ERCIM NEWS

European Research Consortium
for Informatics and Mathematics
www.ercim.org

Mathematics for Everyday Life

a special theme edited jointly by ERCIM
and the European Mathematical Society

Contributions
Contributions must be submitted to the local editor of your country

ERCIM News online edition
The online edition is published at http://ercim-news.ercim.org/

Subscription
Subscribe to ERCIM News by: contacting the ERCIM office (see address above) or by filling out the form at the ERCIM website at http://ercim-news.ercim.org/

Next issue:
July 2008, Special theme: Supercomputing at Work

Cover:
photos by courtesy of AFP and INRIA.

Mathematics Everywhere

The developed world is full of modern technology that we take for granted. Mobile phones, Internet, credit cards and CD and DVD discs are only a few examples of innovations that have revolutionized everyday life in the past thirty years. Common to all these is that their functioning depends heavily on mathematics. Another thing to note is that in all these cases, the mathematics was not invented for the sake of the technological innovations - it had already been developed as pure mathematics and lay ready to be applied when the time was ripe.

In Internet and mobile phone telecommunication the message is encoded and passed from one computer to another or from one phone to another. Errors always occur and may lead to the message becoming completely obscured. Error detection and self-correction is therefore essential in all telecommunication. Modern automatic error correction is based on deep mathematics such as Galois theory developed in the early 19th century by Evariste Galois. Telecommunication, as we know it, would not be possible without Galois theory. Error correction is equally important for the proper functioning of CDs and DVDs.

Digital security is an important issue in today's society. We want to be confident that our phone calls are not eavesdropped, that we can safely shop on the internet without our credit card information being intercepted and that bank secrecy and safety is not jeopardized. The solution to the security problem is efficient encryption. Cryptography for this purpose uses modular arithmetic (a part of number theory). A standard method in public-key cryptography relies on the fact that no fast algorithm is known for factorizing a very large number. Therefore the public key used for encryption could be based on the product of two very large prime numbers, whereas the secret private code needed for decryption would be based on the prime factors themselves.

The most popular way of retrieving information from the Internet is certainly to use Google. It is amazing and seems like magic that in most cases the first hit contains the information one was looking for. Again, the reason for the success is mathematics (in this case linear algebra) and an efficient algorithm. Kurt Bryan and Tanya Leise have written an article on the linear algebra behind Google aptly entitled "The 25 billion dollar eigenvector". The approximate market value of Google was indeed 25 billion USD when the company went public in 2004. The article is freely available at http://www.rose-hulman.edu/~bryan/googleFinalVersionFixed.pdf.

In this article I have given three examples of modern technologies that we use daily and that could not have been invented without mathematics. Good mathematics is usually created for its own sake and it will eventually find industrial applications. A general trend is that the time span between the mathematical invention and the application becomes shorter and shorter. Apollonius of Perga investigated the conic sections around the year 200 BC and Kepler used this theory in the formulation of his laws on planetary motion some 1800 years later. Galois theory had to wait only about 150 years before it found its applications in telecommunication and very recent results in number theory are used in cryptography. It is very likely that contemporary research in mathematics will influence our daily lives in the very near future perhaps in an unexpected way.

The European Science Foundation is preparing a Forward Look on Mathematical Modelling, and has received a proposal from the CNRS, France, to develop one on Mathematics and Industry. Forward Looks serve as strategic instruments, where the best researchers describe the status quo of their scientific domain, envision its evolution and impact in the next 5-10 years, and predict the needs for training, infrastructure and funding. The Forward Looks provide the national research funding and performing organizations as well as the European Commission a Europe-wide analysis to facilitate their decision making on targeting research funds.

Marja Makarow

Professor Marja Makarow
Chief Executive,
European Science Foundation.

Contents

R&D AND TECHNOLOGY TRANSFER

EVENTS

Next issue: July 2008
Next special theme: Supercomputing at Work

Evol@Mons 2008 - Doctoral Research Seminar on Software Evolution

by Tom Mens and Lionel Seinturier

In February and March 2008, two ERCIM member institutes, INRIA and FNRS, organized a doctoral research seminar on software evolution and adaptive middleware. The seminar, held under the auspices of the ERCIM Working Group on Software Evolution, was targeted at Belgian and French PhD students with a strong interest in software engineering.

Software engineering is a research discipline within computer science in which many PhD students in different universities are active. To increase awareness of the importance of software evolution as an essential subdiscipline, and to boost research in this domain, the Graduate School in Computing Science (GRASCOMP) of F.R.S.-FNRS (Belgium) decided to co-organize with the Ecole Doctorale Sciences pour l'Ingénieur (EDSPI) and the Collège Doctoral Européen (CDE) of Lille Nord-Pas-de-Calais (France) a doctoral seminar on software evolution and software adaptation.

The seminar organizers were Tom Mens (UMH, Belgium) and Lionel Seinturier (INRIA Lille, France). The first day of the seminar, entitled 'Evol@Mons 2008', was held in Mons, Belgium on 25 February 2008, and was devoted to the topic of software evolution. The second day of the seminar, entitled 'Adapt@Lille 2008', was held in Lille, France on 13 March 2008, and was devoted to the topic of adaptive middleware.

Evol@Mons attracted over forty participants, half of whom were PhD students, mainly coming from France and Belgium. Four renowned international researchers presented their latest research results. Stéphane Ducasse (INRIA Lille, France) presented research in software reengineering; Ralf Laemmel (University of Koblenz-Landau, Germany) discussed evolution challenges around XML languages; Andy Zaidman (Delft University of Technology, The Netherlands) talked about the relationship between software evolution and software testing; and Tudor Girba (University of Bern, Switzerland) explored how software evolution can be understood through the modelling of history.

Sponsors
- Académie Wallonie-Bruxelles: http://www.academiewb.be/
- F.R.S.-FNRS Graduate School in Computing Science: http://www.grascomp.be
- Ecole Doctorale Sciences pour l'Ingénieur : http://edspi.univ-lille1.fr/
- Collège Doctoral Européen: http://cde.univ-lille1.fr/

Links:
Evol@Mons: http://w3.umh.ac.be/genlog/EvolMons/EvolMons2008.html
Adapt@Lille: http://www.fil.univ-lille1.fr/~seinturi/doct/AdaptLille2008.html
WG website: http://w3.umh.ac.be/evol/

Please contact:
Tom Mens,
Software Evolution Working Group coordinator
Institut d'Informatique, Université de Mons-Hainaut, Belgium
Tel: +32 65 37 3453
E-mail: tom.mens@umh.ac.be

ERCIM
European Research Consortium for Informatics and Mathematics

Organizers
Michel Wermelinger, The Open U., UK
Ciarán Bryce, INRIA, Rennes, France
Paul Wernick, U. of Hertfordshire, UK

Program Committee
Giuliano Antoniol, Montreal Polytechnic, Canada
Mikio Ayoama, Nanzan U., Japan
Sarah Beecham, U. Hertfordshire, UK
Andrea Capiluppi, U. Lincoln, UK
Ned Chapin, InfoSci Inc, USA
Massimiliano di Penta, U. Sannio, Italy
Stéphane Ducasse, INRIA Lille, France
Pierre Duquesne, IRISA, France
Jean-Marie Favre, U. Grenoble, France
Harald Gall, U. Zurich, Switzerland
Michael Godfrey, U. Waterloo, Canada
Jesus M. Gonzalez-Barahona, U. Rey Juan Carlos, Spain
Rachel Harrison, U. Reading, UK
Reiko Heckel, U. Leicester, UK
Stan Jarzabek, National U. of Singapore, Singapore
Michele Lanza, U. Lugano, Switzerland
Radu Marinescu, U. Timisoara, Romania
Kim Mens, U. catholique de Louvain, Belgium
Tom Mens, U. Mons-Hainaut, Belgium
Chrystopher Nehaniv, U. of Hertfordshire, UK
Vaclav Rajlich, Wayne State U., USA
Juan Ramil, The Open U., UK and U. Mons-Hainaut, Belgium
Claudio Riva, Nokia, Finland
Terry van Belle, Google, USA
Arie van Deursen, TU Delft, The Netherlands

Important Dates
Abstracts due	9 June 2008
Papers due	16 June 2008
Notification due	18 July 2008
Final versions due	4 August 2008

Call for Papers

Evol'08
4th Intl. ERCIM Workshop on Software Evolution and Evolvability

http://evol08.inria.fr

At the 23rd IEEE/ACM Intl. Conf. on Automated Software Engineering

15-16 September 2008, L'Aquila, Italy

Organized by the ERCIM Working Group on Software Evolution
http://www.planet-evolution.org

This workshop is the merger of the ERCIM Workshops on Software Evolution and the IEEE International Workshops on Software Evolvability, each series looking back on three successful events. The rationale for a common event is to capitalize on the synergies to be found when theorists and practitioners meet.

Theme and Topics
The theme is "bridging boundaries". Examples of boundaries to be bridged are:
- **Academia and industry:** How can academic research in software evolution become more accepted by industry and how can industry contribute to academic research?
- **Theory and practice:** How can insights gained from empirical studies and theoretical research impact on tools, techniques and methodologies, and vice-versa?
- **Intangible and tangible:** Can theories, concepts and measurement techniques developed in science and engineering for the evolution of man-made objects and in the natural world (decay of materials, evolutionary biology, virus epidemics, etc.) be adapted to the evolution of an intangible man-made artifact like software? Can software evolution theories, concepts and metrics be useful to other disciplines?

Topics include, but are not limited to:
- **Application areas:** distributed, embedded, real-time, ultra large scale, and self-adaptive systems, web services, mobile computing, information systems, etc.
- **Paradigms:** support and barriers to evolution in aspect-oriented, agile, component-based, and model-driven software development; service-oriented architectures, etc.
- **Technical aspects:** co-evolution and inconsistency management of various software artifacts, impact analysis and change propagation, dynamic reconfiguration and updating, architectures and notations for evolvability, etc.
- **Managerial aspects:** effort estimation and risk analysis for software evolution, processes explicitly supporting evolvability, etc.
- **Empirical studies and industrial experience**
- **Interdisciplinary approaches:** adaptation of evolutionary concepts and measures from other disciplines (biology, geology, etc.) to software evolution
- **Theories and models** of system evolution processes

Submissions
Three types of papers can be submitted. **Position papers** (up to 4 pages) may present wild and speculative ideas, and will be judged on the potential to generate interesting discussions at the workshop. **Tool papers** (up to 6 pages) should describe academic, not commercial, tools. The workshop will include one or more sessions for tool demos. **Research papers** (up to 10 pages) should describe original research.

Papers that address the workshop theme are especially welcome. Given the scope of the host conference, papers should present concepts, techniques or methodologies that are automated or amenable to automation. Submission and publication details will be announced on the workshop website.

Towards a Cooperation with the European Mathematical Societey

by Keith Jeffery

With the jointly edited special theme of this issue on 'Mathematics for Everyday Life', ERCIM and the European Mathematical Society are publicly launching a relationship that is expected to evolve into a joint programme of activities, and also to strengthen the 'M' in ERCIM.

ERCIM is the European Research Consortium for Informatics and Mathematics. Over the last nineteen years, an increased emphasis has been placed on information technology (or more precisely, ICT – Information and Communications Technology), mainly because of the funding priorities for research at both national and European levels.

In March 2006 Sir John Kingman, then president of the European Mathematical Society (EMS), approached ERCIM and we gladly responded, leading to a meeting and exchange of letters. Later that year, both boards approved the relationship and a task force was set up during 2007 to propose concrete actions. The task force was led by Jan Karel Lenstra (CWI general director, ERCIM Vice-President and EMS member), along with Ulrich Trottenberg (director of the Fraunhofer Institute for Algorithms and Scientific Computing – SCAI) from the ERCIM side, and Jouko Väänänen (EMS treasurer) from the EMS side.

The discussions resulted in several proposed initiatives:
• an issue of ERCIM News with a dedicated special theme on mathematics, with the sub-objective of raising the public profile of mathematics; this issue is the realization of that initiative
• bringing together the fellowship programmes of both organizations to encourage mobility of young researchers in Europe following individual submissions to the 7th Framework Programme
• bringing together our policies on open access to research information, and lobbying the European Commission and more widely, in order to improve open access.

In the background there have also been discussions about EMS members joining appropriate ERCIM Working Groups, as well as joint research proposals and joint approaches to strategic advice to be given to the EC and national governments.

This issue of ERCIM News includes a keynote by ESF president Marja Makarow (arranged by Jouko Väänänen of EMS) and a special theme section full of interesting and relevant articles. It is the public launch of the relationship between ERCIM and the EMS and will doubtless lead to greater cooperation and greater influence for mathematics and ICT both nationally and Europe-wide.

Link:
http://www.emis.de/

Facilitating and Fostering ICT Cooperation between Europe and India

ERCIM is participating in the 'Euro-India ICT Cooperation Initiative' (EuroIndia), a European project addressing strategic goals to identify and sustain European Union and Indian research and technology development (RTD) potential. Key objectives include the mapping of ICT research and innovation activities across India, a survey of Indian ICT R&D players, and the dissemination of European funding opportunities to Indian ICT players through information days.

Science and technology cooperation between Europe and India has grown rapidly in recent years. The new joint cooperation initiatives launched under the European Commission's (EC) funding stream for 2007-2013 will support efforts towards EU-India strategic partnerships on key topics of mutual interest. The EC's 7th Framework Programme (FP7) offers a prime opportunity to capitalize on Europe's immense reservoir of research resources and tools in information and communication technology (ICT), and to build on the strengths of India to help achieve key economic, societal and developmental goals.

EuroIndia will help pave the ground for a durable and sustainable institutional framework that will strengthen links between the two regions and bring mutual and lasting benefits. The project will seek to align common areas of interest with the priorities for Europe's i2010 (the EU policy framework for the information society and media) and the Indian Information Technology Policy. Grids, new network architectures, e-health and entrepreneurship are among the ICT themes and issues that have much to gain from international cooperation, helping to drive forward the development of technology that will ultimately benefit large communities.

The first EuroIndia Info Day will be held on Tuesday 22 April 2008, in conjunction with the Networked Media Workshop (NEM) on Wednesday 23 April. Both events will be hosted by the Indian Institute of Sciences in Bangalore. Lab visits in Bangalore have been organized for Thursday 24 April. The Info Day will increase the visibility of EC programmes in India and prepare the ground for lasting strategic partnerships. European experts and European Commission officials will share their know-how and explain the inner workings of EU-funded research projects, which will serve as practical examples on how to move from ideas to successfully funded international research projects.

The EuroIndia initiative is led by the Department of Informatics at the Copenhagen Business School, and the partners are ERCIM, Infra Technologies (France), Trust-IT Services Ltd (UK), the Federation of Indian Chambers of Commerce and Industry, and the Indian Institute of Technology Bombay.

Link:
http://www.euroindia-ict.org/

IM2IM Working Group Workshop on "Modelling and Simulations in Health"

by Marc Thiriet

The annual workshop of the ERCIM Working Group 'IT and Mathematics applied to Interventional Medicine' (IM2IM) was held on 21-25 October 2007 at the National Taiwan University (NTU) in Taipei, Taiwan.

This workshop was held not only for scientific exchanges but also in the spirit of answering calls of the 7th Framework Programme of the European Union, largely open to non-EU countries. The workshop comprised four scientific sessions, a set of tutorials aimed at introducing students to the use of applied mathematics and engineering science in health problems, and a discussion on defining proposals for research grants.

Presentations

Michael Tzu-Ming Chang (Department of Surgery, Tungs' Taichung MetroHarbor Hospital, Taichung, Taiwan) gave a presentation on stomach dynamics and surgical design for gastric bypasses used to treat strong obesity with lethal risk. Flow dynamics and coordinated motions between stomach parts must be retained to optimize surgical procedures. Individualized simulations of gastric kinetic patterns will be useful for clinical practice.

André Garon (Département Génie Mécanique de l'Ecole Polytechnique de Montréal) talked about the design and optimization of a ventricular assist device (VAD) for heart failure. The problem to be solved is: which type of cardiac assist pump is best for a given patient, and how should it be implanted? There are two main types of LVAD – pulsatile and continuous pumps. Continuous flow generates wall remodelling and a higher sensitivity to wall defects.

Michel Delfour (Département Mathématiques and Statistiques and CRM, University of Montréal) spoke on optimal design with illustration by coated stents used to treat arterial stenosis. Academic stent models are used for easy stent geometry description. The notion of dose of SMC proliferation inhibitor rather than concentration is introduced for a coated stent. Asymptotic dose is a simple and valid tool for stent design.

Marc Thiriet (REO team, LJLL, University Pierre et Marie Curie, and INRIA, France) gave a tutorial on biofluid mechanics and on image-based (patient-specific) modelling. Although the blood-flow simulations in any explored segment of the vasculature are carried out in a deformable fluid domain, the numerical results remain questionable because: (1) the in vivo material constants are often unknown, and (2) the vessel wall is assumed to be a more or less passive material. The second part of the presentation was then devoted to modelling that integrates mechanotransduction. The latter phenomenon regulates the size of the fluid computational domain by local short-term regulation of the vasomotor tone.

Yin-Yi Han et al. (National Taiwan University, National Taiwan University Hospital, National Cheng-Kung University and Yuan-Ze University) presented their work on 'Application of Fourier cosine spectrum and spectrogram to analyse artery pulse and ECG data'. This study is aimed at developing robust models for monitoring the adaptation of patients to various procedures and after treatments, such as artificial knee joint replacement, and liver and kidney surgery.

Numerical studies in biomedical applications at the National Center for High-performance Computing (NCHC) in collaboration with Chang Gung Memorial Hospital and National Health Research Institute were presented by Ren-Jieh Shih, and included obstructive apnea; dyspnea from vascular rings, which compress airways; cerebral aneurisms; a simple model of a stenosed deformable vessel with bypass graft; stent expansion and implantation; two dental implants with different fixation designs; computer-assisted construction of a cranioplasty implant; and 3DR of the tracheobronchial tree.

I-Liang Chern et al. (Department of Mathematics, Taida Institute for Mathematical Sciences, National Center for Theoretical Science at Taipei, NTU) proposed a coupling interface method (CIM) under a Cartesian grid for solving elliptic complex interface problems in arbitrary dimensions, where the coefficients, the source terms and the solutions can be discontinuous or singular across the interfaces. He gave a proof of the solvability of the coupling equations.

Hurng-Sheng Wu (Department of Surgery, Show-Chwan Memorial Hospital, Chang-Hua) spoke on new developments in minimally invasive surgery. Robotic and traditional mini-invasive (MIS) surgery is carried out in Taiwan in association with IRCAD (Strasbourg, France). Working through fixed entry points has the disadvantage of limiting the manoeuverability of instruments inside the body cavity. Looking at a two-dimensional screen, surgeons are handicapped by the loss of visual depth perception. These limitations are considered to be the major burdens of laparoscopic surgery for surgeons. A new robotic surgical system that has overcome the limitations of conventional laparoscopic technology can provide surgeons with enhanced visual control and dexterity.

A revisit of counter-pulsation circulation support using hybrid circulation model and wave intensity analysis was presented by Pong-Jeu Lu et al. (Department of Aeronautics and Astronautics, Center for Biomaterials and Heart Science Research, National Cheng Kung University, Tainan, and Cardiovascular Research Center, National Cheng Kung University, Tainan). Counter-pulsation perfusion has been fulfilled using either intra-aortic balloon pump (IABP) or para-aortic blood pump (PABP) to treat various acute and/or chronic heart failure.

Pacemaker efficiency and optimal electrode positioning was discussed by L. El Alaoui and L. Dumas (INRIA REO team) using a model of electrochemical impulses. Though current pacemakers give good results, certain questions still arise: how many electrodes should be set? Where should the electrodes be placed? When should the electrodes act? Such problems can be solved with optimization tools like genetic algorithms.

A. Garon and coworkers (Département Génie Mécanique de l'Ecole Polytechnique de Montréal and INRIA REO team)

spoke on a computational model of flow in the carotid artery and its validation using PIV. Flow was steady because of the context of a continuous left ventricle assist device. Steady flow has been investigated for various flow distributions in a carotid artery network with two successive embranchments, the carotid bifurcation and a branching of the external carotid artery. Numerical tests have been carried out using the finite element method (P1-P1 stabilized approximation). A phantom has been built from the surface mesh, and the velocity field has been measured using particle image velocimetry. Numerical and experimental results are in good agreement (see Figure 1).
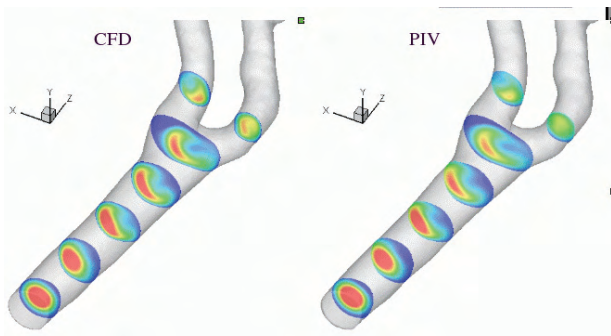
Figure 1: (left) Numerical steady velocity isocontours in selected cross-sections of a carotid artery network; (right) velocity field measured in the same loci using PIV. The phantom was built by rapid prototyping from the surface mesh of the computational model (study carried out at Ecole Polytechnique de Montréal in the framework of INRIA Associated Team 'CFT').

Guan-Yu Chen and collaborators (Department of Electrical Engineering, National Tsing Hua University, Hsinchu) are developing a model-based 3D and 4D cardiac ultrasound system. Ultrasonic imaging is superior for its real-time observation. A patient's heart can be reconstructed from data obtained by conventional 2D ultrasound with controlled probe motion.

The talk of Ruey-Feng Chang (Department of Computer Science and Information Engineering, Graduate Institute of Biomedical Electronics and Bioinformatics, National Taiwan University) targeted computer-aided diagnosis for breast tumours based on ultrasound imaging: the Breast Imaging Recording and Data System (Bi-RADS) provides shape, orientation, margins, boundaries etc. 2D B-mode echography can be combined with elastography to improve results. 3D ultrasound can display tumour spiculation, blood supply (vessel distribution) and so forth. After using a 3D thinning algorithm, the reconstruction of vascular trees allows certain features to be extracted (eg volume ratio, length, curvature and number of branches).

Catalin Fetita et al. (Artemis team, INT, France) presented a 3DR assessment of airway wall thickness with MDCT for therapy planning and evaluation of novel asthma therapies. An axis-based morpho-topologic description allows cross-sections or regions of interest to be defined for parameter quantification. The Lagrangian motion equation controlling the model evolution is parameterized so as to reach equilibrium at the level of the outer bronchus contour, as well as to handle local wall deformations and blood vessel contact zones.

Jun Feng (Northwest University, China) and Horace Ip (AIMtech Centre, and Department of Computer Science, City University of Hong Kong) spoke on the reconstruction and analysis of medical shapes using Statistical Piecewise Assembled Models (SPAM). Statistical deformable models provide an extensible framework with which to segment and reconstruct shapes from medical and biomedical datasets. The research goal of SPAM is a reconstruction methodology that can hierarchically define the shape and texture structures of highly flexible anatomies, automatically select the landmarks, and robustly build the point correspondence among the training samples.

Chien-Cheng Chang and Po-Hsiang Tsui (Division of Mechanics, Research Center for Applied Sciences, Academia Sinica, Taipei, and Institute of Applied Mechanics, National Taiwan University) spoke on local scatterer concentration imaging using the Nakagami statistical model. The ultrasonic B-mode image is used to examine the internal structures of the biological tissue. The Nakagami parameter is able to detect the variation of the scatterer concentration, and thus can be used to assist in the B-mode image for tissue characterization. The Nakagami image can be combined with the use of the B-mode image to simultaneously visualize the tissue structures and the scatterer properties for a better medical diagnosis.

3D medical imaging and its clinical applications in surgery assistance were presented by Beender Yang (Yen Tjing Ling Industrial Research Institute, National Taiwan University). 3D medical content always comprises enormous image data. To deal with this problem, most medical facilities equip their centralized radiology departments with advanced 3D software tools to process 3D medical image data into a series of key planar images for their referring physicians and clinicians.

Adel Blouza and coworkers (Laboratoire de mathématiques of University of Rouen and University Haute-Alsace in Mulhouse, and REO team) delivered a talk on stent optimization. An optimization process is built to seek the best three geometric parameters (strut spacing, strut height and strut width) of a simplified bidimensional stent, which reduces blood vorticity in the fluid to minimize eddy formation and elevates blood vorticity at the wall to minimize particle residence time.

Cheng-Maw Ho and collaborators (Department of Surgery and of Medical Imaging, National Taiwan University Hospital, Department of Engineering Science and Ocean Engineering, NTU, and Department of Marine Engineering, National Taiwan Ocean University) presented their work on simulation and validation of hemodynamic changes after live-donor right hepatectomy. The objectives of this study are to reconstruct the portal vein and its intrahepatic branches to simulate the hemodynamic changes after the resection.

