatizálási Kutató Intézete
P.O. Box 63, H-1518 Budapest, Hungary
Tel: +36 1 4665644, Fax: + 36 1 466 7503
http://www.sztaki.hu/

Technical Research Centre of Finland
VTT Information Technology, P.O. Box 1200, FIN-02044 VTT, Finland
Tel:+358 9 456 6041, Fax :+358 9 456 6027
http://www.vtt.fi/