Links:
IM2IM Working Group:
http://www-rocq.inria.fr/im2im/

Please contact:
Marc Thiriet, INRIA, France
E-mail: Marc.Thiriet@inria.fr
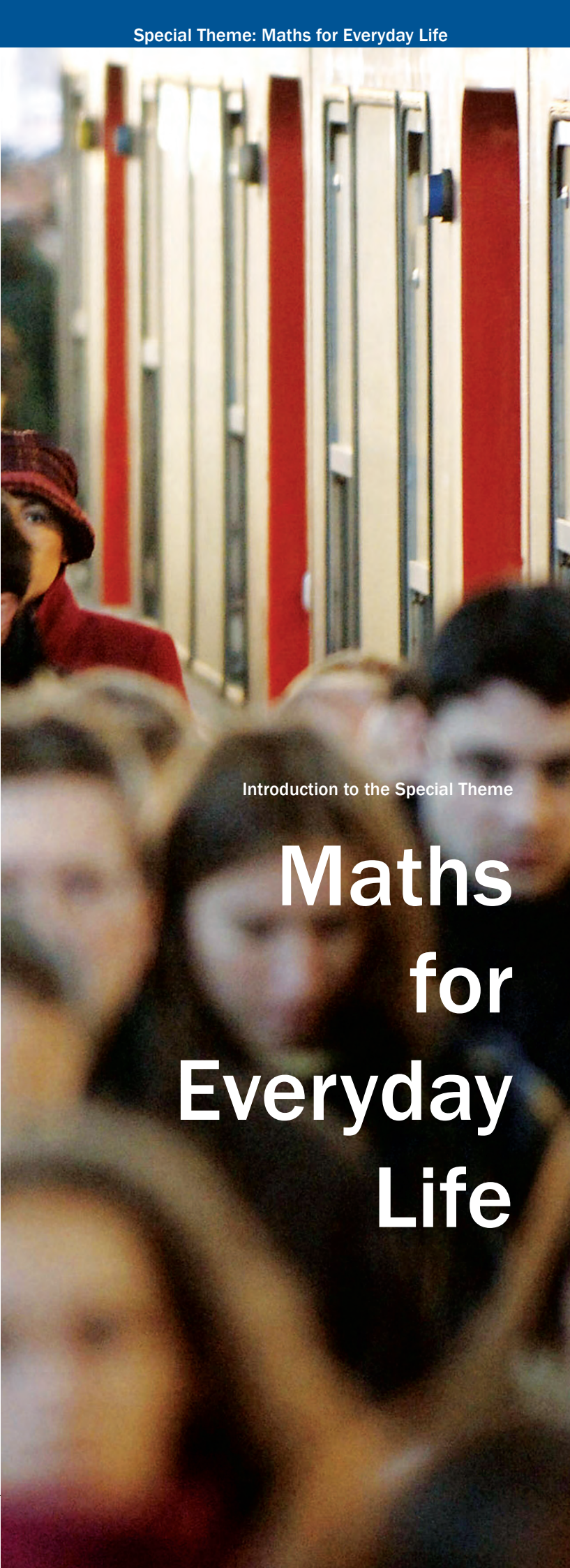
Introduction to the Special Theme

Maths for Everyday Life

by Jouko Väänänen and Ulrich Trottenberg

Mathematics saturates everyday life more and more. It is used not only in large applications running on huge computers to predict weather or to calculate parameters for an expensive industrial process or marketing strategy: it has now become ubiquitous in the more mundane aspects of our existence. A good example is the mobile phone. Mobile phone technology depends heavily on such fundamental areas of mathematics as analysis, algebra, and number theory.

Mathematics is in principle inexpensive. As the old joke says, a mathematician needs only paper, a pencil, an easy chair and a waste basket. Also, the criterion for success in mathematics is by and large universally accepted. This makes mathematics an attractive 'investment'. Moreover, a mathematical result is valid forever. It may fall out of fashion, or fall outside the current area of application, but even the oldest known mathematical formulae – such as that for solving quadratic equations, known 2400 years ago by Babylonians, Chinese and later the Greeks before being crystallized into its present form in 1100 AD by a Hindu mathematician called Baskhara – are the bread and butter of present-day elementary mathematics. Alas, the downside is that the results are usually not immediately applicable – and therein lies the risk. Who wants to 'invest' in something that may not lead to applications for several hundred years? The good news is that the distance between theory and application is becoming shorter and shorter.

Mathematics can be compared to a pyramid. On the top of the pyramid are applications of mathematics to health, weather, movies and mobile phones. However the top of this pyramid would not be so high if its base were not so wide. Only by extending the width of the base can we eventually build the top higher. This special feature of mathematics derives from its internal structure. A good modern application of mathematics can typically draw from differential equations, numerical analysis and linear algebra. These may very well draw from graph theory, group theory and complex analysis. These in turn rest on the firm basis of number theory, topology and geometry. Going deeper and deeper into the roots of the mathematics, one ends up with such cornerstones of logic as model theory and set theory.

It is clear that mathematics is heavily used in large industrial projects and in the ever-growing electronic infrastructure that surrounds us. However, mathematics is also increasingly infiltrating smaller scale circles, such as doctors' reception rooms, sailboat design and of course all kinds of portable devices. There has also been a change in the way mathematics penetrates our society. The oldest applications of mathematics were probably in various aspects of measurement, such as measuring area, price, length or time. This has led to

tremendously successful mathematical theories of equations, dynamical systems and so on. In today's world, we already know pretty accurately for example the make-up of the human genome, yet we are just taking the first steps in understanding the mathematics behind this incredibly complex structure of three billion DNA base pairs. Our understanding of the mathematics of the whole universe of heavenly bodies, even going back in time to the first second of its existence, is better than our understanding of the mathematics of our own genes and bodies.

What is the difference between the hereditary information encoded in DNA and the information we have about the movements of the heavenly bodies? Is it that we have been able to encapsulate the latter into simple equations, but not the former? Or is it perhaps that the latter has a completely different nature than the former, one that makes it susceptible to study in terms of equations, while the former comes from a world governed by chance, and algorithms, a world of digital data, where the methods of the continuous world do not apply?

Another well-known instance of mathematics in society is cryptography in its various guises. There exist numerous situations in which data must be encrypted such that it can be publicly transmitted without revealing the content. On the other hand, sometimes a party may find it vitally important to break a code that another party has devised for its protection. Some companies want to examine the data of our credit card purchases in order to have access to our shopping patterns. Some governments want to do the same with regard to what they deem less innocuous patterns of behaviour. Cryptography is a typical example of the mathematics of the digital world. Digital data has become important in almost all fields of learning, a natural consequence of advances in computer technology. This has undoubtedly influenced the way people look at fields of mathematics such as number theory, that were previously thought to be very pure and virtually devoid of applications, good or bad. Now suddenly everybody in the possession of big primes has someone looking over their shoulder.

This infiltration is quite remarkable and elevates mathematics to a different position from that which it previously occupied. Mathematics is no longer a strange otherworldly subject, practised by a few curious geniuses but for most people best left alone. The spread of microprocessors into every conceivable aspect of our everyday life has brought heavy-duty computing into our homes, into our classrooms and into scientific laboratories of all kinds. Naturally it is unnecessary for everyone to understand all this computing, which can take place in microseconds without our noticing. But it means that anyone who refuses to acknowledge the role of mathematics will see the changing technosphere as something strange and in the worst case as something irrational or

even frightening. A very good way to understand and come to terms with an important aspect of modern life – our ever-growing dependence on interpreting digital data – is to have a basic knowledge of mathematics.

Basic knowledge: what does this mean and how is it attained? Clearly, this takes us into the realm of mathematics education. Strictly speaking, education is not an application of mathematics, but it is nevertheless of increasing importance to the mathematical world. Every time the OECD's PISA (Programme for International Students Assessment) results arrive, some people ask why some countries always seem to score highly in the mathematical skills of 15-year-olds. Without attempting to answer this difficult question, one must admit that it is important and that maths education will face huge challenges in the future, not least because of the infiltration of mathematics into all levels of society. This infiltration clearly has much to do with the revolution triggered by the development of computers over the last fifty years. Has this revolution arrived in schools, and in maths education? Most students now own a computer with an Internet connection. This is used for games, chatting, text processing and surfing, but do they use the computer for mathematics? Are mathematical modeling (ambitious problem solving) or algorithmic thinking (expressing mathematics in such a way that the computer can handle it) taught at school? There is much that can be done here, in curricula, in textbooks and in everyday life at school.

In this special issue on Mathematics for Everyday Life, we present a selection of mathematical projects that are in some way relevant, directly or indirectly, to our everyday lives. We start with projects that have applications in the health sector and continue with the closely related topic of image processing. We then go on to the timely topic of weather (one of the prime examples of large-scale computing), the effects of which are immediately felt when the beach turns into a swamp, contrary to the weather report. We present three projects in transportation, one on ships, one on trains and one on cars. In the section on society we touch upon topics like rating, trading and immigration. We also include two articles on the topic of mathematics education. The special issue ends with an article on a little mystery inside mathematics.

Please contact:
Jouko Väänänen
University of Amsterdam, The Netherlands
University of Helsinki, Finland
E-mail: jouko.vaananen@helsinki.fi

Ulrich Trottenberg
Fraunhofer Institute for Algorithms
and Scientific Computing (SCAI), Germany
E-mail: ulrich.trottenberg@scai.fraunhofer.de

Inverse Problems: Making the Unseen Visible with Mathematics

by Mikko Kaasalainen and Lassi Päivärinta

Mathematical analysis can make visible the insides of objects such as our bodies, rivers or the Earth, and is revealing entire new worlds in space. It may also work in the opposite way in designing tricks that hide things from our view.

The Finnish Centre of Excellence in Inverse Problem Research, funded by the Academy of Finland, was started in 2006. The centre comprises six research groups in Finnish universities, led by the inverse problem group at the Department of Mathematics and Statistics at the University of Helsinki. The centre's research is focused on developing the mathematical theory of inverse problems and solving inverse problems in a variety of applications, ranging in size from the molecular to the galactic level. The main goal is to build efficient and reliable mathematical models of targets even from very incomplete and noisy data, and this often results in the creation of images of entities that would otherwise remain unseen. Here we present a few examples.

In medical imaging, more precise information is often needed about the 3D structure of a tissue than can be obtained with ordinary x-ray techniques. The detector records whether an x-ray was absorbed in its path through a tissue, but the images do not indicate the extent to which the x-ray was absorbed at particular points along its path. In other words, we are not able to determine depth of detail in the image. The 3D structure of a tissue can be determined by imaging the target from different directions and then mathematically computing the proportion of x-rays absorbed by the tissue at different points. This standard technique is used in computer tomography (CT). However, a disadvantage of CT is that it exposes the patient to high doses of radiation since many x-ray images are needed.

Statistical inversion techniques developed by our group alleviate this problem. By incorporating into the algorithm statistical a priori knowledge about the structure of interest, the number of images needed to calculate a reconstruction is significantly reduced. An example of this a priori knowledge is the positivity of the target function: tissue does not strengthen x-rays at any point. A priori knowledge of tissue differentiability is also frequently used in reconstruction calculations.

We are also developing a wholly different technique, called electrical impedance tomography, for viewing the insides of our body. This simple and inexpensive method is based on conducting very small currents through the body and measuring them on the surface: again, mathematics can turn such information into an actual image. The search for such a method also led to the solution of a long-standing hypothesis by Alberto Calderon.

We are also interested in solutions to geological and meteorological problems. The varying densities and materials below the surface of the Earth can be analysed with seismic imaging, and the bottoms of rivers or lakes can be accurately mapped with advanced sonar techniques. In the latter, we have developed pulse codes to pack as much information as possible into the transmitted and received sound signals, obtaining unprecedented spatial resolution. We use the same technique in radar experiments: with weather radar, for example, we are able to map the insides and the movements of regions of extreme weather with precision unattainable by traditional radar techniques.

In astronomy, too, our work finds application. Millions of asteroids in our solar system are seen only as points of light, even with the largest telescopes. Mathematics, however, makes it possible to reconstruct the rotation states and
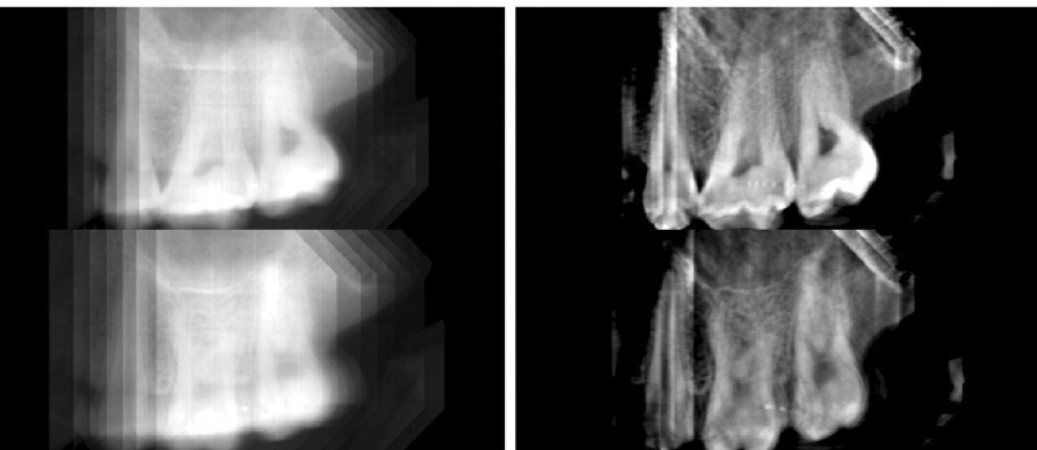

Figure 1: (left) Two slices of a traditional x-ray image reconstruction of teeth; (right) the corresponding slices of a reconstruction made with our statistical inversion methods from the same raw data.
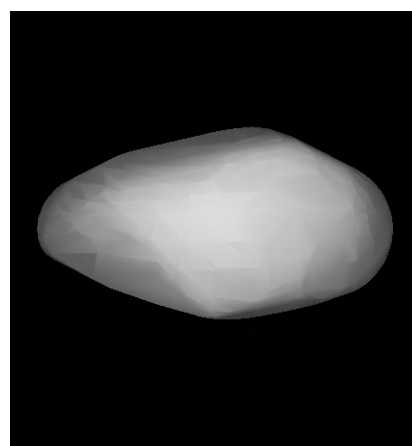
Figure 2: The reconstructed shape of asteroid 1862 Apollo, whose rotation speeds up due to sunlight.

shapes of asteroids merely from brightness variations that can be recorded with small telescopes. The problem is to determine the shape of an object from the sizes of its projection-like quantities in different directions. We have shown that, contrary to the belief held for almost a century, this inverse problem of generalized projections can be solved. The solution is based on the fact that the object is not always illuminated and viewed from the same direction, ie we measure more than the sizes of its shadows. Related to this is a practical solution to the Minkowski problem: how can a polyhedron be reconstructed when only the areas and orientations of its facets are known?

Using this technique, it is now possible to carry out a comprehensive mapping of one of our solar system's least known

regions, the asteroid belt. This method has also resulted in completely new discoveries, such as asteroid rotation powered by sunlight. This finding is the most internationally reported Finnish research result ever. We can directly see how the pressure of the photons slowly but surely influences the motion of asteroids. With this knowledge we can predict the motion of near-Earth objects more precisely, and may even be able to help avert a collision with the Earth.

Finally, just as an example that mathematics used in inverse problems cuts both ways: we have shown that with suitable optical materials it is mathematically possible to create optical wormholes. With such invisible tunnels, light can be transmitted from one site to another, without anyone seeing it between the two sites or even realising

that there is a tunnel in the first place. With the engineering techniques of the future, this method can even be used in building appliances such as 3D televisions.

Links:
http://math.tkk.fi/inverse-coe
http://www.rni.helsinki.fi/~mjk
http://www.rni.helsinki.fi/~ljp
http://math.tkk.fi/~mjlassas/index.html.en

Please contact:
Mikko Kaasalainen
University of Helsinki, Finland
Tel: +358 9 19151441
E-mail: mikko.kaasalainen@helsinki.fi

Lassi Päivärinta
University of Helsinki, Finland
Tel: +358 9 19151456
E-mail: lassi.paivarinta@rni.helsinki.fi

A Needle in the Brain

by Albert Ali Salah

A surgeon about to operate on a small region within the brain has a difficult job. By listening to the sounds of voltage discharge patterns of single neurons, recorded with very fine needles inserted into the brain just prior to the operation, expert surgeons try to determine whether or not they are on target. Can real-time signal processing and analysis help the surgeon?

The Study Group Mathematics with Industry (SWI) workshops aim at bringing mathematicians (and occasionally computer scientists) together for a week to work on some difficult unsolved industrial problem. Besides reinforcing scientific, industrial and social relations, participants are challenged to come up with a fresh perspective on the problem and more often than not this leads to directly usable results and methods for industry. This year's workshop, organized at the University of Twente in the Netherlands (28 January – 1 February 2008), hosted a project on the real-time classification of single-neuron recordings, jointly proposed by Philips Research and the Amsterdam Academic Medical Centre, who have been collaborating on this topic for some time.

The problem involves helping neurosurgeons get their bearings during deep brain surgery. The method currently used involves inserting fine needles into the brain to record neuron action potentials for periods of about ten seconds, converting the activity to sound waves,

Can real-time signal processing and analysis help the surgeon?

and playing it to the surgeon, who then decides whether the needle is on target or not. The two principal aims of the workshop project were to determine which methods of analysis and information presentation would make the life of the surgeon easier by classifying recorded neural activity on the fly; and to incorporate the knowledge of the expert surgeon into the analysis in such a way as to aid inexperienced surgeons. The latter problem is particularly important since expert knowledge is highly qualitative, depends on intuition honed by many surgeries, and is very difficult to encapsulate as a procedural description.

Apart from the modelling of expert knowledge, there are several challenges in this problem. In detecting neural activity a needle records a great deal of background noise, which needs to be accounted for. Deep brain recordings have much higher noise levels than cortical recordings. Depending on the proximity of neurons in the area, several neural activities including cellular

action potentials, axonal fibre bundles and field potentials can be recorded with a single needle, and the fact that closely spaced neurons usually have highly correlated activities makes their separation difficult. Even though we can attribute several general characteristics to a neural spike, they have different shapes and firing patterns, which sometimes change with time and almost always overlap with other sources. A single neuron can have relatively regular interspike intervals, or it can be a bursty neuron with alternating periods of low activity and high-frequency firing. Furthermore, neurons can become active or inactive during a single recording, and the number of neurons contributing to the signal may change.

Spike sorting is not a recent problem: it has been around since the 1960s. Early methods relied on template matching, and required heavy offline processing. More recent methods combine feature extraction, probabilistic modelling and clustering. The accuracy and efficiency of these methods are much greater than before, but most are still too computationally intensive to be used during the surgery, and do not work well with deep brain recordings.

Our study group inspected two main approaches to the problem during the workshop. After the detection and alignment of individual spikes, several features can be extracted from each spike, and used in a classification framework in an unsupervised manner. The spike length, amplitude, total area, polarity, ratio of peaks, or simply the potentials sampled at a fixed rate can serve as features. A Karhunen-Loewe transform followed by a clustering on the projection space produces a fast, clear separation of spike shapes that usually vary smoothly in time. This method is useful even for non-stationary spike shapes, and works well if the shapes are sufficiently discriminative.

Our second approach uses the temporal structure of the spikes. The temporal dependencies can be analysed with Fourier analysis or autocorrelation methods, but the non-stationary nature of the firing rates, irregularities due bursty neurons and the changing number of sources make this task difficult. To robustly identify the trends, we take an approach similar to autocorrelation analysis. We shift the spike sequence

Figure 1: A sample of recorded activity from a dying neuron. Listening to the sonified signal is really spooky, as it strongly resembles a scream.
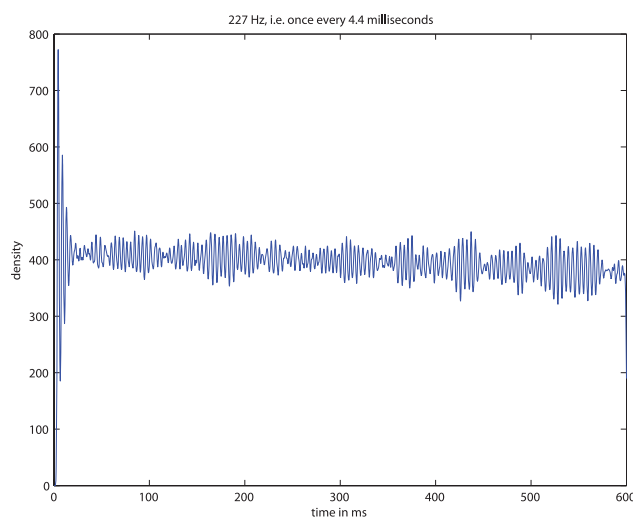
Figure 2: The greatest peak of the shift-stack histogram corresponds with the most prominent neural activity in the recording, which in this case shows the presence of a high-frequency (227Hz) neuron.

repeatedly to align each successive spike with the origin of the temporal axis. We then convolve each spike with a fixed Gaussian function and stack these Gaussians. The peaks of this accumulated function reliably identify periods of neural activity, even if the neuron is inactive from time to time during the recording. Furthermore, the expert surgeon could identify broader trends (eg tremor) in the shift-stack histogram.

We have obtained promising results on a small set of recordings, and even though the workshop is over, the project continues. We are currently working on several extensions, with the hope that some of our ideas may eventually make their way into the operating room.

Links:
http://wwwhome.math.utwente.nl/~swi2008/
http://www.amc.uva.nl
http://www.research.philips.com
http://homepages.cwi.nl/~salah/

Please contact:
Albert Ali Salah
CWI, The Netherlands
Tel: + 31 20 592 4214
E-mail: a.a.salah@cwi.nl

Mathematical Tools for Securing a Telemedicine Platform: Monitoring, Communication and Storage

by Thierry Simonnet

Hidden Markov Models, Bayesian statistics, cryptography, relational algebra, signal filters, the Harris detector and wavelet transforms are among the mathematical tools necessary to set up a telemedicine platform developed by ESIEE-Paris (Ecole Supérieure d'Ingénieurs en Electronique et Electrotechnique). The platform offers medical and communication services to patients, especially for cases of pre-Alzheimer's disease.

The telemedicine platform developed by ESIEE-Paris offers medical and communication services to patients, and is particularly helpful for cases of pre-Alzheimer's disease. It is the result of several telemedicine projects that started in November 2003, like the RNTS (Réseau National Technologies pour la Santé) project TELEPAT and after it, TANDEM. The platform has two main components – a central server and local equipment (PDI - Passerelle Domestique Internet - Domestic Internet Gateway) – that communicate using a secure IP Network over the Internet (VPN).

Population ageing and the financial situation of health services make it quite difficult to satisfy all needs and to maintain the quality of medical care. One method of reducing medical care costs is to reduce the average duration of patient hospitalization, and to reinforce home support by formal (professionals) and informal (familial) caregivers or facilitate home hospitalization. For people who need frequent medical care or constant observation in their everyday life – such as those suffering from cardiac or Alzheimer's diseases, and the frail or elderly – a prolonged stay in a medical centre can result in separation from their entourage. Staying at home is a way to avoid this problem and help the patients maintain their social links.

Advanced functions are under development; these include anti-spam tools for mail, instant messaging filters, improved video quality (for the purpose of using patient television as a visiophony monitor) and robotics management. These developments are scheduled for 2011.

The platform was first designed and set up using standard OpenSource tools (Xen, OpenLDAP, Postfix, Horde GroupWare, jabber and visiophony). This platform is available for two kinds of hardware platform using both Debian Gnu/Linux: Xeon and Itanium-2 processors. The latter offers mathematical capabilities, useful for security and calculation purposes.

The second step was to enhance the critical functions to avoid any mistakes or false positive detection using mathematics tools:

• *Hidden Markov Model:* the automatic segmentation and classification of ECG data uses statistical approaches such as Hidden Markov Models, derived for sub-beats modelling for ambulatory ECG recordings on the patient. This sensor set constitutes a remote real-time supervision of the patient's cardiac activity at home, and uses a combination of actimetric and health tendency data from the patient that must be correlated with pulse.

• *Bayesian statistics:* the use of Bayes' theorem for mail body content reduces the amount of spam. The aim is to integrate a tool that gives a spam/ham probability for a message using a phrase-based rather than word-based approach. This tool works as a filter and can also be used for instant messaging.

• *Cryptography and relational algebra:* to protect confidentiality, the identity and medical data of a patient are split into two sets. The first is stored in an LDAP (Lightweight Directory Access Protocol) directory, using a regular security level. Medical data and the results of cognitive exercises are stored in distributed databases. Only authorized medical personnel can associate identity data to a set of medical results or to an emergency call after a monitoring alarm. The dis-
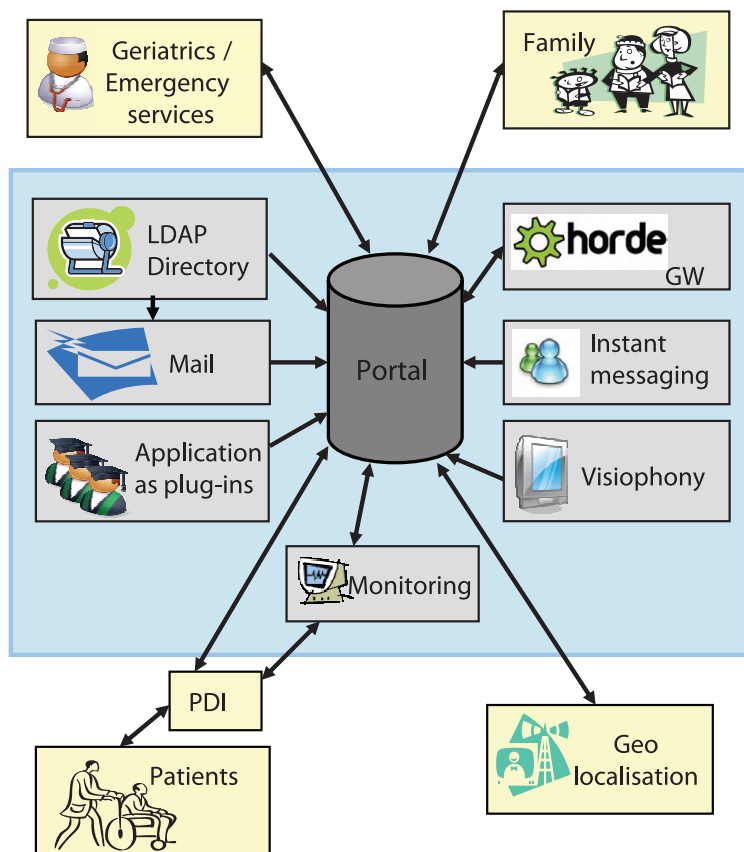
Figure 1: Telemedicine platform.

tributed database uses a field authentication scheme not only to avoid external attacks but also to keep multiple levels of confidentiality managed by the LDAP directory.

- *Signal processing:* for monitoring data, the local base station can perform one or more filtering processes on received signals in order to improve their signal-to-noise ratio and quality, and to estimate the patient's state of health (eg slow or abrupt variations in heart rate to lower the risk of bradycardia). It carries out the fusion of the various physiological and actimetric values in order to calculate an alarm or emergency index, and then retransmits this through a secure VPN link to the remote server of the medical control station.

- *Image processing using a Harris detector:* with new developments in static video, robotics and augmented reality, the use of this detector will

provide the means to detect any changes in a patient's house and then assign rules for robot moves.

- *Wavelet transform:* a high-quality visiophony service is necessary. For a home-based solution, ad-hoc wireless peripherals are convenient. The use of a motion-compensated spatio-temporal wavelet transform allows the best video quality to be maintained and avoids latency and jitter. A set of optimized algorithms will be deployed on both the server side and the PDI side to improve quality and fluidity. In the near future, an emotion recognition tool will be also implemented.

With two new projects now running (QuoVADis and CompanionAble), this platform will have new functionalities: for instance, a robot (as companion) will be able to help a patient with certain activities such as handling pill boxes, relaying alarms, relaying the voice of an operator or doctor, visualizing the home

using augmented reality, emotion recognition and smart home management.

For platform validation, in particular for Alzheimer's patients, the ESIEE-Paris team is working in close cooperation with many partners: with Broca Hospital (Assistance Publique Hopitaux de Paris) for content generation for cognitive stimulation and day-time management as well as ethics, with INT for monitoring and sensors, with private companies like Legrand for smart homes, with University of Reading for project management.

Please contact:
Thierry Simonnet
Groupe ESIEE-Paris, France
Tel: +33 1 45 92 66 24
E-mail: t.simonnet@esiee.fr

The Analysis of Dynamical Diseases by Optimal Transportation Distances

by Michael Muskulus and Sjoerd Verduyn-Lunel

Diseases influence the dynamics of normal physiological processes, and by analysing measurements of the latter it is possible to accurately and automatically detect and diagnose diseases. It is a fact that diseases with similar symptoms are sometimes incorrectly diagnosed and treated, but methods such as ours can help prevent this. The method itself is based on calculating abstract distances between time series of measurements.

Optimal transportation problems arise in a variety of ways in everyday life. Originally formulated by Kantorovich as the problem of optimally transporting manufactured goods from their suppliers to some markets, it can also be studied in its measure theoretic version, where it corresponds to the problem of optimally moving a distribution of sand and rocks such that the surface flattens out. When the distributions considered are instead given by the time averages of two dynamical systems, the optimal cost is an abstract measure of the distance between their long-term dynamical behaviour. These time averages are computed from time series by way of a delay vector reconstruction, as is common in nonlinear time series analysis.

When computing the optimal cost, which is called the Wasserstein distance

in the mathematical literature, the cost per unit of (probability) mass moved is proportional to the distance travelled. Numerically, the continuous problem is approximated by a discrete transportation problem, for which polynomial general-purpose algorithms exist. One direction for future research is the search for more efficient algorithms that make use of the special structure of the problem, i.e. that costs fulfil the triangle inequality. At the moment, the problem is further approximated by bootstrapping smaller subproblems from it, as the computations are otherwise too time consuming.

Residual Wasserstein Distances

Since we want to compare dynamical behaviour of physiological systems, the variability between subjects poses a serious problem. For example, if the

amplitude of a parameter is different in two time series, is this due to anatomical differences or to a change in the dynamics? Since this is a priori unknown, it is not possible to simply normalize the time series.

We therefore defined the residual Wasserstein distances as optimal transportation distances where an initial translation and relative scaling of the two time averages incurs no cost. The resulting distances are scale-invariant and can be computed efficiently by an iterative majorization method, combined with the AUCTION algorithm due to Bertsekas. The latter starts from already computed solutions and relaxes them to optimal solutions of similar transportation problems. A software package for the statistical computing environment R has been developed

which implements this method, and is available from the author's web page.

Dynamical Diseases

The concept of a dynamical disease has been defined by Milton & Mackey in a seminal paper as a change in the qualitative dynamics of a physiological control system when one or more parameters are changed. This idea allows the tools of nonlinear science to be applied in a clinical context as well, treating physiological processes as a noisy dynamical system. Diseases then correspond to parameter changes, leading to different long-term dynamical behaviour. The validity of this assumption has to be evaluated empirically.

Application to Breathing Data

An interesting application is the analysis of lung function, which is measured by superimposing an artificial pressure oscillation to the air and recording the integrated response of the lung. Two parameters were investigated from such forced oscillation recordings, characterizing the resistance and elasticity of the lung tissue. The dataset comprised twelve one-minute breathing measurements from 25 patients; it was supplied by P. J. Sterk and A. Slats and is described in full detail in their article published last year. Thirteen of the patients suffered from mild asthma and twelve from chronic obstructive pulmonary disease (COPD). These two lung diseases can be difficult to diagnose correctly when patients start to develop symptoms.

Figure 1 shows some of the original time series and two-dimensional representations of the computed distances. The latter are results obtained by residual Wasserstein distances (panel E) and two alternative methods, distances based on the means of the two parameters (panel D) and standard Euclidean distances between the time series (panel C).

Conclusions

The classification of lung diseases by residual Wasserstein distances is an interesting application of the concept of dynamical diseases and indeed allows better classification than by classical means. We are also investigating the possibility of tracking the progress of a disease by these distances, and the application of our method to different datasets, for example EEG or MEG brain recordings.

Link:
http://www.math.leidenuniv.nl/~muskulus

Please contact:
Michael Muskulus
Leiden University, The Netherlands
Tel: +31 71 527 7058
E-mail: muskulus@math.leidenuniv.nl
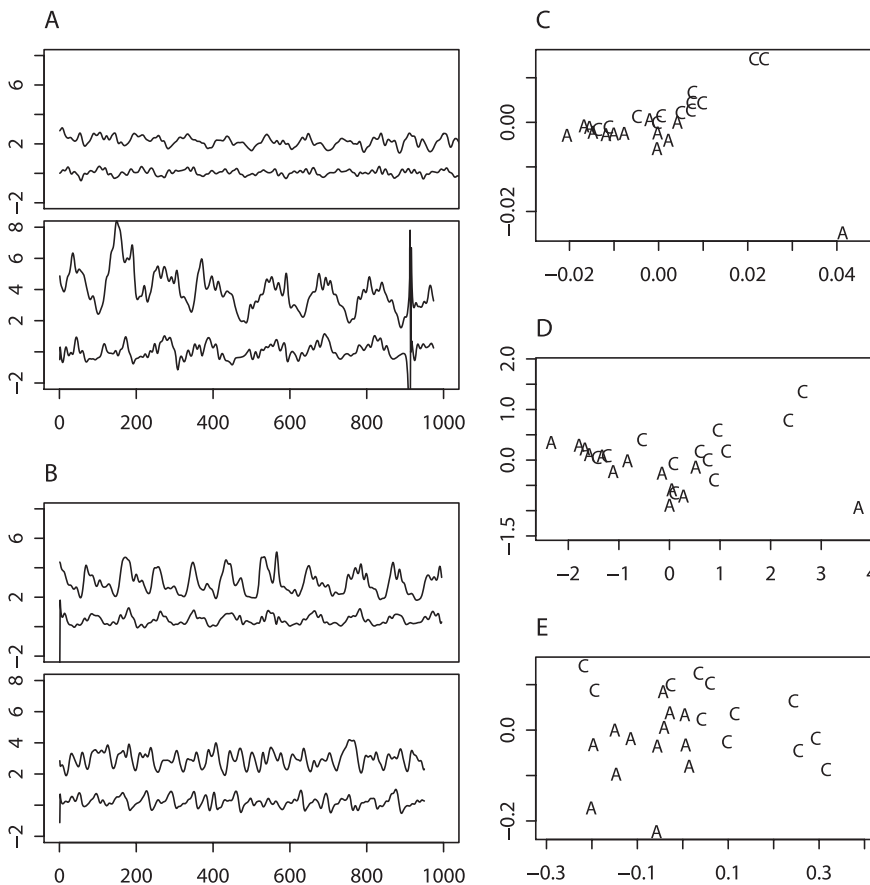
Figure 1: Time series of four randomly chosen patients either with asthma (A) or COPD (B), where the upper curve in each panel shows resistance at 8 Hz and the lower curve elasticity at 8 Hz. Time is given in samples. The distances between the time series of all 25 patients are shown in a two-dimensional representation, the upper panel (C) shows Euclidean distances, the middle (D) shows distances in mean, and the lower panel (E) residual Wasserstein distances.

Evolutionary Suicide

by Mats Gyllenberg

The accelerating speed at which species are becoming extinct is of major and worldwide concern. Usually human activity is blamed, but while the destruction of natural habitat and the emission of greenhouse gases are certainly affecting the ecology of many species, are they the only causes of species extinction? Is it possible that natural selection could drive a species to extinction? A crude view is that evolution is a process with a certain direction: simple organisms evolve into more complicated ones, weaker individuals are selected against and thus evolution produces stronger and stronger populations. This view is simply false. Natural selection acts at the level of individuals (in fact, at the level of genes) and it is quite possible that what is advantageous for the individual turns out to be disastrous for the species.

Darwin's discovery of natural selection as the mechanism of evolution and Mendel's subsequent discovery of the basic principles of heredity led to one of the most remarkable paradigm shifts in the history of science. The mechanism is often paraphrased as "the survival of the fittest" and some of the basic problems, eg the very definition of fitness, are inherently mathematical. Evolution does not, of course, take place in a vacuum. Individuals continuously interact with the environment and the fitness of an individual depends on the environment it experiences. As this environment includes and is influenced by the rest of the individual's conspecifics and competing species, it is clear that evolution is intimately linked to population dynamics.

Adaptive dynamics is a relatively new mathematical theory that explicitly relates evolution by natural selection to ecology, that is, population dynamics. Intensive research on adaptive dynamics is being carried out at the University of Helsinki, the International Institute for Applied Systems Analysis (IIASA) and the University of Liverpool, to name only a few (see links at below). Using this theory one can address and often answer questions such as "When can a rare mutant invade a population?", "Under what circumstances does speciation take place?", "Are there evolutionary attractors?" and many more.

Ecological interactions and population dynamics are modelled as a dynamical system. A population consists of individuals that differ from each other in age, size and other characteristics. The state of the population is the distribution of these characteristics, which is an infinite-dimensional quantity.

In Figure 1 we have plotted a possible bifurcation diagram of a one-dimensional projection of such an infinite-dimen-
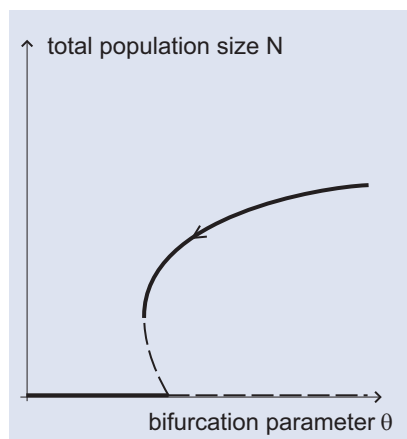
Figure 1: A possible bifurcation diagram of a one-dimensional projection of an infinite-dimensional dynamical system.

sional dynamical system. On the horizontal axis is a bifurcation parameter θ and on the vertical axis is the total population size N. Thick lines correspond to stable steady states and dashed lines to unstable ones. The bifurcation from the steady state N=0 corresponding to population extinction is a so-called subcritical or backward bifurcation. In a certain parameter range there is bistability: in addition to the stable extinction state there is another stable steady state corresponding to a viable population.

Assume now that the parameter θ describes a heritable trait that is subject to natural selection. The invasion fitness of a rare mutant θ' introduced into a resident population of individuals of trait θ is defined as the long-term exponential growth rate of a (hypothetical) clan of such mutants in the environment set by the resident population. If the invasion fitness of the mutant is greater than zero, then the mutant can invade and possibly replace the resident. We can therefore provide the branches of stable steady states in a bifurcation diagram with an arrow indicating the direction in which the life-history

parameter under selection will change in the course of evolution.

In Figure 1 we have assumed that selection favours smaller values of θ and have therefore drawn an arrow pointing from right to left on the nonzero branch of steady states. If this is indeed the case, the parameter θ will decrease and the steady population size N will follow the thick line until it reaches the tip of the branch. Then, because the arrow (or selection gradient) still points to the left the population will suddenly go extinct (drop to the steady state N=0).

The above scenario is an example of evolutionary suicide. Individuals with smaller θ-values do better than individuals with greater θ-values and will take over. Eventually this leads to extinction of the whole population. It has been proved that evolutionary suicide is always related to a backward bifurcation of the type depicted in Figure 1. In a forward (supercritical) bifurcation in which the stable steady extinction state bifurcates into a stable nonzero steady state without the intermediate unstable steady state of Figure 1, evolutionary suicide is not possible. In evolutionary suicide the population therefore goes extinct from a relatively high population density. Gradual extinction occurring by a species becoming rarer and rarer has a different mechanism.

Links:
http://www.helsinki.fi/~mgyllenb/
addyn.htm
http://www.iiasa.ac.at/Research/EEP/
http://pcwww.liv.ac.uk/~twevans/
homepage

Please contact:
Mats Gyllenberg
University of Helsinki, Finland
Tel: +358 9 19151480
E-mail : mats.gyllenberg@helsinki.fi

Functional Analysis and Image Processing

by Mario Arioli and Daniel Loghin

Image processing is ubiquitous in modern life. Digital cameras on cellular phones or other devices produce an incredible number of pictures that are normally stored and processed on PCs. In addition to normal family pictures, sources such as CCTV cameras, satellites and telescopes acquire from the earth and from the far reaches of the universe images that need some form of post-processing.

Mathematicians are particularly attracted by the deep connection between this problem and several esoteric fields of functional analysis and variational calculus. Digital images are commonly presented as matrices of scalars for grey-scale images or vectors for colour images. These matrices are seen as the values of a distribution (generalized function) $u_0(x)$ defined on an open and bounded 2D domain Ω. This allows a functional analytic setting for image-processing problems and in particular, for the design of digital processing algorithms through partial differential equation models.

In their book (T. Chan and J. Shen, 'Image Processing and Analysis', SIAM, 2005) Chan and Shen give several examples of mathematical models of noise and describe images as distributions. In this framework, the denoising process can be modelled by variational problems.

One popular model for image denoising is Rudin, Osher and Fatemi's model, where we seek a distribution u(x) in the space of the Bounded Variation (BV) distributions, which is the solution to the following nonlinear minimization problem (1):

$$\mathrm{Min}\ \left\{ \int_\Omega |\ \nabla u\ |\ dx + \lambda \int_\Omega (u_0(x) - u(x))^2\, dx \right\}$$

Here, Ω is the unit square for the sake of simplicity and $u_0(x)$ is the image affected by Gaussian white noise.

It is standard to seek a solution to (1) by solving a related nonlinear parabolic equation using a pseudo-time-stepping algorithm in order to approximate the steady-state configuration u(x).

Another possible model we are currently investigating can be described by the use of fractional Sobolev spaces H^α, $0 < \alpha < 1$. An exhaustive presentation of these spaces can be found in the first book of Lions and Magenes (J. L. Lions and E. Magenes, 'Problèmes aux limites non homogènes et applications', Dunod, 1968). In this denoising model we seek a distribution $u(x) \in H^\alpha$ which is the solution of a quadratic minimization problem (2).

$$\mathrm{Min}\ \left\{ |\ |\ u(x)\ |\ |^2_{\alpha_\square} + \lambda \int_\Omega (u_0(x) - u(x))^2\, dx \right\}$$

Problem (2) is approximated by a finite-element method that produces the linear system of equations $(S^\alpha + \lambda I)\, u = \lambda u_0$, where we need to compute the α power of a special matrix S. Owing to the large size of the problem, the numerical solution to this problem is computed by an iterative solver that uses a Lanczos method applied to a generalized eigenvalue problem in order to approximate S^α.

These methods are illustrated in Figure 1. In a) we give an example of an image with a resolution of 512x512 pixels; in b) we show the same image with the addition of random white noise. The size of the matrices and vectors arising from both methods is $512^2 = 262{,}144$. Both methods were considered with the same value of the regularising parameter $\lambda = 1/50$. In c), we show the result computed using method (1) via a Matlab implementation provided by Pascal Getreuer (2007). In d) we show the result computed using method (2) for $\alpha = 0.5$.

Please contact:
Mario Arioli
STFC, UK
E-mail: m.arioli@rl.ac.uk

Daniel Loghin
University of Birmingham
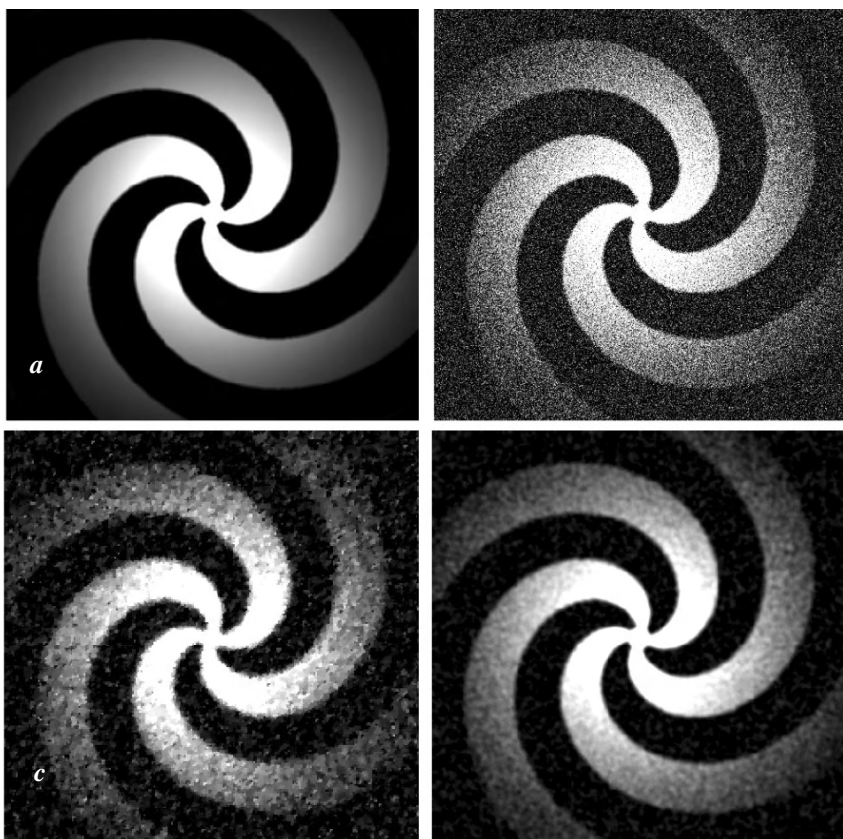E-mail: d.loghin@bham.ac.uk

Figure 1: a) original image; b) noisy image; c) denoised image using method (1); d) denoised image using method (2).

JPEG 2000 – Bringing Flexibility to Digital Cinema

by Pascal Pellegrin, François-Olivier Devaux and Pedro Correa

After a long birth we can now safely assume that digital cinema is with us to stay, bringing the best picture quality to cinemas. Among the numerous changes required to revolutionize the cinema industry is the need for video compression. Despite the recognition of MPEG standards, JPEG 2000 has been chosen to fulfil this task thanks to its scalability and compression quality. Licence-free and based on the wavelet technology, this format is bringing flexibility to digital cinema.

In 2002, seven of the biggest Hollywood studios created the DCI (Digital Cinema Initiative), aimed at producing the first digital cinema specifications. This official document describes the technological issues that must be respected by the various processes and material and security protocols in order to be compliant with Hollywood's prerequisites on the quality of content playback and security throughout the distribution and projection chain.

The DCI specifies that films must be compressed using JPEG 2000 with a maximum bit-rate of 250Mbps. It allows two different formats for digital movies: the 2K format, with a resolution of 2048 x 1080 pixels and the 4K format, with a resolution of 4096 x 2160 pixels. Despite the fact that 4K improves the visual quality, the cost of the necessary equipment means that most cinemas have currently chosen to install 2K projectors. This kind of choice has a historical precedent in 35mm and 70mm film formats.

While the coexistence of 35mm and 70mm formats required the creation of reels for both, JPEG 2000 enables studios to encode a single 4K version of the movie. With JPEG 2000 scalability, the 2K version can easily be extracted from the 4K version. This feature comes from the compression algorithm itself. The first step of any compression algorithm is to reduce the redundancy in the image. The wavelets used in JPEG 2000 have proven to be highly efficient in doing this through a multi-resolution decomposition of the image. This decomposition splits the original image (4K) into four sub-bands, one containing the lower resolution (2K) and the others containing the details necessary to reconstruct the original image (see Figure 1). The process is repeated on the lower-resolution sub-band several times, and each sub-band is then encoded separately with an entropy coder. Prior to the projection, the decoding process can discard the sub-bands of 4K details to produce 2K images.
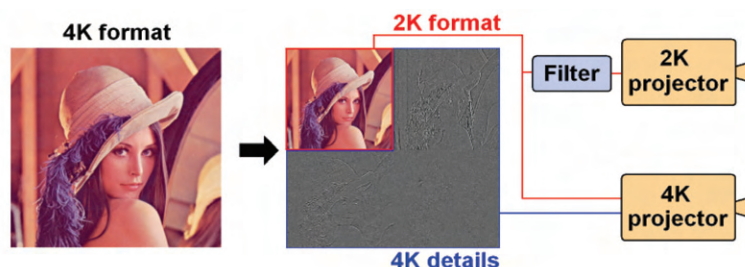
Figure 1: Multi-resolution wavelet transforms bring flexibility by allowing 4K movies to be displayed on 2K projectors. The EDCine project has studied how to maximize the experiences of both 4K and 2K users, and has shown that visual artefacts from aliasing can be reduced with a post filter applied after 2K decompression.

In the context of EDCine, a European project intending to bring digital cinema standards to Europe, the UCL (Université catholique de Louvain) is currently studying ways of making the most of JPEG 2000 scalability for digital cinema. We have raised two issues related to the way this scalability is exploited, and showed that the interoperability between 2K and 4K formats can be improved.

The first issue concerns the bit-rate limitation. Under such constraints, the information to be included in the 250Mbps must be selected in order to maximize the visual quality of the compressed image. This process is called the rate allocation. When a 4K image is encoded, the quality is usually optimized for 4K theatres, without taking into account the 2K theatre experience. Our research has shown that we can significantly improve the 2K quality without noticeably deteriorating the 4K quality, by taking both 2K and 4K user experiences into account during the rate allocation process.

Figure 2: Aliasing reduction with a post-decompression filter.

The second issue is related to the wavelet transform. Prior to the sub-sampling of an image, a half-band low-pass filter must be applied. This filter removes high-frequency content that cannot be represented in the low-resolution image, respecting Shannon's theory. While the wavelet transform presents unquestionable benefits to the compression quality, it is not a true downsampling filter, since it does not completely discard all high frequencies before performing the sub-sampling. In some specific cases, this issue can lead to visual artefacts called aliasing. By applying a post-decompression filter on the 2K image, we can improve the wavelet downsampling and remove most of this aliasing (see Figure 2).

Thanks to JPEG 2000 scalability, the complexity of the proposed solution is four times lower than a standard downsampling from 4K to 2K.

Link:
EDCine project:
http://www.edcine.org

Please contact :
Pascal Pellegrin, François-Olivier Devaux, Pedro Correa Hernandez
Université catholique de Louvain, Belgium
Tel: +32 1023 8484
E-mail: pellegrin@tele.ucl.ac.be,
francois.devaux@uclouvain.be,
pedro.correa@uclouvain.be

WAGRIT: A Web-based Application for Agricultural and Environmental Monitoring

by Umberto Amato, Maria Francesca Carfora and Paolo Colandrea

Recent results from the WAGRIT project (Web for AGRIculture and environmenT), funded by the Italian Space Agency, have seen the development of algorithms for the classification and segmentation of remotely sensed images. The goal is to provide a client-server Internet application for agricultural monitoring of cultivated areas, exploiting remotely sensed high spectral resolution images.

Remote sensing is making an increasingly significant contribution to the mapping and monitoring of vegetation. Satellite and aircraft platforms are able to quickly gather very large amounts of data; in addition, remotely sensed data can be archived so that it is possible to track changes in the Earth's surface over long periods of time.

One of the most important advances of the last decade is the availability of multispectral and hyperspectral sensors able to measure the radiance emitted by the Earth's surface in several narrow spectral bands. An important use of remotely sensed image data is the monitoring of land coverage for diverse applications: deforestation, agriculture, fire alerting etc. Other applications include land classification and segmentation, which are useful in fields such as land-use management and the monitoring of urban areas, glacier surfaces and so on. A lot of information can be extracted from these images and applied, for example, in monitoring soil conditions, supporting cultivation management or mapping land usage.

Land classification exploits the fact that we are able to identify the type of land cover associated with a given pixel by its unique spectral signature. The use of medium- or high-resolution spectral data opens new application opportunities: coverage of a wider fraction of the electromagnetic spectrum at a better spectral resolution means a better representation of the spectral signature corresponding to each pixel and better recognition of the unique spectral features of land categories.

However, the effectiveness of standard univariate classification techniques applied to multispectral data is often hindered by redundant or irrelevant information present in the multivariate data set.

Processing a large number of bands can paradoxically result in a higher classification error than processing a subset of relevant bands without redundancy, if multispectrality is not correctly taken into account.

Image processing can also provide boundary recognition and localization. One of the most frequent steps in deriving information from images is segmentation: the image is divided into homogeneous regions that are estimated to correspond to structural units in the scene, and the edges to be detected are calculated to correspond to the contours of these units. In some cases, segmentation can be performed using multiple original images of the same scene (the most familiar example is that of colour imaging). For satellite imaging this may include several infrared bands, containing important information for selecting regions according to vegetation, mineral type and so forth.

The WAGRIT project has been developed within the framework of the Italian Space Agency funding program to support SME technology development. The main functions of WAGRIT are: authenticated access to data and services via Intranet/Internet; multi-platform client applications; raster and GIS data browsing and retrieval from centralized archives; centralized data processing on the server side; data handling and editing on the client side; and simultaneous visualization of up to four images and synchronized operations (pan, zoom etc). In particular, the project has addressed the question of supervised classification based on statistical approaches and of land segmentation based on a variational approach.

Discriminant analysis was used in the first case. It was applied in the context of vegetation detection to establish relationships between ground and spectral classes. We have extended classical discriminant analysis with (a) a linear transform of the original components into principal or independent components, and b) a univariate nonparametric estimate of the density function for each separate component. In this way we are able

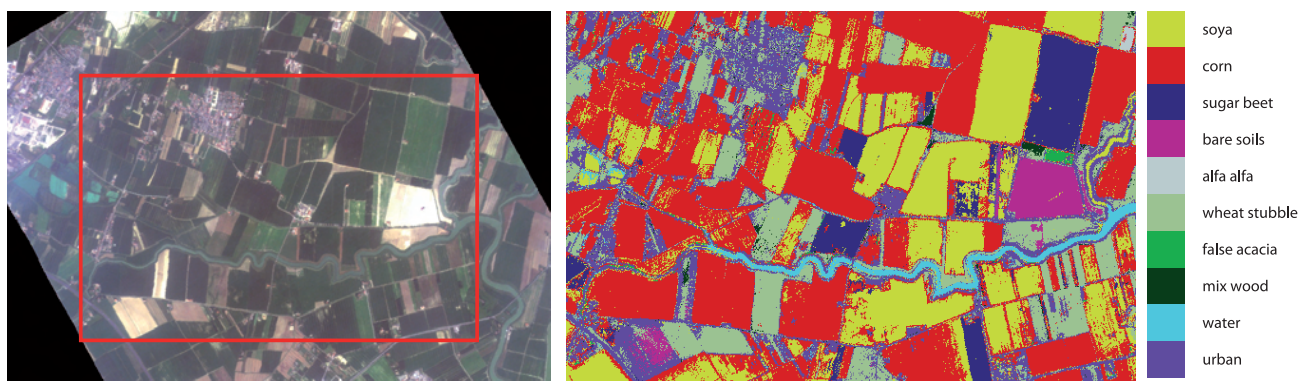|	
soya	
corn	
sugar beet	
bare soils	
alfa alfa	
wheat stubble	
false acacia	
mix wood	
water	
urban	

Figure 1: RGB representation of an MIVIS ((Multispectral Infrared and Visible Imaging Spectrometer)) image (left) and the corresponding cultivated areas classified by WAGRIT (right).

to circumvent the problem of dimensionality and also to apply discriminant analysis to the land-cover problem where representation of land typology by parametric functions is inadequate.

For the segmentation problem, we chose a variational formulation motivated in part by the desire to combine the processes of edge placement and image smoothing. Indeed, classical edge detection techniques (Marr-Hildreth, Canny and their variants) separated these processes: the image is first smoothed to suppress noise and control the scale, and edges are detected subsequently, for example as gradient maxima. One consequence of this approach is pronounced distortion of the edges, especially at high-curvature locations. Corners tend to retract and to be smoothed out; the connectedness of the edges at T-junctions is lost. By introducing interaction between the edge placement and the smoothing, this effect could be fixed.

Both classification and segmentation methods have been tested on MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) data for which a ground truth validation was available.

Figure 1 shows results on an MIVIS hyperspectral image of an area in the neighbourhood of the Venice Airport (image and ground truth data kindly provided by IMAA-CNR). Here a very fine classification, undetectable by the naked eye, is made possible by the large spectral depth of the MIVIS measurements, which is well exploited by the processing scheme.

Please contact:
Maria Francesca Carfora
IAC CNR, Italy
Tel: +39 081 6132389
E-mail: f.carfora@iac.cnr.it

Mathematics Makes Waves

by Argiris I. Delis, Serafim Poulos, Nikolaos A. Kampanis and Costantin E. Synolakis

Waves represent a driving force affecting coastal and urban areas. Mathematical models and their computational counterparts can provide simulation and forecasting tools that help us study their behaviour. FORTH-IACM is participating in European projects that are working to forecast the behaviour and effects of flood waves and tsunamis. This involves both exploiting and further developing existing simulation expertise and experience in field measurements and observation methods. These are envisaged to be a necessary complement to high-fidelity mathematical models.

Waves, although a source of delight, can apply significant and sometimes destructive pressure on coastal and urban areas, since their energy can grow enormously. Mathematical models account for such phenomena and offer a way of understanding how they form and propagate. Numerical discretization of such models provides tools to simulate existing observations and to forecast that which is yet to be seen and accounted for.

Free surface-water flow models provide the mathematics necessary to simulate flood waves. The full flow field, being turbulent and of geographical size, is described by the Navier-Stokes (NS) equations in complex 3D domains, supplied with appropriate turbulence closure models. The cascade of length and time scales therefore is huge, which makes the problem expressed in the Reynolds-Averaged (RANS) form computationally very demanding. Of particular difficulty is the discretization of the equations, the handling of the air-water interface movement and the poorly described turbulence characteristics. Recently, related research has been initiated in FORTH-IACM emphasizing high-resolution numerical techniques for the NS equations, in particular compact schemes and semi-implicit time-stepping.

A simpler yet reliable model is obtained by depth-averaging the NS equations using the shallow-water approximation. The water is considered to be an incompressible fluid with depth-averaged horizontal particle velocities, some variants as regards friction, and the Coriolis force (usually neglected). In addition, pressure is assumed to be hydrostatic, vertical accelerations negligible and depth-averaged viscous and turbulent stresses are applied. These are reasonable assumptions under the shallow-water hypothesis in many practical applications. As an alternative, the Bussinesq approximation is often used when dispersion is or is assumed to be relevant in modifying the waveforms. Such models are usually referred to as depth-averaged models. They provide qualitative approximate solutions efficiently and are therefore widely used in engineering applications.

Due to the complex nature of the water motion, especially during the process of wave breaking, the numerical models used to simulate the run-up of breaking long waves must be treated meticulously. Related research at IACM-FORTH focuses on the development of finite-difference and finite-volume
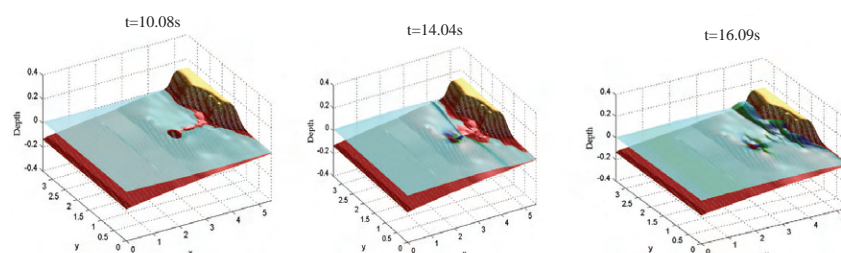
Figure 1: Instances from a simulation of the 1983 tsunami at Okushiri, Japan, performed at IACM-FORTH with a shallow-water equation model.
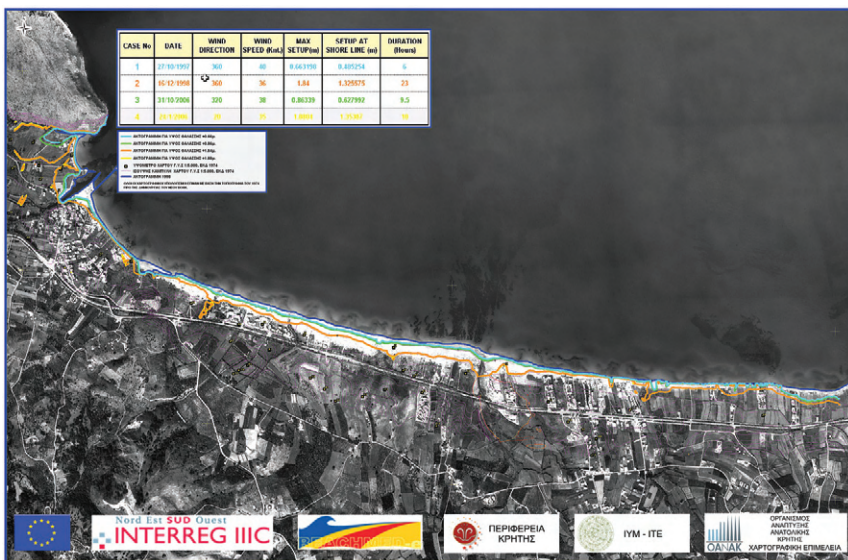
Figure 2: Flood map of a coastal area in north-western Crete extreme weather events.

methods for solving the depth-averaged shallow-water equations on general 3D topographies, with special attention given to the modelling of shock (bore) waves and the generation of wet/dry fronts.

FORTH-IACM operates depth-averaged computational models (of shallow-water and Bussinesq type with emphasis on complex 3D domains) in the context of related EU projects. One of these is the TRANSFER project, which studies tsunami processes and hazard and risk assessment for the Mediterranean coast. Long waves are simulated by shallow-water simulation models coupled with in situ measurements and observations;

the study of realistic scenarios is feasible and risk-reducing strategies can be developed. Another related project is the BEACHMEDe project, which focuses on the protection of the Mediterranean coastal zone from erosion and the implementation of evolving best practices to an observatory structure of the coastal zone. A major component of the project is to study the flooding of low coastal areas under extreme weather phenomena, and to use the associated flood maps in the civil planning of these areas.

Becoming familiar with observation and measurement techniques acquired in practice became an initiative for FORTH-IACM. It is hoped that investing in the development of relevant know-how will result in deeper insight into the wave phenomena under investigation and provide the means for major improvements in the reliability and effectiveness of existing simulation and forecasting models.

Please contact:
Nikolaos A. Kampanis
IACM-FORTH, Greece
E-mail: kampanis@iacm.forth.gr

Maths in Flood Protection

by Jörg-Volker Peetz, Barbara Steckel and Norman Ettrich

The 2002 flooding of the Elbe River in Dresden, Germany, showed that apart from the obvious destruction caused by surface water, considerable damage was caused by groundwater and water from the sewer system. Groundwater levels can rise quickly due to overflowing sewers or above-ground flow, causing basement flooding and structural damage to houses. Thus, a coupled simulation of the three components – surface water, groundwater and the sewer system – is important for flood risk management.

The objective of the project 3ZM-GRIMEX is the development of a software system for just such a coupled simulation. The strategy is to use established simulation programs for each component and MpCCI (Mesh-based Parallel Code Coupling Interface) for combining the codes into one simulation tool.

The involved codes are RisoSurf (Fraunhofer Institute ITWM) or TrimR2D (Public Domain) for the surface, Hamoka (University of Kaiserslautern) or Hystem-Extran (Institut für technisch-wissenschaftliche Hydrologie, Hannover) for the sewer system and

PCGEOFIM (Ingenieurbüro für Grundwasser GmbH, Leipzig) for the groundwater. In these codes partial differential equations are numerically solved; shallow-water equations are used in one dimension for the sewer system and two dimensions for the surface flow, and Darcy´s Law in three dimensions is used for the groundwater.

The pilot application area in the project is the urban region of Dresden. Here the simulated area is divided into a global model and a few local models. The global model extends parallel to and on either side of the river Elbe (the area with the yellow background in Figure

2), where buildings and streets are only roughly taken into account and the sewer system is modelled without details. Here the combination of the programs TrimR2D, Hystem-Extran and PCGEOFIM is applied. The local models (illustrated by coloured rectangles in Figure 2) are computed with details on the surface, such as buildings and curbs, and with more manholes in the sewerage system. In this case the combination of the programs RisoSurf, Hamoka and PCGEOFIM is used.

Identifying and defining the relevant water flows between the individual components of the flow system was an

important step of the project. The implementation of these interactions is based on MpCCI (Fraunhofer Institute SCAI). MpCCI manages the communication between the individual programs: the mapping between the different model geometries, the time synchronization, and the data exchange including spatial interpolation.

The flow system includes diverse states depending on the expansion of the flood. Each of the individual simulation components works with its own boundary conditions and sends one quantity to and receives one quantity in return from each of the other components. For example, for the coupling between the surface water program and the groundwater code the coupling areas are given by the potentially flooded elements (triangles or rectangles) of the surface model and by the top side of the three-dimensional volume cells nearest to the surface of the groundwater model. The quantity sent by the surface program is the water height in metres above ground level at the cell centre. The quantity sent in return by the groundwater code is the water velocity (or water flux per area) measured in metres per second. The same procedure is applied to each of the other two combinations: the surface code and groundwater code respectively with the sewerage simulation.

Since the three components have different simulation dynamics, a customized coupling algorithm had to be invented. Having faster dynamics, the programs for the surface flow and the sewerage system must couple more frequently with each other before they both couple with the groundwater.

The coupled simulation is implemented and validated for a generic test model. For some local models, simulations have already been successfully performed. Work is continuing on the global model simulation. The 2002 flood will be simulated with and without planned protection measures. The city of Dresden is interested in the effects of these measures on future floods.

The partners in the project 3ZM-GRIMEX are: DGFZ Dresdner Grundwasserforschungszentrum e.V., TUD Technische Universität Dresden, ITWM Fraunhofer Institut für Techno- und Wirtschaftsmathematik, SCAI Fraunhofer Institut für Algorithmen und Wissenschaftliches Rechnen, UFZ Umweltforschungszentrum Leipzig-Halle GmbH and Umweltamt Landeshauptstadt Dresden. The project started in March 2005 and is expected to finish in June 2008. It is funded by the German Federal Ministry of Education and Research (BMBF) within the research focus RIMAX.

Links:
http://www.dgfz.de/hochwasser/3ZMGRIMEX
http://www.mpcci.de/fileadmin/mpcci/Userforum/MpCCI_8th_UserForum.pdf

Please contact:
Jörg-Volker Peetz
Fraunhofer Institute for Algorithms and Scientific Computing – SCAI, Germany
Tel: +49 2241 14 2945
E-mail:
joerg-volker.peetz@scai.fraunhofer.de

Figure 1: Flood in Dresden in 2002, Semper Opera (courtesy: Feuerwehr Dresden).
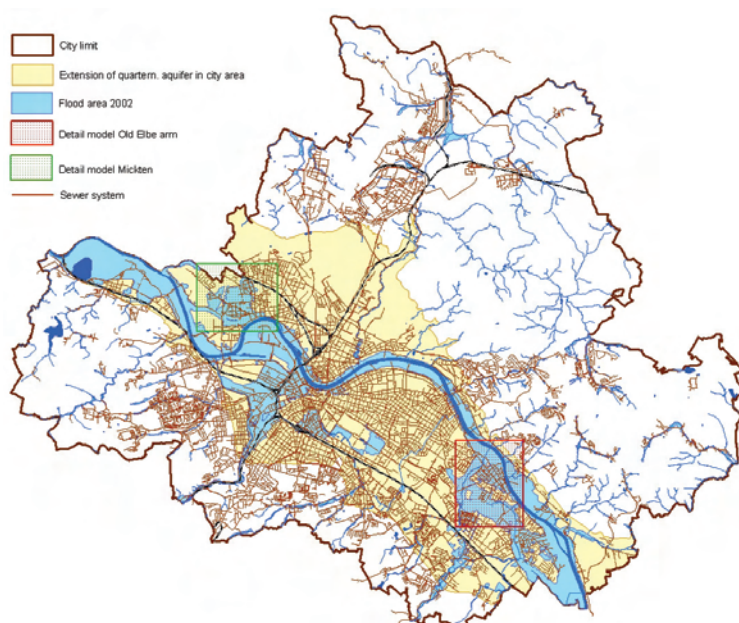

Figure 2: Dresden; computational areas of groundwater and sewer water (courtesy: Dresden, Office for Environment).

Clouds by Chance: Improving Atmosphere Models with Random Numbers

by Daan Crommelin

The performance of numerical models that simulate atmosphere and oceans is essential to weather prediction and climate research, both of which are topics of obvious societal relevance. In the past, the quality of weather forecasts and climate simulations has increased thanks to several developments. Increases in computer power, more detailed observations concerning the state of the atmosphere and oceans, and theoretical advances in the formulation of numerical models have all contributed to the better performance of weather and climate simulations.

Notwithstanding this progress, a major obstacle for further improvement of climate and weather models is the current treatment of sub-grid-scale processes in these models. Currently, weather prediction models covering the entire globe have grid spacings of at least 10-20km; grid spacings in climate models are about 100km or more. Physical and dynamical processes with spatial scales below this grid scale cannot be resolved explicitly in numerical models, even though they can be very important for the behaviour of atmosphere and climate. Making steps forward in the treatment of these sub-grid-scale processes is paramount to model improvement and thereby to more accurate forecasts and climate studies.

A prime example of an important yet small-scale process is convection: the vertical motion of (moist) air, intimately related to cloud formation and precipitation. Numerical models that can resolve convection and cloud dynamics need grid spacings of less than one kilometre. Because such high resolution is out of reach for global models, the impact of convection and clouds on resolved model variables must be represented in one way or another. These representations are called parameterizations.

Because of the importance of convection, in particular for the tropical atmosphere, the quality of convection parameterizations has a significant impact on the overall accuracy of weather and climate models.

Operational weather and climate models employ a suite of parameterizations, thereby aiming to represent the effect of a collection of unresolved processes. Most of the parameterization schemes currently used are deterministic in nature: each state of the resolved model variables gives a single, unique outcome of the parameterization scheme. For example, air temperature and humidity are resolved explicitly at dozens of vertical levels throughout the atmosphere. One class of convection parameterization schemes takes the vertical profiles of humidity and temperature in a vertical column of the model and determines what convection and precipitation (if any) occurs. If the same constellation of vertical profiles occurs twice, the parameterized convection and precipitation will be the same too.

In recent years, researchers have come to realize the limitations of this deterministic approach. Unresolved processes may well have their own

dynamics and need not be slaved to the resolved model variables. Even if one is able to calculate correctly the mean impact of the unresolved processes, neglecting their inherent variability is detrimental to the quality of the model simulations. In terms of the example just given: while the parameterization scheme may assign the correct mean convection and precipitation to given vertical profiles, in reality there may be significant deviations from this mean response. Interestingly, such deviations can become more important if the model resolution increases: a higher resolution means fewer convective cells in each vertical model column, so that the sample mean of the convective cells in a single column should vary more between columns.

In order to account for the inherent variability of many sub-grid-scale processes, researchers have started to look at alternative approaches to parameterization. One approach that has drawn a lot of research interest concerns stochastic parameterizations: approaches that carry elements of randomness in them. The basic idea is to let chance (in fact, a random number generator) choose from a range of possible responses at each time step of a simulation, rather than to

Figure 1: Improved representation of small-scale processes, such as clouds and convection, is of great importance for more accurate weather and climate modelling. Representation by random processes, known as stochastic parameterization, is a promising new approach in this area. Copyright 2008 EUMETSAT.
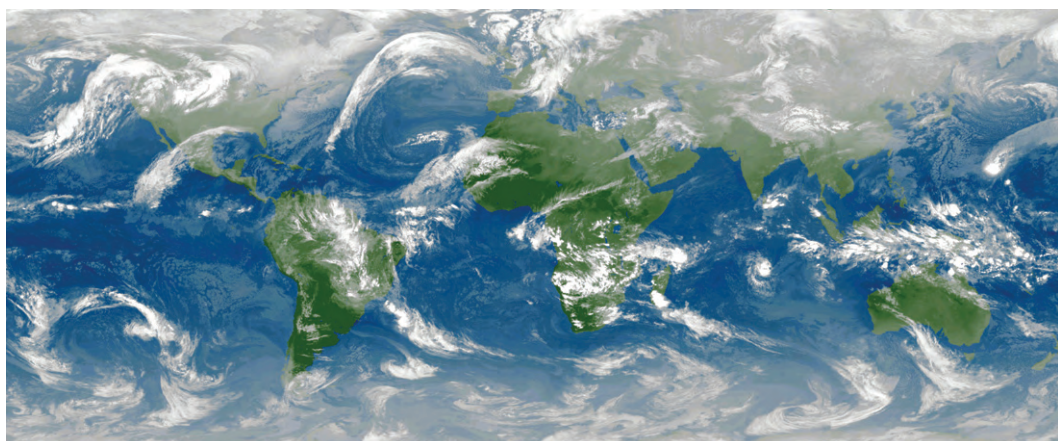
use some kind of mean response of the sub-grid-scale process.

Stochastic parameterizations can take many shapes and formulations. For example, there are several possible answers to each of the following questions: (i) what class of random processes or stochastic models should be used? (ii) how can the correct parameters of such a model be obtained (thereby determining, for example, the distribution of possible sub-grid-scale responses)? and (iii) how should the stochastic model(s) for the sub-grid-scale responses interact with the model for the large-scale (resolved) variables?

Recent work carried out at CWI in collaboration with New York University employs conditional Markov chains to formulate a stochastic parameterization scheme. The sub-grid-scale responses are modelled as Markov chains, implying that there is a finite number of possible responses. The responses evolve in time by jumping randomly between different possibilities, in a way that is consistent with a set of jump probabilities derived from data of the sub-grid-scale processes. The jump probabilities depend on the (time-evolving) state of the resolved variables, hence the term 'conditional Markov chain'. This approach was successfully implemented in a test model environment, resulting in more faithful model statistics, improved forecast skill and better ensemble forecasting properties (so-called ensemble spread). Future work will focus on implementation in models of higher complexity.

Links:
http://www.cwi.nl/~dtc/

Please contact:
Daan Crommelin
CWI, The Netherlands
Tel: +31 20 592 4194
E-mail: Daan.Crommelin@cwi.nl

Maths Improves Quality of Life: An Early-Warning System for Environmental Effects on Public Health

by Panagiotis T. Nastos, Nikolaos A. Kampanis, George Kochiadakis, Panagiotis Vardas and Kostas I. Strataridakis

Air pollution and weather have an impact on public health through their effects on the respiratory and cardiovascular system. An early-warning system can be operated where mathematical simulations, forecasting and statistical tools are able to exploit measurements and observations. It is expected that our system will cooperate with the weather-monitoring network of the Natural Disasters & Risk Assessment Facility of the Region of Crete. A pilot study has been initiated by IACM-FORTH and the cardiology department at the University Hospital of Crete.

In his treatise 'Of Airs, Waters and Places', Hippocrates (430 BC) pointed out that environmental conditions play a role in the pathogenesis of disease. In recent years, several studies have indicated that environmental variability is correlated with mortality and morbidity rates.

Many recent studies have concluded that ambient air pollution (photochemical or particulate matter) originating from human activity in cities (traffic, central heating, industrial processes etc) or by various natural mechanisms (Saharan dust transport, acid rain etc) has a short-term effect (with a lag of two to seven days) on morbidity and mortality rates. This is particularly evident with respect to respiratory and cardiovascular complaints and is most obvious in vulnerable sections of the population. More specifically, the dry deposition of dust can exacerbate asthma and other respiratory morbidities, while the wash-out effect from precipitation transfers the accumulated atmospheric pollutants to the earth's surface, where they are absorbed.

Apart from ambient air pollution, other factors such as abrupt weather changes and accompanying phenomena (eg emergence of cold fronts, heat waves and amplification of extreme events) contribute to the worsening of people's health. In combination with the geomorphology and topology of the region, these atmospheric anomalies have a strong influence on human discomfort.

The island of Crete is a suitable region on which to focus, since air pollution is apparent in the larger cities and the geomorphology of the island is responsible
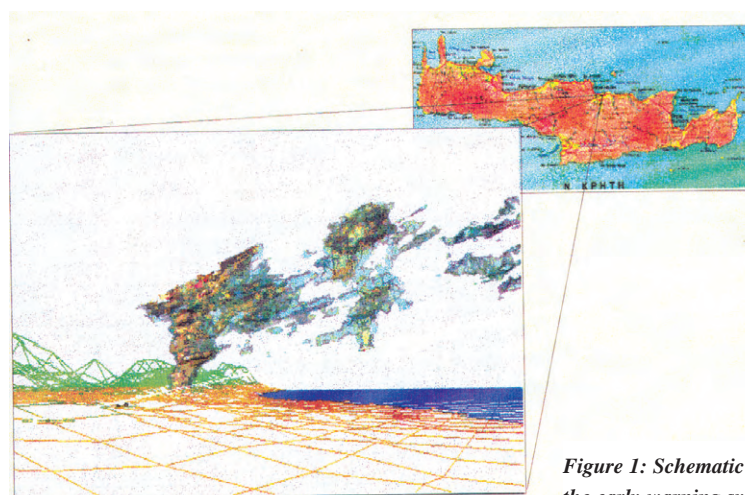
Figure 1: Schematic view from the early-warning system.

for the emergence of extreme weather conditions. The Cretan mountains are orientated perpendicularly to the southern air mass flow, generating the so-called Föhn winds. Coming down from the lee of the mountains, these dry, hot winds can have an abrupt effect on prevailing bioclimatic conditions.

IACM-FORTH has already been working on an early-warning system for a pilot study. By forecasting extreme weather events and detecting when ambient air pollution exceeds specific thresholds, the system can provide authorities with prior warning of conditions that are likely to cause or exacerbate cardiovascular and respiratory problems. Furthermore, multivariate statistical methods are applied to environmental and medical data (mainly acquired from the Cardiology Department at the University Hospital of Crete) in order to construct a model that can interpret the effects of environmental conditions on either morbidity or mortality. This system is designed to complement the existing network of meteorological stations of the Natural Disasters & Risk Assessment Facility of the Region of Crete, which can relay real-time data to an operational centre through a public broadband wireless communications network.

Please contact:
Nikolaos A. Kampanis
IACM-FORTH, Greece
E-mail: kampanis@iacm.forth.gr

Computational Methods for More Fuel-Efficient Ships

by Barry Koren

The flow of water around a ship powered by a combustion engine is a key factor in the ship's fuel consumption. The simulation of flow patterns around ship hulls is therefore an important aspect of ship design. While lengthy computations are required for such simulations, research by Jeroen Wackers and Barry Koren has shown that these computations can be conducted with much greater speed.

Turbulent water flow reduces the efficiency of a ship's propeller. The propulsion system works best when the water is undisturbed, but that certainly isn't the case in a ship's wake. The stern of most ships is therefore designed to ensure a relatively regular flow pattern. The bow wave is also a key factor in energy consumption. Energy is expended in creating waves: a smaller bow wave therefore results in less energy loss.

Ship designers study these phenomena in order to design better ships. The ultimate goal is to calculate the ship geometry that will best meet the various demands placed on the vessel, not only in terms of fuel efficiency, but also with respect to stability, safety and logistical efficiency. To study the properties of ships, designers need software to simulate wave and wake patterns around the hull. However, the computation of such flow patterns tends to be a time-consuming process, because waves take a long time to dissipate. During simulation, the waves wash around in the computer for a long time before a steady wave pattern emerges. Numerous computational steps are required before a usable result is obtained. Moreover, the simulations must be repeated for different sailing conditions and ship speeds. Hence there is a need for computational methods that produce a steady wave pattern more quickly.

Figure 1: Two ships at cruising conditions. The upper ship generates a water wave with quite a high amplitude (see halfway hull). The wave contains a lot of energy, which has been transferred to the water by the ship, and is not returned to the ship. The hull of the left ship has been redesigned, at the Maritime Research Institute Netherlands (MARIN), to lower the aforementioned wave. The result is clearly visible: the right ship has a significantly lower wave drag. CWI cooperates with MARIN on the development of computational methods for the optimization of ship-hull shapes.

The Ever-Changing Surface

One of the principal barriers to fast computation is the surface of the water. Computations could be carried out much more quickly if the water surface were not a factor.

Jeroen Wackers and Barry Koren found an algorithm to quickly calculate the steady flow pattern without having to progress through each successive time phase. They explicitly factored in the air above the water surface. Air is a fluid with very low density. Several good algorithms exist to describe the interplay of two fluids, allowing rapid computation of a steady wave pattern in which all forces are in equilibrium. With air above it, the water surface no longer constitutes the boundary of the problem, it lies in the interior of the computational domain, and boundary conditions need not be specified for it.

The entire simulation area – water and air – can be efficiently treated in the same manner.

Much Greater Speed

Using this two-fluid approach, flow of water and air in a canal was simulated. Irregularities on the canal bed caused waves on the surface, as is the case in reality. The results were calculated dozens of times more quickly than with a classical simulation method, in which every successive time phase must be computed.

The study of Wackers and Koren will enable a reliable and efficient method of calculating flow around ships, allowing the prediction of performance, stability and control under various sailing conditions. This will give rise to better design tools, and ultimately to better ship designs.

Wackers conducted the main part of his research at CWI as part of the BRICKS programme, and some additional work was performed at the National Maritime Research Institute in Japan. In November 2007, he obtained his PhD cum laude at TU Delft. Currently, he is a post-doc in an internationally leading research group in ship hydrodynamics at Ecole Centrale de Nantes, France.

Links:
http://homepages.cwi.nl/~jeroenw/
http://homepages.cwi.nl/~barry/

Please contact:
Barry Koren
CWI, The Netherlands
Tel: +31 20 592 4114
E-mail: Barry.Koren@cwi.nl

Challenges for Societal Logistics

by Rob van der Mei

Over the past few decades, information and communication technology has affected everyday life and changed our society dramatically. Today, our service-oriented economy largely depends on the proper planning of societal processes, including for example healthcare logistics, traffic and railroad planning, and capacity planning of communication systems. This has created the need for in-depth knowledge about societal logistics, the proper planning of societal processes.

While societal logistics (SL) affects our everyday life, it tends to receive attention only when things go wrong. For example, many ambulance service providers fail to provide an optimal service in emergencies due to inefficient personnel planning. Many healthcare organizations suffer from excessively long waiting lists due to improper planning of healthcare professionals, so that patients in severe need may face lengthy delays before they receive care. Many railroad-scheduling systems are based on outdated planning techniques and are overly sensitive to minor disturbances, causing unnecessarily long waiting times during rush hour. Many highroads in urban areas are overly congested during rush hour due to inefficient use of the available capacity of highways. Many helpdesks at customer service centres suffer from inefficient planning of agents and are under-staffed, causing long waiting times for customers. These are just some examples of situations where under-performing societal processes influence our daily life.

Consider for example capacity planning for trains: during rush hour, trains in urban areas may be overly full and many passengers are forced to go without a seat. The obvious solution is simply to make the trains longer by adding carriages. In practice however, this does not work. Rather than being simple off-the-shelf products, train carriages are very expensive and may take years to order and manufacture. Hence, the addition of carriages needs to be planned years in advance, and is not a short-term solution. A smart way to overcome short-term capacity problems in trains is to couple and decouple carriages to provide additional capacity

Figure 1: Railroad service providers are adopting advanced scheduling algorithms.

when really needed, distributing capacity in such a way that it is available at the right time and the right place. In this context, the challenge is to design efficient scheduling algorithms for how and when to couple and decouple carriages.

At first glance, a simple solution seems to be to consider all possible train schedules, including all possible coupling/decoupling combinations. However, the number of possible schedules is virtually unbounded, and practice it may take years of computation time to identify the best schedule, even with the fastest available computers.

The phenomenon of a fast-growing number of possibilities commonly occurs in solving planning problems. This raises great scientific challenges: how to identify algorithms that determine an efficient schedule within a reasonable time frame? This area of expertise requires in-depth knowledge from both mathematics and computer science. To solve this complex problem, one may represent the set of possible

schedules as for example a set of data points in a virtual and highly dimensional space. This representation provides an understanding of the problem and an intuition for how the optimal schedule should look. Based on this type of fundamental in-depth mathematical approach, software can be implemented to efficiently schedule the distribution of carriages for railway service providers.

In many societal application areas, the economic relevance of the proper planning of logistic processes can be easily demonstrated and quantified in terms of increased revenue or cost savings. However, in practice there is often some reluctance to implement new planning tools and techniques. Nonetheless, in our experience the importance and usefulness of proper planning for scarce resources is starting to gain wider acceptance. For example, an increasing number of healthcare service providers are starting to realize the importance of healthcare logistics, and are adopting advanced planning tools and showing great improvements

in efficiency. Railroad service providers are adopting advanced scheduling algorithms. We also observe growing interest from customer context centres in improving their efficiency by implementing state-of-the-art workforce planning tools, and many ICT service providers are adopting advanced capacity planning tools.

In short, societal logistics is an exciting and promising new research area of growing societal interest. It requires a multidisciplinary approach, combining the expertise of different sub-areas within mathematics and computer science. Together with research themes in the earth and life sciences, 'software as service' and the data-explosion, societal logistics is one of the focus areas at CWI.

Link:
http://www.cwi.nl/

Please contact:
Rob van der Mei
CWI, The Netherlands
E-mail: mei@cwi.nl

Interactive Optimization with DesParO

by Daniela Steffes-lai, Clemens-August Thole, Igor Nikitin and Lialia Nikitina

Product optimization is an important step in the process of product development. How does the behaviour of a product change when certain parameters are varied? The answer is given by the optimization environment DesParO.

DesParO, an interactive environment for design parameter optimization, was developed at the Fraunhofer Institute for Algorithms and Scientific Computing SCAI. Its operation involves the initial sampling of a space of design variables by a limited number of simulations using Design of Experiments techniques. On the basis of these samples, DesParO constructs a nonlinear metamodel with radial basis functions. The user is then able to explore interactively the whole space of design variables and to find the optimal region with respect to multiple design objectives.

DesParO allows design problems to be interactively explored by user-driven continuous change of design variables and instant evaluation of design objectives. Constraints to the design objectives can be applied by setting

upper/lower boundaries on corresponding axes. For example, an operation such as the minimization of a single objective can be achieved by shifting the objective's upper boundary towards the minimum. The availability of solutions is then immediately visible as the appearance of 'green islands' on the axes of design variables and design objectives.

Successful optimization with a metamodel is possible only if its tolerances are taken into account. An important feature of DesParO is therefore robust tolerance prediction: the metamodel predicts not only the value of the design objective, but also the tolerance limits on the objective. For noisy objectives this allows constraints including the tolerance to be satisfied in a safe manner, and robust optimal design to be

obtained with guaranteed 3sigma confidence.

In estimating the tolerance, the following cross-validation procedure is used. In the dataset composed of simulation results, one of the points is removed and the metamodel interpolates simulation results to this point. The obtained interpolated result is compared with the real simulation result, and their difference yields the tolerance of the metamodel at the given datapoint.

Due to the interpolation property, the metamodel exactly reproduces the values at those datapoints, which are included in the dataset. As a result, the tolerance at the datapoint equals the deviation of the metamodel when this point is removed from the dataset. For intermediate points that do not belong
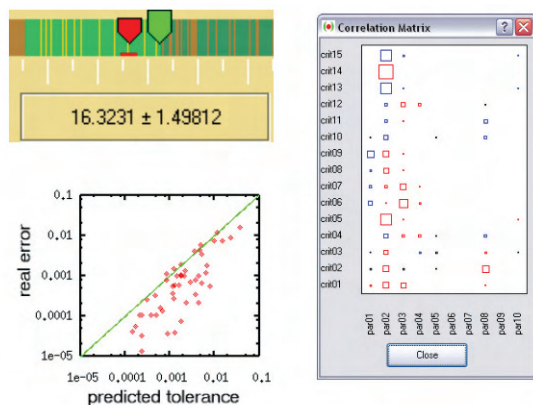
Figure 1: Tolerance prediction in DesParO (top left) and its comparison with the real error (bottom left); sensitivity diagram in DesParO (right).

to the dataset, the predicted tolerance is defined analogously as the deviation of the metamodel when each of the data-points is removed, combined by a cumulative criterion. Using fast update methods, we are able to evaluate the described tolerance characteristics in real time, together with the values of criteria.

DesParO also features global sensitivity analysis. A pattern of interdependencies between the optimization criteria and the design variables is automatically recognized and represented as an easy-to-read colour-coded diagram. The diagram indicates the most influencing design variables and the most sensitive optimization criteria, and also shows a sign of dependency: increase (red), decrease (blue) or non-monotony (black).

While the general purpose of optimization is to find an optimal design (eg the minimal value of a design objective), scatter analysis can reveal a robust design (minimal error of design objective). DesParO unifies these two capa-

bilities and allows users to find the robust optimal design, where both the values and the errors of design objectives are optimal.

Additionally DesParO provides interpolation of bulky data, such as FEM data files containing the results of numerical simulation, for the user-specified values of design variables. This allows users to visualize a full solution immediately and to inspect the resulting optimal design in detail.

DesParO not only predicts tolerances of single criteria values but also estimates the uncertainties of distributed values stored in FEM data files. The estimated uncertainty is a good measure of scatter or essential non-linearity in such bulky data. Designs with small error are predictable and robust, while the parts with high uncertainty have unpredictable behaviour.

DesParO has been successfully applied to the solution of several real-life optimization problems; in particular, the

constrained car design optimization at Volkswagen AG. The goal is to minimize the total mass of the vehicle by varying the thicknesses of fifteen car body components while simultaneously targeting constraints on eleven additional optimization criteria related to safety and comfort characteristics. Optimization with DesParO has allowed to achieve a significant mass reduction while satisfying all constraints. Robustness of the design is also evaluated using computation of distributed uncertainties in DesParO.

Link:
http://www.scai.fraunhofer.de/desparo.html?&L=1

Please contact:
Daniela Steffes-lai
Fraunhofer Institute for Algorithms and Scientific Computing – SCAI, Germany
Tel: +49 221 470 6089
E-mail:
daniela.steffes-lai@scai.fraunhofer.de
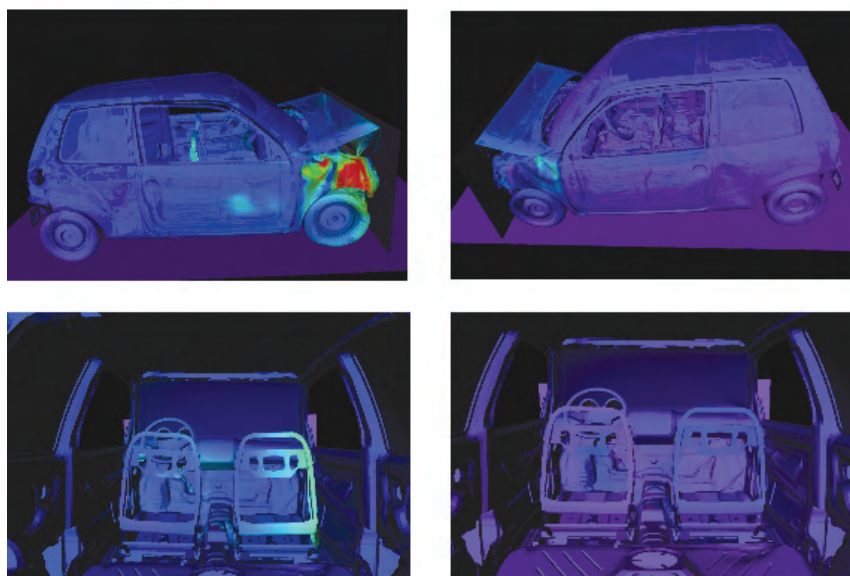
Figure 2: Distribution of uncertainties, showing high-scatter design (left) and robust design (right).

Who Rated What? A Recommender System Benchmark Winner Report

by András A. Benczúr and Miklós Kurucz

Recommender systems suggest products, movies, books or news articles based on earlier behaviour such as the known ratings of users. The recommender system of the Data Mining and Web Search Group of SZTAKI recently won a major recommender benchmarking competition, Task 1 of the KDD Cup 2007.

The KDD (Knowledge Discovery in Databases) Cup is the world's most prestigious data-mining competition, and is held each year in conjunction with the conference of the ACM Special Interest Group for Knowledge Discovery in Databases (ACM SIGKDD). Last year's competition saw participants from leading international institutions such as IBM research, Neo Metrics and Inductis.

The competition was organized over a unique data set of great interest to the research community. In October 2006 Netflix provided over 100 million ratings from over 480 000 randomly chosen anonymous customers on nearly 18 000 movie titles. KDD Cup 2007 focused on predicting aspects of movie-rating behaviour. In Task 1 'Who Rated What in 2006?', the goal was to predict which users rated which movies in 2006; for Task 2 'How Many Ratings in 2006?', participants had to predict the number of additional ratings of movies.

In our winning prediction method for Task 1, we used a combination of the following major methods from three different areas of applied mathematics, listed in ascending/descending? order of accuracy:
- linear algebra: a low-rank approximation of the known user/movie pair matrix
- statistics: movie-movie similarity values corrected by confidence interval
- data-mining algorithms: association rules obtained by frequent sequence mining of user ratings considered as ordered item sets.

By combining the predictions by linear regression, we reached first place with a prediction with root mean squared error 0.256, which can be further improved to 0.245 by extended experimentation with association rules. The runner-up result from Neo Metrics was 0.263. Compare this with a pure all-zeroes prediction giving 0.279, and the difficulty of the task is evident.

In our first method based on linear algebra, we used the full 0–1 matrix of all known ratings for training, and the rank k approximation of this matrix yielded our prediction. A rank k approximation can be considered as a prediction based on k independent factors. While in practice the explanation of the factors is never obvious, we may think of family

Figure 1: Sample time series for the number of ratings of a movie with related events such as DVD release shown on the horizontal time axis.

movies, thrillers, comedies etc as factors, and model users as a mixture of such interests. The Singular Value Decomposition (SVD) of a rank r matrix W is given by $W = U^T \Sigma V$ with U an $m \times r$, Σ a $r \times r$ and V an $n \times r$ matrix such that U and V are unitary. By a classical result of linear algebra, the Eckart-Young theorem, the best rank k approximation of W with respect to the Frobenius norm is given by:

$$\left\| W - U_k \Sigma_k V_k \right\|_F^2 = \sum_{ij} (w_{ij} - \sum_{l \leq k} \sigma_l u_{li} v_{lj})^2$$

Here U_k is an $m \times k$ and V_k is an $n \times k$ matrix containing the first k columns of U and V and the diagonal Σ_k containing first k entries of Σ where u_{li} and v_{lj} denotes the strength of user i and movie j in factor l, respectively, while σ_l is the

factor importance weight. Since we observed overfitting for larger number of dimensions, we used the 10-dimensional approximation. In our implementation we used the Lánczos code of the publicly available solver svdpack in which we abstracted data access within the implementation to computing the product of a vector with either the input matrix or its transpose in order to handle the matrix with 100 million non-zeroes.

Our item-item similarity-based recommender computes the adjusted cosine similarity based not just on the existence of the ratings w_{ij}, but also their values R_{ij} in the range of one to five stars according to:

$$sim(i, j) = \frac{\sum_u (R_{u,i} - \overline{R}_u)(R_{u,j} - \overline{R}_u)}{\sqrt{\sum_u (R_{u,i} - \overline{R}_u)^2} \sqrt{\sum_u (R_{u,j} - \overline{R}_u)^2}}$$

Here is the average of the ratings of user u and summations are for all users u who rated both j and j_0. Since the number of such users can sometimes be very small, we replaced the above value by its lower 95% confidence interval of

the adjusted cosine similarity obtained by Fisher's r-to-z transform using $1/(n_{ij0} - 3)$ for the squared standard deviation:

$$z = (\ln(1 + r) - \ln(1 - r))/2.$$

In our third method, we used association rules for movies mi of form $m_1, \ldots, m_s \rightarrow m$ where the number of users who rated $\{m_1, \ldots, m_s, m\}$ are above the prescribed minimum support. The confidence of this rule is the ratio of users who rated $\{m_1, \ldots, m_s, m\}$ versus just $\{m_1, \ldots, m_s\}$.

In combination with linear regression, low-rank approximation performed best, a phenomenon considered to be more or less 'fact' by the movie ratings recommender community. Association rules performed very close to a relatively carefully tuned item-item recommender. We stress here that tuning predictions based on association rules is a very time-consuming and resource-heavy task and our method is far from being the result of exhaustive experimentation. The main lesson learned is probably the fact that very different data-mining techniques catch very similar patterns in the data, making it increasingly difficult to improve prediction quality beyond a certain point.

Our results can be applied in an online or mobile service for recommending books, news articles, RSS feed items or arbitrary products given rating or text description. In the current phase we are building a framework that is capable of integrating our existing algorithms with a flexible framework to serve a wide range of recommender applications.

Links:
Data Mining and Web Search Group:
http://datamining.sztaki.hu
The KDD Cup 2007:
http://www.cs.uic.edu/Netflix-KDD-Cup-2007/
The full research report:
http://www.cs.uic.edu/~liub/KDD-cup-2007/proceedings/task1-1.pdf

Please contact:
András A. Benczúr
SZTAKI, Hungary
Tel: +36 1 279 6172
E-mail: benczur@sztaki.hu

Trading Sugar Beet Quotas - Secure Multiparty Computation in Practice

by Ivan Damgård and Tomas Toft

Information is a valuable resource in modern society and confidentiality is thus an important issue. However, it is often possible to obtain significant added value by combining information from different sources. A fascinating question is whether it might be possible to obtain the advantages of sharing information without the costs of unwanted leakages. Perhaps surprisingly, the answer is yes, and the solution involves a combination of computer science, mathematics and information economics. We present the first real application of techniques from the Danish research project Secure Information Management and Processing (SIMAP), in which the authors have been involved.

Basic research in cryptology has shown that it is possible to combine and process information from several sources and at the same time control exactly what information is revealed. The technique is known as secure multiparty computation (SMC), and while the first solutions suggested were very inefficient, the current state of the art allows us to perform interesting computations.

In principle, the idea is simple: all necessary data are supplied and processed in encrypted form. The results made public will therefore only be those that the involved parties agree to have decrypted. Computing without actually looking at the data may seem impossible; nevertheless this is exactly the challenge that has been solved in basic research since the late 80s.

To gain an intuition into the techniques, consider the equation $g^x g^y = g^{x+y}$. Thinking of x and y as data and g^x as an 'encryption' of x, we see that multiplying encryptions adds the data implicitly without accessing it. The actual solutions use similar relations, and are based on both classical number theory and basic algebraic concepts such as polynomials over finite fields.

The application scenario for the SMC techniques on which SIMAP has focused is the following. Several thousand Danish farmers produce sugar beets, which they sell to Danisco, the only Danish sugar producer. The farmers have contracts – production rights – entitling them to produce and deliver beets to Danisco. Contracts can be traded, and it has recently become necessary to reallocate contracts to where production pays off best. Historically, trade has been very limited, so a national market is needed to facilitate it.

A good strategy for this is a so-called double auction. Briefly, the goal is to determine the market clearing price, a price per unit at which all trade occurs. For each potential price, each party (bidder) specifies how much he would buy or sell if this were the actual price. All such bids go to an auctioneer, who determines the price where total supply equals total demand. All parties then trade their desired amounts at this price.

While a single trusted party could serve as auctioneer, this is not satisfactory in the given scenario. For instance, bids reveal information about a farmer's economic position and productivity, making farmers reluctant to accept Danisco as auctioneer. On the other hand, contracts may act as security for a farmer's debt to Danisco, whence they would not accept the farmers' association, DKS, running the auction alone. Relying on a third party such as an external consultancy house would be a very expensive option. It was therefore decided to use
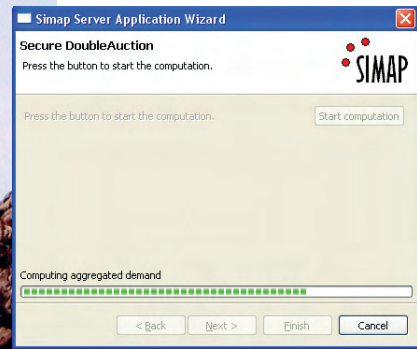
Figure 2: One of the three the server applications during the computation.

Figure 3: The result of the computation. At 199 DKK the market wants to buy 2349 tons, and wants to sell 2057,44 tons, some alternatives are shown, but 199 DKK is the best approximation to having demand equal supply.

Figure 1: A screen shot from the applet used for placing bids. If the price is 700 DKK or lower, the bidder is willing to buy 100 tons, if the price is 400 DKK or lower, he wants to buy 300 tins.

SMC, which allows the double auction to be run without having to place trust in a single party. The role of auctioneer is then distributed among Danisco, DKS, and SIMAP.

The system was comprised of a Web server receiving bids, and three servers performing the secure computation. Each farmer supplied his bids through an applet, which sent encrypted bids to a database. After the deadline for the auction had passed, the servers were connected to the database and to each other, and the market clearing price was securely computed along with the quantity to be traded by each bidder.

The auction had a total of 1200 participating bidders. The actual computation took place on 14 January this year and lasted about thirty minutes. The result involved around 25,000 tons of production rights changing ownership; to our knowledge this was the first large-scale and genuinely practical application of SMC.

Not only was the auction system a success from a technological point of view, but in addition the users, DKS and Danisco, were happy. Interestingly, 80% of bidders responding to a survey said that the confidentiality of their bids was important to them.

In conclusion, although practical SMC is still in its infancy, it holds great promise as a tool in many settings. This potential stems from the fact that SMC keeps secret everything that is not intended to be public. Not only does this provide confidentiality, it also short-circuits discussions about which parts of the data are sensitive, and which common security policies should apply to such data. Such discussions might well have brought the whole project to a halt if Danisco and DKS had tried to run the auction using conventional methods.

Please contact:
Ivan Damgård
University of Aarhus, Denmark
Tel: +45 89425780
E-mail: ivan@daimi.au.dk

Tomas Toft
Eindhoven University of Technology
and CWI, The Netherlands
E-mail: T.Toft@cwi.nl

Mathematics and Social Science: A Statistical Mechanics Approach to Immigration

by Pierluigi Contucci and Cristian Giardina

Is modern science able to study social matters like those related to immigration phenomena on solid mathematical grounds? Can we for instance determine cultural robustness and the causes behind abrupt changes from cultural legacies? Can we predict, cause or avoid swings? A novel approach is under investigation using the statistical mechanics formalism devised for the study of phase transitions in physics.

From the current growth rate of European immigration it is clear that in a few decades, people born outside Europe will represent a large percentage of the continent's total population. Although from an emotional point of view immigration is often perceived as a threat, to a large extent it represents an economic opportunity. When two cultures are merged, issues like the survival of each cultural identity play a major role in determining a proper and functional mutual integration. Historically there are several examples in which one cultural trait, despite being carried by only a small fraction of people, overcomes another in a relatively short time and with associated dramatic changes. In other cases, two different cultural traits may coexist peacefully for long periods of time.

Are we able to study these phenomena on solid scientific grounds? For instance, is it possible to establish what determines cultural robustness and what causes sudden changes from pre-existing cultural legacies? Can we predict or avoid such changes? From a modern epistemological perspective, can we build a 'simple' mathematical model that in terms of a few measurable parameters would provide a predictive description of the observed phenomenology at a social level?

Two research projects have taken on the challenge: a European team (CULTAPTATION) and a Strategic Team of University of Bologna . What is the idea the teams are hunting after? People interact, they exchange information, and within a given community they tend on average to imitate each other. While for a handful of people it is necessary to study all possible decision strategies, a million subjects have a well-defined social average status that is largely independent of individual details. The science that learnt how to infer the macroscopic properties of a large number of particles from rules governing mutual interaction of small groups is called statistical mechanics; it began with the work of Boltzmann and was used to derive the laws of thermodynamics. In recent decades a statistical mechanics formalism has proven to be an excellent method for studying typical problems in which a system is described by a large number of individuals and average properties are being investigated.

With this perspective, a statistical mechanics model has been introduced that aims to describe the interaction of two groups, for instance immigrants and residents. The model assumes that the elements of the two populations of sizes N_1 and N_2, with $N=N_1+N_2$ a very large number, interact within themselves with an interaction strength J_1 in group 1 and J_2 in group 2. Moreover a cross-group interaction with a tuneable strength J_{int} is present between individuals of different groups. The model is of mean-field type: it is assumed that individuals are nodes of a fully connected graph. By means of parameters that measure the strength of the interactions and by considering the original cultures prior to cultural meeting, it is possible to provide a quantitative description of the system. The model considered is rich of structure and able to predict, as the ratio N_1/N of the population varies, not only the coexistence of cultures but also and especially sudden changes acting with the features of phase transitions. Figure 1 displays those occurrences.

Future developments will evolve in two directions (I. Gallo, PhD thesis, in preparation). The first is to quantify the predictive value of the model by

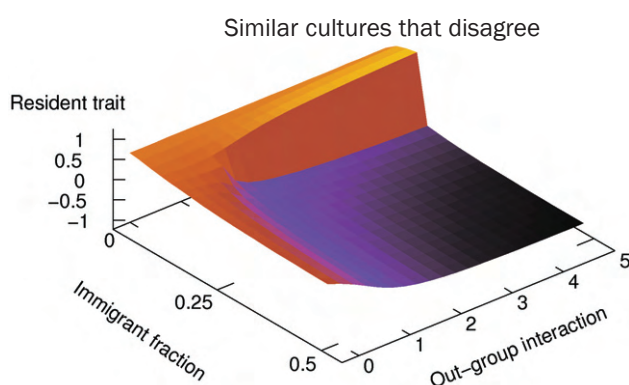Similar cultures that disagree

Figure 1: Influence of immigration on resident culture. The figure portrays the mean cultural trait after cultural contact as a function of the fraction of immigrants N_1/N and the strength of the cross-group interaction J_int. Picture source: http://arxiv.org/abs/0712.1119

statistical estimation of parameters starting from poll data and using the maximum likelihood methods, thereby bridging theory and experiment. The second is to extend to realistic random interaction networks the formalism used so far. There is indeed clear evidence that the social interaction network among people exhibits several topological features that appear in random networks of 'small world' and 'scale-free' types. The necessity to extend the statistical mechanics methods to complex network environments is of fundamental importance. With this aim, the conference YEP-V addressed to Young European Probabilists has been organized by the authors. It was held in March 2008 at EURANDOM, Dutch institute member of EMS and ERCOM, to which one of the authors (C.G.) is affiliated. That initiative will continue and develop in a forthcoming conference at Banff International Research Station, Canada, in November 2009.

Links:
http://www.intercult.su.se/cultaptation/
http://www.dm.unibo.it/~contucci/sf.html
http://arxiv.org/abs/physics/0606062
http://arxiv.org/abs/physics/0702076
http://www.eurandom.tue.nl/workshops/
2008/YEPV-r/YepVmain.htm
http://www.birs.ca/birspages.php?task=
displayevent&event_id=09w5055

Please contact:
Pierluigi Contucci
Bologna University, Italy
Tel: +39 051 2094404
E-mail: contucci@dm.unibo.it

Cristian Giardina
EURANDOM & TU/e, Eindhoven,
The Netherlands
Tel: +31 40 2472212
E-mail: c.giardina@tue.nl

The Future of Mathematics Education in Europe

by Olga Caprotti and Mika Seppälä

The level of education of their workforces determines the success of nations in global competition. Quantitative reasoning and the ability to apply mathematical methods in general will be the most important components in the skill set of tomorrow's workforce, meaning mathematics education has great strategic importance. The question of how to educate more people in mathematics, preferably with fewer resources, is an equation that cannot be solved by mathematics alone: computer science and linguistics are also needed. The WebALT eContent project has developed solutions that automate parts of mathematics instruction. Automation is the only way to improve the delivery of education, and to offer the opportunity to learn to everybody.

Learning to master certain routine tasks, such as computing with fractions, solving equations and computing limits, derivatives and integrals, forms a large part of mathematics education in secondary and early tertiary education. Training these skills produces the computational fluency and execution of procedures required, together with conceptual understanding, to support efficient problem solving. Drills and formative assessments can be delivered especially well by automatic learning systems. Computer-assisted assessment is based on advanced algorithmic exercises that are newly generated each time they are invoked. This is the most valuable aspect of e-learning materials. The WebALT project 2005-2006 (EDC-22253) developed a grammar that is able to encode these algorithmic problems so that they can be generated automatically in several European languages. This is made possible by employing Web standards (to represent the algorithmic exercises) in combination with advanced computational linguistic tools (to produce the various

verbalizations). This technology contributes both to the preservation of the linguistic diversity and richness in Europe and to the creation of a pool of standardized tests aligned with the Bologna process. WebALT multilingual

Figure 1: Online homework and assessment on a portable Internet device.

exercises are language-independent and can be adopted across borders. This multiplies the value of the content many times over.

The algorithmic problems together with high-quality supporting materials empower instructors to teach large numbers of students with the same effort needed to teach just one small group. Grading of homework, quizzes and examinations becomes automatic, available to students any time, anywhere. Even lectures can be delivered automatically as podcasts, turning mobile devices to portable lecture halls. The WebALT eContent was coordinated by the University of Helsinki. The Technical University of Catalonia (UPC), the Technical University of Eindhoven and the University of Cologne were partners in the project. Maths for More was the commercial partner associated to UPC. Currently the partners are members of the Joining Educational Mathematics thematic network (JEM), whose aim is to coordinate content-enrichment activities in the area
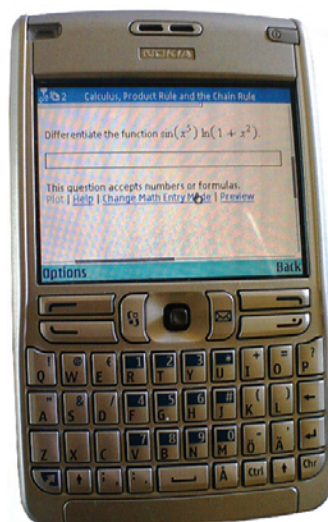
of e-learning in mathematics, to maintain standards and to deliver synoptic high-quality user information and support pages.

The kind of technology, services and content showcased by the WebALT project has the potential to industrialize instruction. Proper use of automation will make the delivery of education much more effective without compromising its quality. The recent final report of the National Mathematics Advisory Panel highlighted the importance of mathematics in the future and noted that "high-quality computer-assisted instruction (CAI) drill and practice, implemented with fidelity, be considered as a useful tool in developing students' automaticity (ie fast, accurate, and effortless performance on computation), freeing working memory so that attention can be directed to the more complicated aspects of complex tasks." This is what the WebALT project has begun to do in Europe. The showcases built and the pilot projects run at schools clearly demonstrate the potential of proper and innovative use of technology in instruction.

Following the US example, the European Union must continue its efforts to educate educators to take advantage of the benefits of technology and new media. The inertia of the academia is, at times, overwhelming. To effect a change, decisive action and further resources are needed. This investment will quickly produce returns, and is absolutely necessary to guarantee the competitiveness of Europe in the global marketplace.

Links:
http://jem-thematic.net
http://webalt.com
http://www.ed.gov/about/bdscomm/list/mathpanel

Please contact:
Mika Seppälä
E-mail: mika.seppala@webalt.net

Mathematics is Accessible!

by Juha Oikkonen

All mathematicians know that mathematics is accessible – for themselves. But how about other people?

The success of our children in their mathematics studies is not always satisfactory. It is also widely known that many obstacles prevent the recruitment of new students into mathematics courses and hinder them in getting started with their studies. (An international survey group is looking at this situation and will report at the next International Congress on Mathematical Education (ICME) to be held this year in Mexico.)

Encouraging results have been obtained with two initiatives implemented in Helsinki, and more or less similar results have also been obtained in, for instance, Oulu. Outside Finland, many others are also working on this problem.

Maths Clubs in Elementary School
In Helsinki in recent years, mathematics university students have organized mathematics clubs in elementary schools. The students work with the children on problems that are not (at least directly) connected to the schools' maths curriculum. The problems give the children experiences of success and introduce mathematical ideas in a concrete way. In these clubs mathematics is a collaborative subject.

Helping Students Get Started
We have recently introduced new ways of teaching certain first-year courses – without, of course, changing their mathematical content.

The students are encouraged to take an active role during lectures; for instance, they can make a choice between a theorem and an example, or specify what kind of an example they would like. The lectures concentrate on the principal (and most difficult) ideas and on revealing the way of thinking that lies behind the polished arguments of the course material.

Traditionally the students take many small exams. If an exam is allowed to act as a threshold that drops away a certain portion of students, then a series of thresholds will cut away an essential number of students. To change this, the students are encouraged to complement their exams with various forms of extra work.

In addition, new modes of peer support have been introduced. First-year students are divided into groups that are guided by second- and third-year students. The purpose of these groups is to help the beginners to become acquainted with one another and with the department, and to widen their views on studying and learning

Please contact:
Juha Oikkonen
University of Helsinki
juha.oikkonen@helsinki.fi

Finland ranked first in OECD's latest PISA survey

Finland once again was the highest-performing country in OECD's three-yearly PISA (Programme for International Students Assessment) test. In 2006, PISA assessed the competencies of 15-year-old students in 57 countries. More than 400,000 students took part. The focus was on science, reading and mathematics. The PISA mathematical literacy domain is concerned with the capacities of students to analyse, reason and communicate ideas effectively as they pose, formulate, solve and interpret mathematical problems in a variety of situations. The assessment focused on real-world problems, moving beyond the kinds of situations and problems typically encountered in school classrooms. The full report is available from the OECD Web site http://www.oecd.org/.

The Continuum Hypothesis: A Mystery of Mathematics?

by Matteo Viale

The continuum is arguably the most fundamental object in all of mathematics. It is the concept behind virtually all measurements. But how many real numbers are there? How many points are on a line in Euclidean space? This is one of the great mysteries of mathematics, and it can be proven to be a mystery: by the work of Cohen in 1963, the methods sufficient for 'everyday mathematics' are inadequate for solving this problem. Here we report recent progress on this question.

The concept of infinity has been a subject of speculation throughout history. In the nineteenth century, Georg Cantor produced an elegant theory in which the notion of infinity could be treated mathematically: set theory. The concepts investigated in set theory are the building blocks on which the whole of mathematics can be built. In set theory the size of an infinite set can be measured by its cardinality.

Many problems regarding cardinal numbers that have a simple formulation are unsolved even after years of effort by outstanding mathematicians. The continuum problem asks for a solution of the continuum hypothesis (CH), and is the first in Hilbert's celebrated list of 23 problems. This problem has an ambivalent nature: it is comprehensible to a vast community of scientists, but the effort devoted to solving it shows that even in mathematics there are deceptively simple questions which may not have an answer. More precisely, the existence of 'solutions' depends on the philosophical attitude of the person seeking them: does every precisely stated mathematical question have a solution? Most Platonists believe so, and a large number of them believe that the latest research in set theory is leading to a satisfactory solution of the continuum problem in particular. A skeptical mathematician, on the other hand, is apt to believe that this problem will never be settled.

While there are many ways to formulate CH, we choose the following:

For every subset X of the real numbers, either there is an injective map from X into the natural numbers or there is an injective map from the real numbers into X.

Gödel and Cohen showed that the accepted axioms of set theory cannot solve CH. Gödel in 1939 was able to produce a model of set theory in which CH is true. In work for which he was awarded the Fields Medal, Cohen in 1963 introduced the forcing method and used it to produce a model of set theory in which CH is false.

While many set theorists (including Cohen himself) are convinced that these results proved that the continuum problem could never be settled, many others (including Gödel) believed that they merely showed that new 'natural axioms' of set theory powerful enough to settle the continuum problem should be sought. In the spirit of the latter approach, a major achievement during the eighties was the proof by Martin, Steel and Woodin that there is a 'true' axiom (projective determinacy), which implies that any counter-example to CH must be very complicated – essentially 'indefinable' in a technical sense.

Recent research aims at isolating 'maximality properties': principles which say that the greatest possible variety of conceivable mathematical objects exists. A 'natural' class of axioms that approximate this criterion, the so-called 'forcing axioms', have been found. These imply the axiom of projective determinacy and the failure of CH, as well as many new and surprising results in general topology and infinite combinatorics. Hugh Woodin has provided a philosophical motivation for the failure of CH: he has solid mathematical arguments to conjecture that any 'maximality principle' able to settle all the problems of mathematics of the same 'complexity' as CH will imply the failure of CH.

Forcing axioms solve another problem in cardinal arithmetic of a 'higher complexity' than CH: the singular cardinal hypothesis (SCH) asserts that the cardinality of the power-set of strong limit cardinals is the least possible. SCH is true in Gödel's model, and models of set theory where SCH is false can be produced only by combining forcing techniques with the use of large cardinals. In my thesis I was able to generalize a result of Solovay in order to prove that a 'popular' forcing axiom, the proper forcing axiom (PFA), implies SCH.

There are grounds to conjecture that SCH is just an example of the class of problems of 'higher complexity' than CH that can be settled by forcing axioms. The correct definition of this class of problems as well as the search for the solutions given by forcing axioms is a topic of active research in set theory.

Matteo Viale has been awarded the 2006 Sacks Prize. The Sacks Prize is awarded by the Association for Symbolic Logic for the most outstanding doctoral dissertation in mathematical logic. It was established to honor Professor Gerald Sacks of MIT and Harvard for his unique contribution to mathematical logic, particularly as adviser to a large number of excellent Ph.D. students.

Links:
http://en.wikipedia.org/wiki/Continuum_hypothesis
http://www.ams.org/notices/200106/fea-woodin.pdf
http://www.ams.org/notices/200107/fea-woodin.pdf
http://www.crm.es/Publications/04/pr591.pdf
http://www.logic.univie.ac.at/~matteo/

Please contact:
Matteo Viale
Kurt Gödel Research Center for Mathematical Logic
University of Vienna, Austria
E-mail: matteo@logic.univie.ac.at

Novel Database for Genetic and Epigenetic Mechanisms in Colon Cancer

by Heather Ruskin, Ana Barat and Ludmila Sarbu

In research on cancer development, alterations in genetic regulatory pathways have attracted more attention than less well-known epigenetic modifications, (eg in DNA methylation, imprinting and chromatin). All are common in cancer, and cause altered gene expression in neoplastic events. Current literature on genetic-epigenetic interactions is largely qualitative and lacks systematic organisation. A novel database is being designed and implemented to provide a way to organise expanding knowledge on genetic-epigenetic interactions, to address key biomedical questions.

Recent research shows that the role of the epigenetic events in the development of cancer is more prevalent than previously assumed. An important need has been identified to integrate epigenetic pathways in the management of gastrointestinal malignancies (A. Rachid, J.P.J. Issa, Gastroenterology, 127, 1578-1588, 2004).

In the context of cancer, recent work dealing with epigenetics in the study of colorectal cancer has shown remarkable improvements in experimental quantitative identification of epigenetic events. For example, [Ogino 2006] have published results which suggest that methylation of the promoter of a gene is not merely a binary value as previously supposed, but that intermediate degrees of methylation can be determined, which influence the extent of the gene expression. Linking results such as this with eg the stage of cancer development, the cell characteristics at this stage and other factors, should provide considerable insight on the dynamics of cancer development. The experimental technique described by S. Ogino, M. Brahmandam et al, Modern Pathology, 19, 1083-1090, 2006, uses real-time PCR (Methylight) to quantify DNA methylation and is likely to add considerably to the volume and quality of data in the public domain.

The structure and development of a tool to provide input to a model of genetic-epigenetic interactions, has a number of key requirements. Firstly, the data must be well-organised, validated and readily accessible to the user for immediate comparison and descriptive analysis. Secondly, the context and standard of the data provision for epigenetic information and that of cancer-related fields must be clearly defined. Thirdly, a visualisation capability is clearly desirable for the end-user, together with more sophisticated data mining options.

Consequently, our approach is to build a relational database, with a user-friendly interface accessible from the web. The stored information can ultimately be used in predictive statistical and data-mining tools for disease risk assessment and decision support. The prototype database DBEpigen is stored on a MySQL server in Dublin City University, Ireland. The entity-relational scheme was designed with an innovative software DBDesigner, which automatically generates the code in SQL and also the schema in XML, useful by its facility in describing and exchanging data on the web. The proposed language for writing the interface is PHP, as it offers excellent connectivity to a wide range of databases including MySQL. PHP is distinct from client-side JavaScript as the code is executed on the server, providing a strong tool to write a database-enabled web page.

The database will concentrate on combining dispersed information, with particular focus on storing the causal relations between different entities, such as environmental factors, epigenetic events, genetic events and final cell states. It is intended to store current research data and incorporate refinements as soon as these become available.

Figure 1:
Epigenetic mechanisms:
a) Methyl residues linked to certain DNA bases lead to geme silencing.
b) Histone modifiactions: acetylation, methylation, phosphorylation, etc.
c) Chromatine compactionrepresses gene activity.

Quantitative database of genetic-epigenetic modifications leading to abnormal cell states.
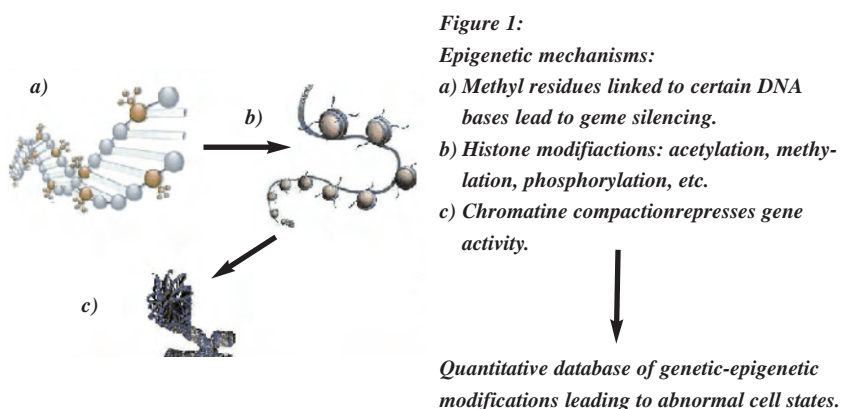
Links:
http://student.computing.dcu.ie/phpmyadmin/
Login: guestuser
Password: guestpass

Please contact:
Ana Barat
School of Computing, Dublin City University, Ireland
Tel: +353 1 700 8449
E-mail: abarat@computing.dcu.ie

An Agent Based Approach to Modelling Microbial Ecosystems

by James T. Murphy, Ray Walshe and Marc Devocelle

A parallel agent-based model of bacterial population growth, called Micro-Gen, has been developed to simulate the complex interactions between individual bacterial cells and antibiotics within a microbial colony. It represents a unique quantitative tool that has the potential to inform the development of antibiotic treatment strategies against harmful microbial pathogens such as MRSA.

In recent years there has been a rapid growth in the understanding of the basic cellular processes of individual bacterial cells through advances in genomics and proteomics research. However, this has introduced a demand to understand how the interactions between the individual system components contribute to the overall population dynamics, which is of great relevance in both ecological and clinical studies. A useful theoretical approach for relating information at the individual cellular/molecular level with emergent population characteristics is the agent-based (or individual-based) modelling approach.

The agent-based modelling approach involves assigning pre-defined rules and parameters to each individual component (eg the bacterial cell) of the population. Therefore, the emergent behaviour of the population as a whole can be examined without the need for population-level laws. This allows the inherent heterogeneity of a population to be accounted for in the model, by explicitly modelling local differences in the environment and between different bacterial cells. This approach differs from the traditional 'top-down' mathematical modelling approaches which represent the growth of the colony as a whole as a function of the normal rate of growth of the bacteria assuming population-averaged parameters.

An agent-based model of bacterial population growth, called the Micro-Gen Bacterial Simulator, has been developed at the Centre for Scientific Computing & Complex Systems Modelling (SCI-SYM) in Dublin City University, Ireland. Its aim is to provide a theoretical framework for investigating the growth and development of bacterial colonies and their interactions with antibiotics. The project has been carried out in close collaboration with Dr. Marc Devocelle at the Centre for Synthesis and Chemical Biology in the Royal College of Surgeons in Ireland (RCSI), Dublin, and his collaborators from the Clinical Microbiology laboratory at Beaumont hospital, Dublin, Ireland.

The simulated culture environment of Micro-Gen is represented by a discrete,

Figure 1: Screenshot of Micro-Gen simulation showing multi-drug resistant MRSA bacterial colonies (yellow) growing on nutrient agar medium (blue). Lighter shade of blue represents higher nutrient concentration.

two-dimensional grid containing diffusible elements such as nutrients, enzymes and antibiotics that the bacterial cells can interact with. The individual bacteria of a colony are represented by software agents, which store the physical traits such as energy state or antibiotic damage and the behavioural rules of the bacteria. The model is adaptable to represent a wide variety of different bacterial species. Figure 1 shows a screenshot from Micro-Gen of bacterial colonies (yellow circles) growing on nutrient agar medium (blue, lighter shade represents higher nutrient concentration).

Micro-Gen is designed to take advantage of parallel computing resources by dividing the simulation environment equally among individual nodes in a multi-processor cluster. The model is highly scalable in order to be able to represent the large concentrations of bacterial cells typically found in natural colonies ($>10^7$ bacteria per millilitre). This is an important factor to consider because the number of interacting cells in a bacterial colony has been shown to have a significant impact on the colony behaviour, especially in its response to antibiotic treatment (so-called 'inoculum effect').

A key component of the model is the ability to quantitatively model antibiotic molecules and their interactions with the bacterial cells. These interactions are governed by defined kinetic parameters specific to the type of antibiotic and bacterial strain being modelled. This allows a quantitative model of antibiotic interactions with bacteria to be built up and their pharmacokinetic properties to be investigated.

The model also incorporates two important antibiotic resistance mechanisms employed by bacterial cells: (A) Special

enzymes released by bacteria, called β-lactamases, which degrade the antibiotic molecules; (B) Reduced binding affinities between the antibiotics and receptors in the bacterial cells. These antibiotic resistance mechanisms are of great clinical concern as their development and spread across many species of bacteria has led to the erosion of the efficacy of many commonly prescribed antibiotics, in particular penicillin and its derivatives.

Tests were carried out to validate the Micro-Gen model by using kinetic parameters applicable to some common antibiotics (penicillin, ampicillin, and cephalothin) versus the clinically important multi-drug resistant bacterial strain methicillin-resistant *Staphylococcus aureus* (MRSA). The cellular and molecular parameters for this model were derived from the biological literature for three different strains of MRSA, and the model was used to predict the Minimum Inhibitory Concentration (MIC), which is a key clinical measure of antibiotic efficacy, of each antibiotic versus the three strains. The MIC of an antibiotic is the minimum effective dose of antibiotic that will succeed in inhibiting the growth of the bacterial colony. When the predicted MICs from the model were compared with experimentally derived MICs for MRSA, they were found to be in close quantitative agreement.

As such, the model represents a good tool for informing antibiotic treatment strategies since it can be used to investigate the principal parameters affecting antibiotic resistance in bacteria and relate this to key clinical indicators such as the MIC of a drug. There is a significant logistical burden associated with growing bacterial cultures and testing novel candidate drug compounds in the lab. However, the ability to simulate a wide variety of different conditions and parameters in a simulated environment could be used to inform rational drug design strategies.

In conclusion, Micro-Gen represents a robust tool for modelling the complex interactions of bacterial cells in colonies and their interactions with extra-cellular molecules such as antibiotics. In particular, the ability to investigate the antibiotic efficacy and predict an important clinical parameter such as the MIC using basic low-level cellular/molecular information represents a significant, novel contribution to the field.

Future work will include expanding the model to represent more complex, three-dimensional bacterial communities, such as biofilms, that form in nature. In these structured communities, dynamic community interactions take place between multiple species of bacteria forming a complex interdependent microbial ecosystem. The agent-based modelling approach is particularly suited for modelling highly heterogeneous and dynamic structures such as these.

Links:
http://www.computing.dcu.ie/~jamurphy/
http://sci-sym.computing.dcu.ie/

Please contact:
James T. Murphy
Dublin City University, Ireland
Tel: +353 1 700 8449
E-mail: jamurphy@computing.dcu.ie

Web Services for Accessing Explicit State Space Verification Tools

by María del Mar Gallardo, Christophe Joubert, Pedro Merino and David Sanán

Formal verification tools generally require users to deal with tedious and time-consuming installation, licensing issues, configuration, documentation, frequent updates and other hardware-related issues. This is the case even if all that is required is a quick check of a tool's adequacy for solving specific a problem. A current joint effort inside the ERCIM Working Group on Formal Methods for Industrial Critical Systems (FMICS) is promoting the use of an electronic tool integration (ETI) platform that allows remote connection through Web services to widespread and numerous verification toolboxes, among them Construction and Analysis of Distributed Processes (CADP).

The purpose of the project is to integrate in a remote and simple way new research tools developed at the University of Málaga. This will allow the static analysis and model checking of C programs into CADP, a popular toolbox for the design of communication protocols and distributed systems. An unexpected result of this project was the development of a Web service that remotely executes any verification tool (of which there are more than 42) or case study (more than 95) of CADP. This research consists in an FMICS Working Group contribution to the Verified Software Initiative (VSI), and resulted from a strengthened cooperation between the FMICS-jETI development group (University of Potsdam and Dortmund, Germany - Tiziana Margaria and Christian Kubczak) and the FMSE group (University of Málaga, Spain - María del Mar Gallardo, Jesús Martínez, Pedro Merino, David Sanán, and Christophe Joubert, the latter being now at Technical University of Valencia, Spain), in June 2006 at Málaga (Spain), June 2006 at IDPT'06 (San Diego, USA), November 2006 at ISOLA'06 (Paphos, Cyprus), and July 2007 at ICECCS'07 (Auckland, New Zealand). The research lines are also part of the Development of Automatic Techniques for Software Verification tasks of the SELF projects.

Our current research is working towards the direct connection of well-established verification toolboxes in a common environment, allowing easier access to efficient (unofficial/unreleased extensions of) verification tools and direct combinations of different formal technologies to solve a given problem. It is based on the FMICS-jETI platform for program verification, which is the new

generation of ETI framework (ERCIM News No.36 - January 1999, 'ETI: An Online Service for Tool Coordination') associated with the International Journal on Software Tools for Technology Transfer (STTT), and is designed for interactive experimentation with and coordination of heterogeneous tools.

So far, the FMICS-jETI repository includes verification tools based on model-checking techniques, applications of model checking to dataflow analysis, parallel model checking, requirement elicitation, model synthesis, testing and automata learning. The follwing article in this issue shows how the strengths of the FMICS-jETI technology – such as simple importing of the functionalities and workflows of a verification problem as SIBs (Service Independent Building blocks) – can be successfully applied to interdisciplinary communities such as bioinformatics, and to problems like quantitative protein analysis.

In order to extend the FMICS-jETI repository to verification tools operating on Labelled Transition Systems (LTSs) extracted from C programs, we have designed atomic services (SIBs) for two new CADP tools. These are ANNOTATOR, for on-the-fly dataflow analysis of abstract program control flow graphs, and C.OPEN, for executing OPEN/CAESAR applications on C programs abstracted modulo a well-specified API. As a direct result of this project, an atomic service called SVL-PATH was created, which allows the remote execution of both I/O files and SVL scripts (a tool-independent coordination language on top of CADP, used for describing verification scenarios, including all invocations of over 42 available verification tools with appropriate options and parameters). We have shown the applicability of the approach by remotely analysing an implementation in C of Peterson's mutual exclusion protocol described by an SVL script. On a client machine executing the jABC framework, we have developed a generic process model, called Service Logic Graph (SLG), which permits the orchestration and choreography of seven atomic services to remotely execute any CADP case study through the SVL-PATH SIB. An important aspect of the approach is that CADP does not need to be altered to offer such service-oriented features. However, the method is currently limited by the fact that GUI tools cannot be directly integrated in the repository, meaning command line tools are preferred.

Concerning future activities, we expect to see the emergence of jETI servers in the FMICS community, offering program verification SIBs as well as running up-to-date verification toolboxes for remote use. A list of available public/private SIBs and corresponding jETI servers will also be published to allow their integration into complex verification process models.

Other ERCIM members cooperating and contributing to the FMICS-jETI platform include INRIA, STFC, CWI, ISTI-CNR and Masaryk University in Brno (CRCIM).

Please contact:
David Sanán
University of Malaga/SpaRCIM, Spain
Tel: +34 952 132846
E-mail: sanan@lcc.uma.es

Plug and Play with FMICS-jETI: Beyond Scripting and Coding

by Christian Kubczak, Tiziana Margaria, Ralf Nagel and Bernhard Steffen

The aim of new technology in software analysis is to save time and money and to help organizations and businesses carry out their core topics and processes more effectively. Whether compliance, governance, auditing, risk management or optimization, any theme that targets quality and efficiency in businesses and organizations relies on software and IT platforms to ensure a fast and accurate response. The FMICS-jETI platform makes this as easy as a plug-and-play solution.

The analysis of safety-critical and business-critical software and systems is the core topic of the ERCIM Working Group on Formal Methods for Industrial Critical Systems (FMICS). Accurate mathematical analysis of industrial systems is greatly supported and simplified with the help of computers. In spite of the use of advanced technology, extensive and error-prone software adaptations are required for the development of new programs and processes, and even the implementation of small changes and adaptations. This mandates extensive validation and testing which must be delegated to programming experts: a costly detour in terms of precious time and absorbed capacity, and a threat to the fast responses demanded by market competitiveness.

FMICS promotes the development and the fast industrial adoption of precise and efficient automated analysis methods. These can help businesses govern their software, harness their risks, and in this way improve their software products. But once the analysis algorithms and tools are there, how can they best be used, customized or combined? Efficient, targeted analyses nearly always require complex combinations of heterogeneous algorithms and transformations, and without a community that shares its knowledge and tools as services; without a repository that knows where such algorithms are available and what capabilities they offer; without a platform that supports the simple, intuitive composition of problem-specific analyses that are immediately executable; the potential user is lost.

The FMICS-jETI framework developed at the Chair of Service and Software

FMICS-jETI Project leader Tiziana Margaria (left) presents Bio-jETI for biostatistical analyses to Ulrich Junghanns, Minister of Economy of Brandenburg, Germany at the CeBIT fair.

Engineering in Potsdam and the Chair of Programming Systems in Dortmund consistently addresses users' individual needs within a service-oriented paradigm. With FMICS-jETI, end-users become active 'prosumers': they are empowered to collect in a flexible way the complex algorithms and analyses they need, to publish them as providers to the community or to the Web, and as users to reassemble them at any time, as they need and without any programming.

Enabling technology relies on the service-oriented modelling framework jABC. With the aid of jABC, not only engineers, but also biologists, statisticians and other non-IT personnel can immediately use existing analysis processes in a push-button fashion, and can even easily and graphically define and modify them on their own.

What works locally at the workplace (analysis components, databases etc) can also be remotely accessed anywhere and at any time using the jETI technology, so that the playground essentially spans the Web!

Proof that the methodology and platforms are robust for much wider interdisciplinary adoption is given by Bio-jETI, FMICS-jETI's sister platform that targets bioinformatics processes in the context of the Center of Applied Proteomics (ZAP). Bio-jETI's goal and emphasis are characterized by the following corresponding project summary.

In the future, research will become more efficient and economical through the use of process-based technology for quantitative protein analysis. Pharmaceutical businesses will for example be able to carry out the analysis of proteomes faster and more on target than is currently possible.

The ZAP bundles the interdisciplinary skills needed to develop such technology in the areas of proteomics, bioinformatics, biostatistics, glycoanalysis and protein-biochips. The Chair of Programming Systems at the Universität Dortmund (Prof. Bernhard Steffen, also an FMICS affiliate) is a scientific partner in ZAP's bioinformatics project. "Statistical evaluations of biological experiments are simplified with the help of computers. However, even minor changes in the software still require programming experts. Up to now, too much effort and time is spent for software adaptation", says Bernhard Steffen.

With the Bio-jETI framework developed at the Chair of Programming Systems in Dortmund, biologists can flexibly collect the complex processes they require, and reassemble them at any time and without any programming. Additionally, researchers are able to share their data and analysis processes worldwide with other research groups or industrial partners.

The benefits and suitability of Bio-jETI for biostatistical analyses were demonstrated at CeBIT 2007 and BIOTECH-NICA 2007 in Hannover, Germany.

Links:
http://jeti.cs.uni-dortmund.de/fmics
http://jeti.cs.uni-dortmund.de/biojeti
http://jabc.cs.uni-dortmund.de

Please contact:
Tiziana Margaria-Steffen,
University Potsdam, Germany
Tel: +49 331 9773040
E-mail: margaria@cs.uni-potsdam.de

Bernhard Steffen
Technical University Dortmund,
Germany
Tel: +49 231 755 5801
E-mail: steffen@cs.tu-dortmund.de

Assisting the Design of an Industrial Groupware System by Model Checking

by Maurice ter Beek, Stefania Gnesi, Diego Latella, Mieke Massink, Maurizio Sebastianis and Gianluca Trentanni

Researchers from the Formal Methods and Tools group of ISTI-CNR and think3, Inc. are collaborating on the application of formal modelling and verification techniques to enhance think3's Product Data Management (PDM) groupware application.

The Formal Methods and Tools (FM&&T) group of the Institute for Information Science and Technologies (ISTI) of the Italian National Research Council (CNR) has a longstanding experience in research on the development and application of formal methods and software tools to specify and verify complex computer systems. In recent years, researchers from FM&&T have worked together with think3, Inc. in order to apply formal modelling and verification techniques to enhance think3's Product Data Management (PDM) groupware application thinkteam. This activity is conducted in the context of the Italian research project tocai.it, which aims at the application and development of knowledge-based technologies to support the aggregation of enterprises over the Internet. think3 is one of the industrial partners in this project.

The goal of Product Lifecycle Management (PLM) is to effectively manage a company's products across their lifecycles. think3's thinkPLM is a suite of integrated PLM applications, built on the thinkteam application, to cater for the product/document management needs of design processes in the manufacturing industry. It allows enterprises to capture, organise, automate and share engineering information in an efficient way, and is used to manage data for products/documents with long or short lifecycles.

The thinkteam groupware products are in continuous evolution and are used by large manufacturing industries which commonly have several dislocated design departments, each of which needs reliable and efficient software systems in order to cooperate efficiently. The many inherent concurrency aspects that think3 needs to address when producing their software, and their awareness of the difficulties this implies when assessing the quality of their products,

have led to them becoming interested in the use of model-checking techniques during the early phases of software design.

FM&&T and think3 are thus collaborating on the employment of model-checking techniques to formalise and verify several design options for thinkteam extensions. However, we are also

A user downloads a CAD file from thinkteam's document repository.

applying model checking to verify a number of properties related to the correctness of groupware protocols in general, ie not limited to the context of thinkteam. One of the difficulties in this domain is that detailed models tend to generate very large state spaces due to the interleaving activity that comes with many asynchronously operating clients. Therefore, our approach is to generate small, abstract models that are intended to address very specific usability-

related groupware issues. This collaboration shows that model checking can be of great help in an exploratory design phase, both for comparing different design options and for refining and improving the description of the proposed extensions.

This way of using model checking is in support of a prototyping-like modelling technique. The focus is on obtaining, relatively quickly, an informed but perhaps somewhat approximate idea of the consequences, both qualitative and quantitative, of adding specific features to an existing groupware system. This differs from the traditional use of model checking as a technique to develop rather complete specifications, with the aim of reaching a maximal level of confidence in the correctness of a complicated concurrent algorithm.

An important result of the joint research concerns the uptake of model-checking techniques by industry. think3 had no previous experience with such analysis techniques. This experience with model checking specifications of a thinkteam extension has been a true eye opener for them, leading them to fully recognize the extent of the many intricate and inherent concurrency aspects of groupware systems like thinkteam.

The relatively simple, lightweight and abstract high-level models that we have developed during the collaboration have turned out to be of great help to focus on the key issues of the development of the interface aspects of think-team, before turning to the more detailed design and implementation issues. think3 has now expressed their intention to become more acquainted with model checking and - ultimately - to acquire the skills to perform automated verification of the (groupware) protocols underlying their software systems themselves.

This shows that our approach, which starts with small models that require little time to fully understand but that nevertheless provides results that would be unfeasible to produce manually, and can be used to generate performance diagrams directly related to issues of interest, can be successfully transferred to industry.

Links:
thinkteam and thinkPLM are registered trademarks of think3, Inc.
http://www.think3.com/

Please contact:
Maurice ter Beek or Mieke Massink
ISTI-CNR, Italy
E-mail: m.terbeek@isti.cnr.it,
m.massink@isti.cnr.it

A Banking Server's Display on your Key Chain

by Michael Baentsch, Peter Buhler, Reto Hermann, Frank Höring, Thorsten Kramp and Thomas Weigold

Hackers are becoming increasingly inventive in their schemes to attack financial transactions on the Internet. Internet banking systems are a particularly attractive target, so it is mainly this application at which work in the IBM Zurich Research Laboratory is aimed, with the invention and implementation of 'ZTIC', the Zone Trusted Information Channel. Its success is the result of establishing a secure channel between a server and a ZTIC connected to a user's PC.

Banks and other institutions handle the problem of transaction security with three techniques: authentication, confidentiality and integrity. SSL/TLS (Secure Socket Layer Security/Transport Layer Security) is commonly used for the latter two issues. Several solutions, such as one-time passwords or challenge-response protocols, are used for authentication. The use of these techniques goes a long way towards handling primitive Internet attacks. Unfortunately, they alone do not provide a complete solution for today's more sophisticated attacks.

In MITM or 'man-in-the-middle' attacks, a hacker intercepts and modifies in an unnoticeable fashion the messages flowing between a user and a financial institution. The modified messages look to the user like those from the financial institution, whereas those to the financial institution look like those from the client. Malware (malicious software) is even more fiendish. Here the attacker manages to install a virus or Trojan horse in a user's personal computer and is then free to manipulate the messages received and sent by the user. Thus malware attacks can redirect communication to the attacker's server and change the data displayed by the user's browser.

Figure 1: The secure channel is opened between the (bank's) server and the ZTIC. The user communicates as usual with the server via a PC.

ZTIC provides security in the presence of both of these attacks.

ZTIC, the Zone Trusted Information Channel, adds a trusted and tamper-resistant secure communication end-point with integrated display to an otherwise untrustworthy client PC. Implemented as a USB device running the TLS/SSL protocol, a ZTIC is about the size of a memory stick and thus can be attached conveniently to a key chain. Through this endpoint, a user can then communicate securely with sensitive online services such as a banking server.

All communication between a user's Web browser and a server is passed through and processed by the ZTIC, which in turn is hooked into the communication path by a networking proxy running on the PC. ZTIC continuously scans the data exchanged between client and server for sensitive operations such as money transfers. For each sensitive operation, it intercepts the communication flow, extracts crucial information for display and verification, and proceeds only after the user has explicitly confirmed the operation by pressing an OK button on the ZTIC. Non-sensitive operations are passed along without the need for user interaction. In addition, ZTIC may serve as a holder of sensitive personal information, such as a private key used in SSL/TLS client authentication. If non-repudiation is a strong design goal of an

authentication solution, it is also possible to utilize a smartcard within a ZTIC to protect private data from extraction and duplication.

For all this, the ZTIC hardware consists conceptually, at a minimum, of a processing unit, volatile and persistent memory, a small display and at least two control buttons (OK and Cancel). An optional smartcard reader is also available. The software is minimally configured with a complete TLS engine including all cryptographic algorithms required by today's SSL/TLS servers, an HTTP parser for analysing the data exchanged between client and server, plus custom system software implementing the USB mass storage device profile and the networking proxy for

running on a PC. All this fits easily into the USB stick implementation.

The information flow is shown in Figure 1. The secure channel is opened between the (bank's) server and the ZTIC. The user communicates as usual with the server via a PC.

The result of any sensitive operation is shown on the small display of the ZTIC, requiring the user to accept or cancel the transaction. Even if there should be malicious software manipulating the flow in the PC, the user can cancel the transaction. What the user sees on the ZTIC display is identical to what the server sees, no matter what malicious intervention may have occurred. Hence, owing to the direct secure connection between ZTIC

and server, the ZTIC essentially provides a window to the server.

ZTIC has been programmed such that no change is required in either the server software or the software running on the client's PC. It runs on all operating systems. The USB stick implementation adds only a minimal and quite acceptable delay to the transaction processing time.

Link:
http://www.zurich.ibm.com/ztic

Please contact:
Michael Baentsch
IBM Zurich Research Laboratory
Tel: +41 44 724 8620
E-mail: mib@zurich.ibm.com

MeshLab: an Open-Source 3D Mesh Processing System

by Paolo Cignoni, Massimiliano Corsini and Guido Ranzuglia

MeshLab is a free and open-source general-purpose mesh processing system designed to assist in the management of not-so-small, unstructured 3D models that typically occur in the pipeline when processing 3D scanned data in the context of Cultural Heritage. MeshLab provides a set of tools for editing, cleaning, healing, inspecting, rendering and converting the resulting meshes.

The MeshLab system was developed by ISTI-CNR in the framework of the EPOCH Network of Excellence funded by the European Commission. EPOCH is a network of about one hundred European institutions collaboratively producing applications involving digital versions of Cultural Heritage material. One of the objectives of Epoch has been to provide a clear organizational and disciplinary framework to improve the quality and effectiveness of the use of information and communication technologies for cultural heritage.

Within this framework EPOCH has created a Common Infrastructure, ie a set of tools, people, institutions and procedures aimed at collaboratively producing applications involving digital versions of tangible cultural heritage objects represented in diverse types of memory institutions. MeshLab is a typical example of such a tool, designed to help the flow and adaptation of 3D data between different CH applications.

MeshLab was designed as a general 3D mesh processing tool with three primary objectives in mind:
- *Ease of use* - users without high 3D modeling skills should be able to use it (at least for the most basic functionalities)
- *CH/3D scanning oriented* - the system should focus on mesh processing tasks instead of mesh editing and design where a number of fierce competitors already crowd the software arena (such as notably Blender, 3DMax and Maya).
- Efficiency - the tool should be capable of managing the millions of primitives which often compose 3D scanning meshes.

MeshLab is thus an intuitive mesh viewer application, where a 3D object, stored in a variety of formats, can be loaded and interactively inspected in a easy way, by simply dragging and clicking on the mesh itself. MeshLab supports an ever growing variety of 3D formats (all the most common ones are supported) to accommodate the broadest

set of users. Once a mesh is loaded, the user can work on it by mean of a large set of direct parametric filters that perform smoothing, re-meshing and simplifying tasks either automatically or by means of interactive tools. The figure shows an example of an interactive filter: when the user drags the mouse over the mesh, a local smoothing is performed in real time. In this case, the result is that the user is washing out some features of the object. This is a typical operation when processing data coming from 3D scanning, which often presents substantial amounts of noise.

It should be noted that in MeshLab no classical design-oriented features or typical CAD functionalities are provided: structured editing of complex scene graphs is not supported by design. Multiple meshes can be loaded together and separately or jointly processed following an approach based on a layers metaphor.

MeshLab currently provides many mesh processing functionalities. For
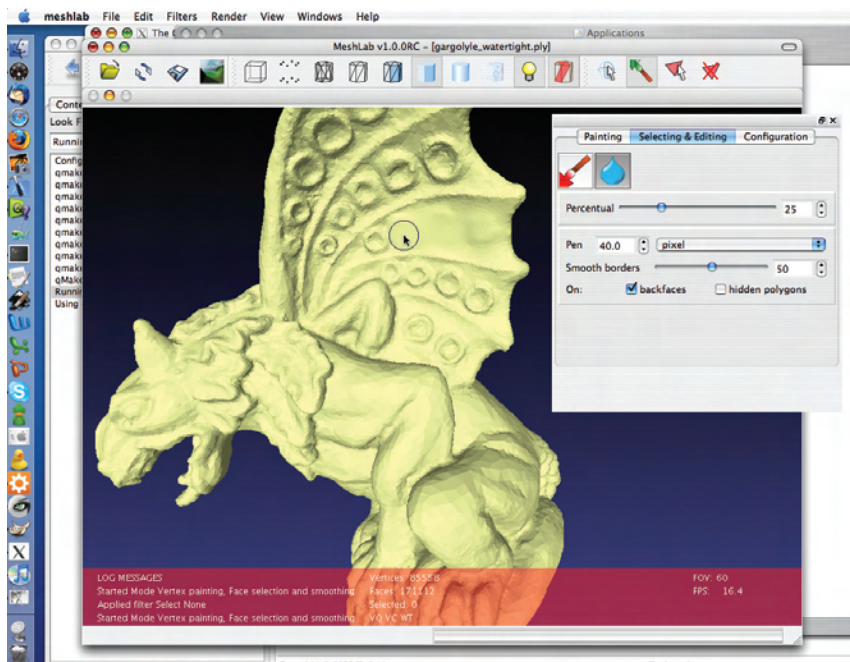
MeshLab, an open source mesh processing tool in action. User can interactively smooth the surface removing unwanted noisy features from a 3D scanned mesh.

reasons of space, we just present a short, incomplete, high-level list of MeshLab features. A large set of the functionalities of MeshLab cover the so called 'mesh cleaning' needs, offering tools to correct the geometric/topological imperfections that often affect 3D scanned data and 3D models in general. Typical examples are removal of duplicated, unreferenced vertices, null faces, small isolated components, coherent normal unification and face flipping,

erasing of non-manifold faces and massive automatic filling of holes. Many mesh inspection tools are provided in MeshLab to analyze and assess in a intuitive, visual, and measurable way the quality and the correctness of the examined meshes.

With the most recent release, a set of tools have been added to MeshLab to implement the full 3D scanned data processing pipeline: from the raw

sources obtained by the hardware acquisition devices to the final clean, ready-to-be-used 3D model. This processing pipeline includes a subsystem for the alignment of 3D meshes that allows to precisely register many different raw range maps and a set of three different algorithms for surface reconstruction that merge the multiple range maps obtained by 3D scanning devices into a single mesh.

The system has proved a greater success than expected. The first stable version was downloaded 30,000 times over a nine month period. The last version has been downloaded more than 5000 times in just the first three weeks. Currently there are thousands of users from all the world, coming from hundreds of universities and renowned commercial companies that have found MeshLab useful in contexts that often differ widely from the original one of Cultural Heritage.

Links:
http://meshlab.sourceforge.net
http://www.epoch-net.org

Please contact:
Paolo Cignoni
ISTI-CNR, Italy
Tel: +39 050 3152926
E-mail: p.cignoni@isti.cnr.it

Real-time Tracking of Sound Parameters in a Multimedia System

by Graziano Bertini, Gianfranco Lucia, Simone Lunardi and Massimo Magrini

Modern multimedia performances and presentations offer innovative methods for user interaction, in order to be more appealing to the audience. Following this trend and in collaboration with VIS S.r.l. (an SME in Rome), the Institute of Information Sciences and Technology (ISTI-CNR) has developed a system called Pandora, which controls real-time video effects applied to filmed or synthesized scenes by means of parameters extracted from sound signals. The system can be used both for artistic interactive multimedia performances and also for other non-artistic applications.

The evolution of electronic technology and the growing presence of computer science in the music field have greatly transformed ways of 'making music', involving various aspects from creation to production and performance, and leading to the appearance of new artistic forms. The audio functionalities are often closely intertwined with the world of

graphics, video, performance, virtual reality and telecommunications, creating artistic and cultural multimedia products. This means that an efficient data-processing system will play an essential role in ensuring that all the operations planned during the conceptualization and design of a performance can be realized rapidly and smoothly, allowing the

performance to take place in real time with a high level of interactivity.

Researchers of the ISTI computerART Lab and the DSP Audio team [1,2,3] have focused on developing systems that detect real-time features from body actions during interactive artistic multimedia performances. Two relevant exam-
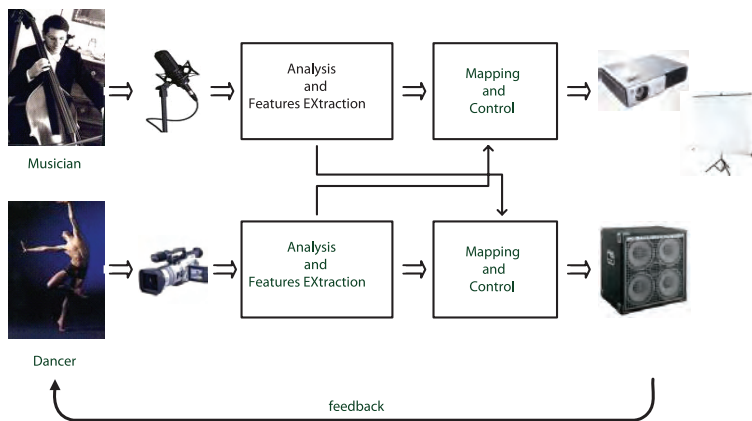
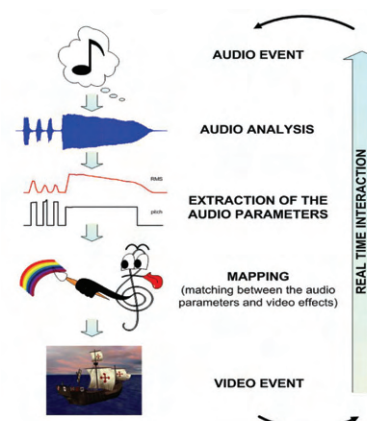Figure 1: Outline of models for controlling audio-video effects.

Figure 2: Pandora principle of operations.

ples are the 'Palm Driver' (in which the movement of a player's hands controls real-time synthesized music via an infrared interface), and the 'PAGe' (in which the movement of a painter's hands in front of a video camera produces a painting on a virtual canvas projected by a video-beam). Other recent methods for feature extraction from audio signals have also been proposed in the framework of the MUSCLE-NoE EU Project [4] (see E-Team7: Semantic from Audio and Genre Classification for Music).

The Pandora system tracks the audio parameters of a live musical performance in order to control the video effects, following a pre-designed storyboard for a movie, a 3D sequence or other video content. The project was proposed by the musician Enrico Cerretti [4], and the video effects have been developed jointly with Infobyte SPA (Rome, [5]). Pandora involves monitoring the performer (actor), and eventually a video operator (director) who can also modify the execution flow, thus setting up bidirectional feedback between the two, ie between music and video. The sequence of main system computations is represented in Figure 2.

Music (or other sounds) produced by the performer are acquired by microphones;

the relative analogue signals are sent to an audio interface and processed in a typical Windows platform in order to dynamically compute the parameters of interest – energy and fundamental frequency. The amplitude can be measured by means of an envelope follower detector from which the true value of the effective energy of the signal will subsequently be obtained. Detection and tracking of the fundamental frequency, our second parameter of interest, is a well-known and non-trivial problem in the literature and many methods have been proposed to tackle it. The algorithm we used works in the time domain and implements the 'Average Magnitude Difference Function' (AMDF), better known as the 'fast autocorrelation function', which exploits sums and differences of signal samples rather than products.

The association of sound parameters for controlling 3D/2D video sequences is usually determined during the planning phase of the performance by a special Multimedia Editor. The values extracted are used directly or by applying suitable mapping. Once the system had been implemented, various applications were developed to test its functionalities and performance. The experiments have confirmed the correct

tracking/extraction of sound parameters produced by traditional instruments (clarinet, flute), in term of low latency and accuracy. Users can easily link these parameters to video effects in various ways (3D shape transformations, colours, shading etc).

The system is not only suitable for interactive artistic multimedia performances but also for other non-artistic applications such as multimedia authoring, company presentations and musical rehabilitation therapy. In the future, the system will be tested with a variety of instruments in order to tune the appropriate settings of the algorithm for a wide range of applications.

Links:
[1] http://tarabella.isti.cnr.it/
[2] http://www.bad-sector.com
[3] http://www.isti.cnr.it
[4] http://www.myspace.com/enricocerretti
[5] http://www.infobyte.it

Please contact:
Graziano Bertini, ISTI-CNR
E-mail: graziano.bertini@isti.cnr.it

Leonello Tarabella, ISTI-CNR
E-mail: leonello.tarabella@isti.cnr.it

Figure 3: Sequence of sails and caravel movements controlled by the RMS sound parameter.

RubberEdge: Improved Interaction with Mobile Devices via Elastic-Edged Touchpads

by Géry Casiez and Daniel Vogel

By adding an elastic input area near the edge of input devices such as touchpads, RubberEdge enhances their performance. This helps users to select objects more quickly that are beyond the reach of a single finger movement on the touchpad surface.

Pointing is a fundamental part of using any computer system. The computer mouse is probably the most efficient pointing device when using a desktop computer, but it is not always practical for mobile devices such as laptops or personal hand-held computers. Many laptops instead include a rectangular surface called a touchpad, on which the user moves their finger to move the display pointer a corresponding distance and direction. However, the limited area of the touchpad, together with the increasing size and resolution of laptop displays, makes it easy to run out of space when making large movements. When this happens, the user needs to lift their finger, move backwards, and then press down again to continue the movement. This is called clutching, and it often has to be done several times to reach distant objects. Clutching hurts performance because the pointer stops moving during each clutching action.

Clutching can be avoided by using a Trackpoint input device, a tiny joystick-like device usually located at the center of the keyboard. Instead of moving the pointer a corresponding distance, the Trackpoint uses finger pressure to control the velocity of the pointer – the more pressure applied, the faster the pointer moves. To reach a distant object, the user keeps pressing in the desired direction without needing to perform any type of clutching. However, using velocity to control a pointer can be imprecise, so a touchpad will be faster for nearby objects when the movement does not require clutching.

RubberEdge combines the advantages of both devices. It eliminates clutching by using a Trackpoint-like device to reach distant objects, but also preserves touchpad performance for nearby objects. The key idea is to add an elastic ring around the outside of the touchpad's position-control zone, creating an additional velocity-control zone. In this way, when the user runs out of room, he naturally transition to velocity control by applying pressure to the elastic edge. Combining two different devices into a single device introduced problems with trajectory and speed discontinuities, and a large part of our work focused on solving these discontinuities to keep the pointer movement smooth.

A formal experiment confirmed that when moving long distances, the RubberEdge technique was faster than standard touchpad-like input. A subsequent user evaluation of a prototype RubberEdge device (for a laptop touchpad) showed that the device was usable and useful, and that users immediately understood that the pointer was controlled differently when they were pushing into the elastic ring. Of course, just like a Trackpoint device, controlling the pointer velocity in this way required some practice. The formal experimental results have also led to the development of models to predict the performance of RubberEdge and standard touchpad input, based on aspects such as the size of the touchpad. These models predict that RubberEdge should be useful for devices such as mobile phones and hand-held computers, as well as laptops.

RubberEdge is a joint research project between the University of Lille and the University of Toronto. A patent has been filed to protect the invention, with a joint agreement between the two universities.

Links:
http://doi.acm.org/10.1145/
1294211.1294234
http://www.lifl.fr/~casiez

Please contact:
Géry Casiez
Laboratoire d'Informatique Fondamentale de Lille (LIFL) and INRIA Lille
University of Lille, France
Tel: +33 3 62 53 15 68
E-mail: gery.casiez@lifl.fr

Daniel Vogel
University of Toronto, Canada
Tel: +1 506 536 4755
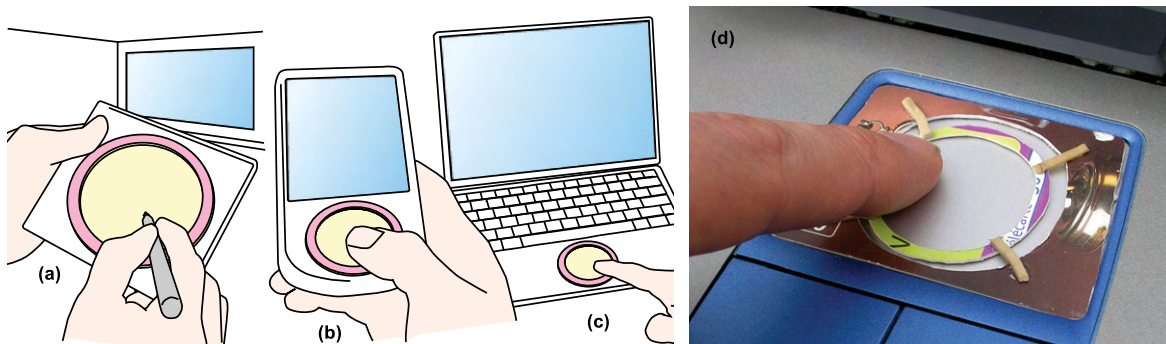E-mail: dvogel@dgp.toronto.edu

Figure 1: Design concepts for RubberEdge devices: (a) hand-held pen tablet for a large display; (b) PDA with touchpad; (c) laptop touchpad; (d) the device prototype for the laptop touchpad. Copyright ACM.

Towards the Creation of a Robust Search Index for Digitalized Documents

by László Kovács, Máté Pataki, Tamás Füzessy and Zoltán Tóth

The simultaneous support of electronic and paper-based document handling is a natural demand of current filing and document management systems. To support the better management of search and retrieval functions and to reduce the high costs of digitizing, the Department of Distributed Systems of SZTAKI analysed the different kinds of error that emerged during the digitization process of Hungarian documents, and examined how these errors affect the searchability of the digitized items. For this reason, a testbed was set up that was suitable for the automatic analysis of digitized texts in a large corpus, and the conclusions and statistics obtained from the analysis were employed in the development of new content management products. The primary beneficiaries of these are civil service and higher-education bodies.

Today the realization of the 'almost paperless office' can be achieved via post-digitization, or more precisely via scanning and OCR, as a huge number of documents still need to be digitized.

For various reasons, errors may occur during the digitization process; in seeking to achieve the highest quality for full text search capabilities, accuracy is thus an important issue. Therefore, the application of a search engine with high fault tolerance would make texts more suitable for search and retrieval purposes and would enhance their usability in practice while considerably reducing the costs of digitizing – primarily because post-processing human intervention to make corrections would be unnecessary.

The primary goal of the project was to build a metric for the errors introduced during the OCR process, particularly for those resulting in the loss or alteration of characters or accents, and to build a robust search index for digital repositories containing automatically digitized, error-prone documents.

Testbed for the Evaluation of Digitalization Error Types

Our testbed consisted of a large corpus containing Hungarian documents in various formats (rtf, txt, pdf and doc), digitizing software capable of character recognition from digital image formats, and a branch of self-developed utilities. The documents were converted to images, different kinds of noise were artificially generated over them (coffee-patches, traces of plying, noise), and they were then sent to the digitizing application. This resulted in digital, textual documents that could be compared with the originals.
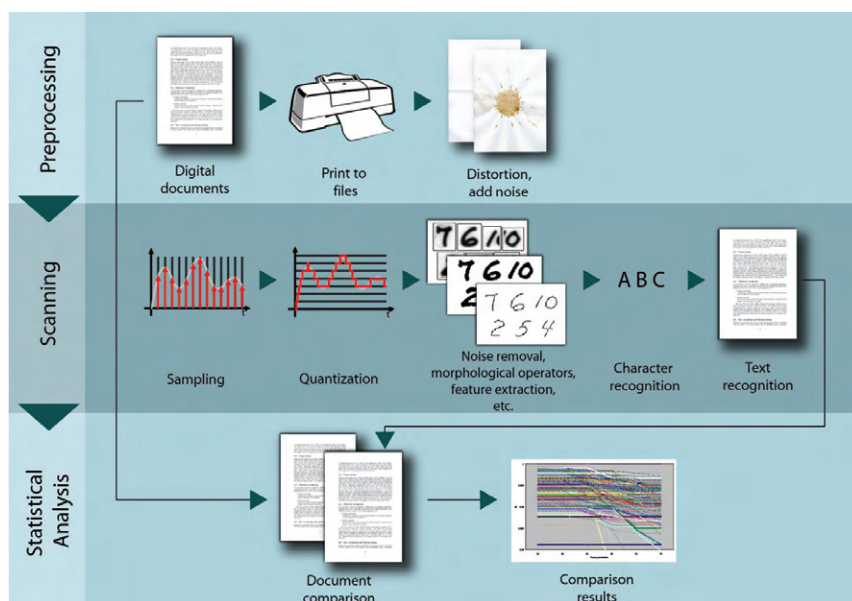
Figure 1: Architecture of the testbed.

The comparison process took place in two steps. First, a manual comparison was conducted for a small number of documents to identify categories of error types. An automatic comparison then took place for the whole corpus. Based on the results of the manual comparison, we evaluated our automatic method and generated different statistics to tune the categorization of the error types.

Actual Findings

As a result, another corpus was built containing words that had been altered to other words and typical accented characters that were recognized as other characters or character series. Though the digitization accuracy rate was quite high (around 95%, which is the expected value also mentioned in the literature), typical character/word changes that could strongly affect the searchability of the output document could still be detected. For example, the most common digitizing error concerns the letter 'i'. Substitutions include the characters 'j', 'l', and '1', which is not surprising as even to a human observer they may appear similar. In this case therefore, the creation of an index mapped to the letter 'i' might present a solution to search-related problems.

Another example is the letter 'm', which was often recognized as 'rn' ('r' followed by 'n'). Hence, when searching for words containing the letter 'm', one could also search for the same word having the 'm' replaced with 'rn'. In reverse, this method is employed by spammers to obfuscate dictionary-based spam filters.

Further, our results confirm the hypothesis that errors related to accented char-

acters like é, á, õ, and ö occur quite often. For example, the character 'o' has three accented variants in the Hungarian language (ö, õ, ó); together with the capital equivalents, this makes eight different but barely distinguishable characters for the OCR software. Even during post-processing, it is hard to tell which variant is the correct one, as there are many meaningful word-pairs that differ only in a single accent (eg kor, kór, kör). Complete statistics were gathered for the most common accented character identification errors.

The fault-tolerant search algorithm that was developed based on these findings has been integrated into the new versions of the Contentum content management product, and may also be used for further collaboration in European projects related to data repositories. In addition, and along with the list of the most common character substitutions, the analysis and the algorithm may provide a good basis in the future for building a robust search index for digital repositories comprising digitized documents.

Please contact:
László Kovács
SZTAKI, Hungary
Tel: +36 1 279 6212
E-mail: laszlo.kovacs@sztaki.hu

Enhanced, Ubiquitous and Dependable Broadband Access using MESH Networks

by Vasilios Siris, Ioannis G. Askoxylakis, Marco Conti and Raffaele Bruno

The reduction of network deployment and operation costs and the integration of wireless access networks with fixed broadband access technology are crucial to allowing small and medium-scale enterprises to enter the high-growth potential mobile broadband access market, and for the introduction of innovative services that require pervasive broadband access.

This is the focus of the thirty-month EC-funded project EU-MESH (Enhanced, Ubiquitous and Dependable Broadband Access using MESH Networks), which commenced in January 2008 and is targetting the objective 'Network of the Future' of ICT's 'Pervasive and Trusted Network and Service Infrastructures' challenge.

EU-MESH's goal is to develop, evaluate and trial a system of software modules for building dependable multi-radio multi-channel mesh networks with QoS support that provide ubiquitous and ultra-high-speed broadband access. The system will be based on a converged infrastructure that uses a wireless mesh network to aggregate the capacity from both subscriber broadband access lines and provider fixed broadband links to form a virtual capacity pool, and will provide access to this capacity pool for both stationary and mobile users. It will support low operation and management costs, through novel configuration and management procedures that achieve efficient usage of both the wireless spectrum and fixed broadband access lines. This will increase the competitiveness of existing providers, lower the barrier for small enterprises to enter the mobile broadband access market, and enable innovative services.

Existing mesh systems are based on non-standard solutions, do not achieve efficient resource utilization, have sub-optimal channel and power control that prohibits large-scale deployment, and

Mesh access network topology.

lack a comprehensive security solution combining proactive and reactive mechanisms.

To address the above, EU-MESH's objectives are to develop:
- algorithms that combine channel access with power and channel control to reduce interference
- QoS and opportunistic routing algorithms to support scalable end-to-end QoS and efficient resource usage
- location-aware automated (re-)configuration procedures that adapt to varying network conditions to provide robust connectivity
- lightweight application layer procedures for seamless mobility over heterogeneous and multi-operator mesh networks, and
- secure routing, communications and handover in multi-operator mesh net-

works, and intrusion detection and mitigation mechanisms that exploit cross-layer monitoring.

The system will be assessed through local experiments and metropolitan-scale trials, from the perspective of a pure wireless network operator and a wired/wireless telecom provider.

The nine European organizations participating in the EU-MESH project are: FORTH-ICS (Coordinator, Greece), National Research Council - CNR (Italy), Technical University of Berlin (Germany), University of Applied Science of Ticino - SUPSI (Switzerland), Budapest University of Technology and Economics - BME (Hungary), Proximetry (Poland), Forthnet (Greece), Thales Communications (France), and Ozone (France).

Link:
http://www.eu-mesh.eu/

Please contact:
Vasilios Siris, FORTH-ICS, Greece
Tel: +30 2810 391726
E-mail: vsiris@ics.forth.gr

Ioannis G. Askoxylakis
FORTH-ICS, Greece
Tel: +30 2810 391723
E-mail: asko@ics.forth.gr

Marco Conti, CNR, Italy
Tel: +39 0503153062
E-mail: marco.conti@iit.cnr.it

Raffaele Bruno, CNR, Italy
Tel: +39 050 315 3078
E-mail: raffaele.bruno@iit.cnr.it

Establishing the First European Research WiMAX Testbeds

by Kostas Pentikousis, Marilia Curado, Pedro Miguel Neves and Marcos Katz

The WEIRD (WiMAX Extension to Isolated Research Data Networks) project is unique in the European R&D scene: by the end of May 2008, WEIRD will deliver not one but four WiMAX testbeds, all interconnected via GEANT2, the pan-European research and education network. By combining theoretical methods with empirical research and prototype development, the project identifies and addresses the needs arising from a variety of scenarios, ranging from environmental monitoring to telemedicine. WiMAX has been much touted (and criticized) during the last years. The WEIRD testbeds are instrumental in separating hype from reality.

In recent years, increasing attention has been paid to the IEEE 802.16 family of wireless local and metropolitan area network (LAN/MAN) standards and its potential to change the field of telecommunications operations and business models. Along with the WiMAX Forum extensions that define an end-to-end architecture, this wireless LAN/MAN technology emerges as a potent proposal for building next-generation wireless networks. According to some projections, 1.3 billion people could have access to WiMAX networks by 2012. Despite the buzz however, there is very little data on what can actually be done with WiMAX, in practice, today. In fact, the current WiMAX-related literature is based primarily on analysis and simulation, making use of the general properties of systems employing Orthogonal Frequency Division Multiple Access (OFDMA), and for the most part draw-

ing on specifics from vendor-provided data.

The primary goal of WEIRD is to establish four cutting-edge research WiMAX testbeds (see Figure 1), which employ both IEEE 802.16d (Portugal and Romania) and 802.16e (Italy and Finland) and interconnect them via GEANT2. In addition to the use of WiMAX as a backhaul and wireless local loop solution, the project considers three specific deployment scenarios: volcano monitoring, telemedicine and fire prevention.

Moreover, WEIRD proposes an architecture that is compliant with recent work by the relevant standardization bodies, such as IEEE 802.16, IETF 16ng and the WiMAX Forum. For example, in order to guarantee full interoperability among different

WiMAX vendors, the WiMAX Network Reference Model (NRM) is used as a foundation, and the Next Steps in Signalling (NSIS) framework is used for Quality of Service reservations. Applications employing the Session Initiation Protocol (SIP) enjoy additional services from the WEIRD system. Legacy applications are supported, and the IEEE 802.21 Media Independent Handover standard has also been considered and integrated into the WEIRD architecture. This allows multi-access nodes to take advantage of the WEIRD architecture and optimize seamless handovers between WiMAX (and other) access networks. Furthermore, in order to allow for independence from the particulars of WiMAX vendor equipment, an abstraction layer has been defined that separates the lower-layer specific functionalities from the upper-layer ones. In order to
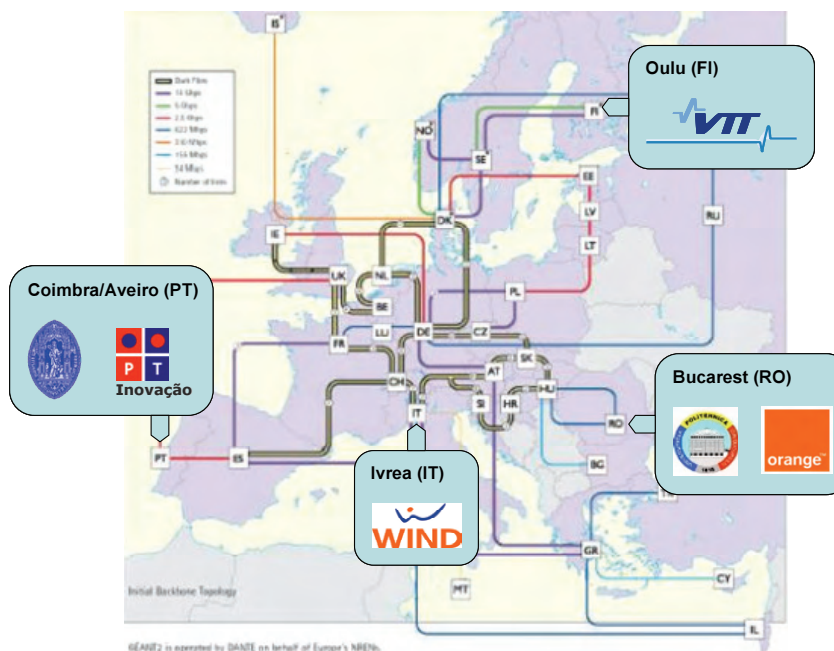
Figure 1: The four WiMAX testbeds.

scheduling and admission control mechanisms have been defined and are being implemented for this package.

Despite the significant interest in WiMAX technology and developments, WiMAX equipment is yet to become readily available at affordable prices. Until recently, only a handful of studies publicly reported results from testbeds or field trials. WEIRD also addresses this lack of data about WiMAX by publishing measurement studies in peer-reviewed articles. For example, measurements relating to the performance of aggregated and non-aggregated VoIP over a fixed WiMAX testbed, as well as IPTV streaming have been recently published.

We expect that WEIRD-developed solutions will have a strong impact on European user communities. For example, the Portuguese Civil Protection agency plans to employ WiMAX and the fire prevention application developed in the project for video surveillance and environmental monitoring in the mountainous regions in central Portugal during the upcoming 2008 fire season (see Figure 2).

WEIRD is a European 'Integrated Project' funded by the 6th Framework IST programme.

Link:
http://www.ist-weird.eu/

Please contact:
Enrico Angori
ElsagDatamat, Italy
E-mail: info@ist-weird.eu

demonstrate the feasibility of the proposed solution the project has also developed a joint prototype, which is deployed on all four testbeds.

Although clearly a testbed-oriented project, to some extent WEIRD also addresses fundamental research issues at the physical layer. For example, the impact of novel WiMAX scenarios at the physical layer was investigated, particularly by modelling and evaluating the operation of WiMAX-based links in difficult mountainous environments. Several multi-antenna techniques were proposed in order to guarantee high performance even under the most stringent conditions. Another pioneering piece of

work carried out in this project was the use of Radio-over-Fibre (RoF) in WiMAX systems, a very promising and cost-effective solution to interconnect antennae and base stations.

WEIRD is also active in two important standardization bodies, the IETF and the WiMAX Forum. A team from WEIRD developed proposed extensions to the IETF NSIS Working Group, specifying the Media Independent Handover-Network Layer Signalling Protocol (MIH-NSLP) to transport IEEE 802.21 messages. In parallel, WEIRD also made a performance evaluation of the first internal release of the WiMAX Forum simulation software package; new
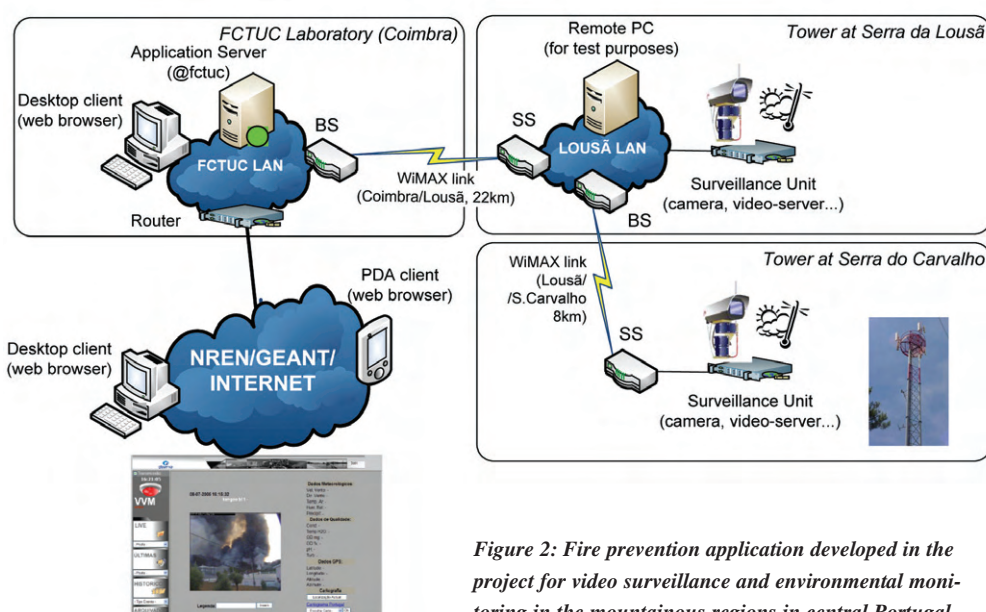

Figure 2: Fire prevention application developed in the project for video surveillance and environmental monitoring in the mountainous regions in central Portugal.

Car-Recycling SME Network with Agent-Based Solutions

by György Kovács and Géza Haidegger

Given that they are crucial in achieving global sustainable development through the saving of primary materials and in diminishing global pollution, the processes of industrial recycling and reuse urgently need advanced ICT networking technology. In the frame of the E-Mult project, the Computer Integrated Manufacturing Laboratory of SZTAKI and its cooperating partners have devised a set of advanced multi-agent solutions and an appropriate methodology with which to support the establishment and operation of dynamic networks of car-recycling SMEs.

Recycling and reuse of End-of-Life Vehicles (ELV) are among the most challenging issues faced by Europe in maintaining sustainable development and decreasing pollution, energy use and material consumption. The main roles in this field are played by several hundreds (or even thousands) SMEs (Small and Medium Enterprises). The E-Mult project (European Multi-threaded Dynamic SME Networks for Market-Driven ELV Recycling - suggests a systematic approach to solving these problems by using networked, multi-agent systems with advanced knowledge management supports.

Our goal is to achieve operating, multi-threaded, agent-based multiregional and transnational networks of SMEs, working together in the European ELV recycling industry using highly dynamic business models. We shall provide innovative solutions in the form of a set of free software Building Blocks (BB) of an open and highly scalable architecture, an agent-based platform for operation of dynamic networks of SMEs, including a powerful distributed decision-support system for network management, and infrastructure for knowledge sharing. The consortium consists of academic and SME partners from Poland (coordinator), Germany, Spain, Austria, Estonia, Holland and Hungary, and IAGs (Industrial Associations Groups) have become involved in order to assist in broader application of the results.

The main Objectives are Derived from Industrial and Eco-Political Needs

In 2000, the EU accepted directive 2000/53/EC to address European waste management, within which a dedicated framework document handles the ELV issue. At the moment, 75% of the metal content of end-of-life vehicles is recycled. The aim of this directive is to increase the rate of reuse and recovery to 85% by average weight per vehicle per year by 2007 and 95% by 2015, and to increase the rate of reuse and recycling over the same periods to at least 80% and 85% respectively. In order to satisfy these requirements, SMEs must have supporting tools and a methodology that will allow them to efficiently run highly sophisticated, complex operations in a strongly interrelated and networked manner.

In developing a methodology and a platform to support SMEs organizing dynamic cooperative networks, our approach is to combine agent-based technology with adaptive, rule-based reasoning and statistical methods. Based on analyses of the needs of SMEs, we concluded that to meet the strategic objectives of SMEs the princi-
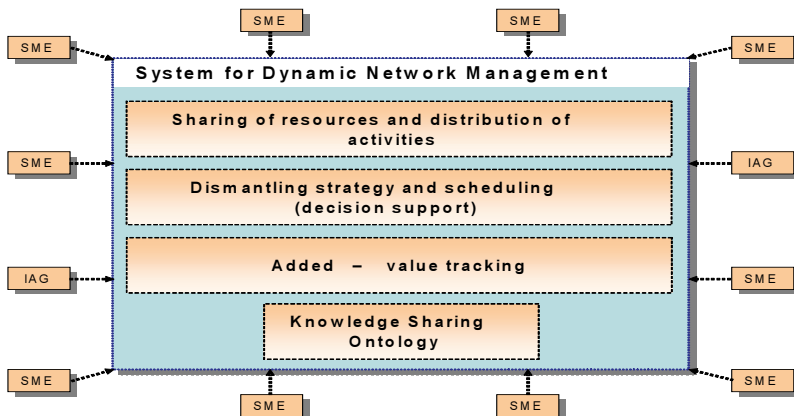

Figure 1: Main functionalities of Dynamic Network Management.

Figure 2. A dismantling station – removing dangerous waste materials.

pal problems to be solved are the following (Figure 1):

• An innovative autonomous, low-cost, multi-layer, multi-agent platform should be established; such a flexible and reliable technology for distributed decision support and knowledge sharing will be used to implement the innovative procedures for managing networks combined with a number of other services, and to assure high interoperability. The project result provides an agent-based platform combining different types of agents to support communication and management within SME-driven networks.

• A set of innovative procedures and algorithms should be created for effective network management based on a combination of probabilistic reasoning, product/process models and statistical methods. These will solve three key problems in the management of dynamic networks of SMEs:
  - optimal sharing of resources and distribution of activities within networks
  - adaptive algorithms for real-time decision-making on dismantling strategy and scheduling of shop floor operations
  - tracing and measuring added values along the recycling chains to solve the critical issue of harmonization between added value in multi-threaded, 'backward' (collection, dismantling) processes and 'standard' added value within forward processes in the production of products using recyclates.

• A methodology should be elaborated to identify optimal enterprise models of multi-threaded, dynamic networks of SMEs, where both economic and ecological/legislative aspects, and complex interactions between processes and market needs are taken into account.
• Methods and tools for knowledge management (KM) should be defined, combining heuristic reasoning and models, using agent technology and including representations of experience-based knowledge.

Case Studies: Experimental Test Networks/Business Cases

There will be two experimental clusters of cooperating SMEs within the project. The BC1 environment will serve as a validation of the potential business benefits envisaged by the project. SMEs will implement the E-Mult System in order to demonstrate the full prototype of international vertical dynamic networking. This implies the cooperation of the complete supplier-dismantling-customer supply chain.

Within the BC2 environment, SMEs will demonstrate the full prototype of international horizontal dynamic networking, aiming to provide recycled materials for new products in day-to-day operation with all BC2 SMEs. Since profitable business is naturally an outcome of selling second-hand parts, any part of an ELV that is currently requested should be instantly accessible. However, if the part is not immediately required, it might be risky to

invest time and energy to separate it, since the scrap metal market can instantly pay for metals and other valuable materials by their volume or weight. Storing parts for long periods consumes resources (warehouse capacity), handling effort, manual operations etc. ELV dismantlers will therefore try to operate an SME network between themselves and the car repair shops from which the demand for replaceable spare parts originates. Networking the sale of scrap metal is also beneficial for SMEs, since they are able to negotiate for better prices with the large scrap-material handlers.

Conclusion

A new, more effective cooperation/collaboration networking environment will be offered for European ELV dismantling, reuse and recycling SMEs. The network will function as a cooperative supply and demand network, and will be realized as a multi-threaded, multi-agent system.

Link:
http://195.187.100.149/emult/

Please contact:
György Kovács
SZTAKI, Hungary
Tel: +36 1 279 6140
E-mail: gyorgy.kovacs@sztaki.hu

Géza Haidegger,
SZTAKI, Hungary
Tel: +36 1 279 6207
E-mail: haidegger@sztaki.hu

Bridging the Gap between Distributed and Multi-Core Computing, and SOA and Grid Computing

by Géraldine Cabannes

ActiveEon is a spin-off company from INRIA that provides support for the ProActive Parallel Suite® solution. Open and non-intrusive, this parallel computing solution can accelerate and scale up distributed applications, enabling greater business agility at lower cost. The solution provides a uniform parallel computing interface, independent of the underlying virtualized infrastructure, for better utilization of existing investments in PC desktops, multi-cores, servers, clusters and grids. ProActive is currently being used in INRIA's AGOS (Architecture Grid-Oriented Service) project.

ActiveEon, founded in 2007 and based in Sophia Antipolis, France, originated from INRIA's OASIS research project, led by Denis Caromel and conducted in partnership with INRIA, the CNRS and the University of Nice Sophia Antipolis. ActiveEon co-develops the open-source middleware ProActive Parallel Suite® in collaboration with OASIS,

and benefits from more than ten years of R&D experience. ActiveEon is the leading open-source publisher of solutions and services in the field of distributed and parallel computing technology.

In February this year, ActiveEon and INRIA organized a two-day hands-on training activity for the AGOS project. Running in partnership with the SCS Pole (Secure Communicating Solutions), this project is a large-scale joint venture involving Hewlett Packard, Oracle, Amadeus, INRIA, the CNRS, SCP (Canal de Provence) and ActiveEon. The goal is to put together a Service-Oriented Architecture (SOA) computing grid to make company computing more flexible. The AGOS project benefits from ProActive technology in several key aspects, including the inherent heterogeneity of targeted resources (grids), integration of the service-oriented aspect, and the fact that the resource manager/job-scheduler tool provides interesting features related to service-level agreement (SLA) management. The AGOS participants enjoyed the hands-on concrete use cases and were able to meet distributed computing specialists with expertise in the complete framework of ProActive – the ProActive Parallel Suite®. With this suite, ProActive is now more than just an application-programming interface (API).

ProActive Parallel Suite® is an open-source Java software suite (released under general public license v2) for parallel, distributed and multi-core computing. The ProActive middleware provides a comprehensive toolkit that simplifies and accelerates the programming of applications distributed on local area networks (LANs), clusters, Internet grids and peer-to-peer intranets, and also features mobility and security. ProActive is particularly well adapted for the development of distributed applications over the Internet, thanks to the reuse of sequential parallelizable code, and through polymorphism, automatic future-based synchronizations and the migration of activities from one virtual machine to another.

Today's business-related advanced computing applications are becoming increasingly complex and require vast computational and storage resources (eg for numerous complex scientific
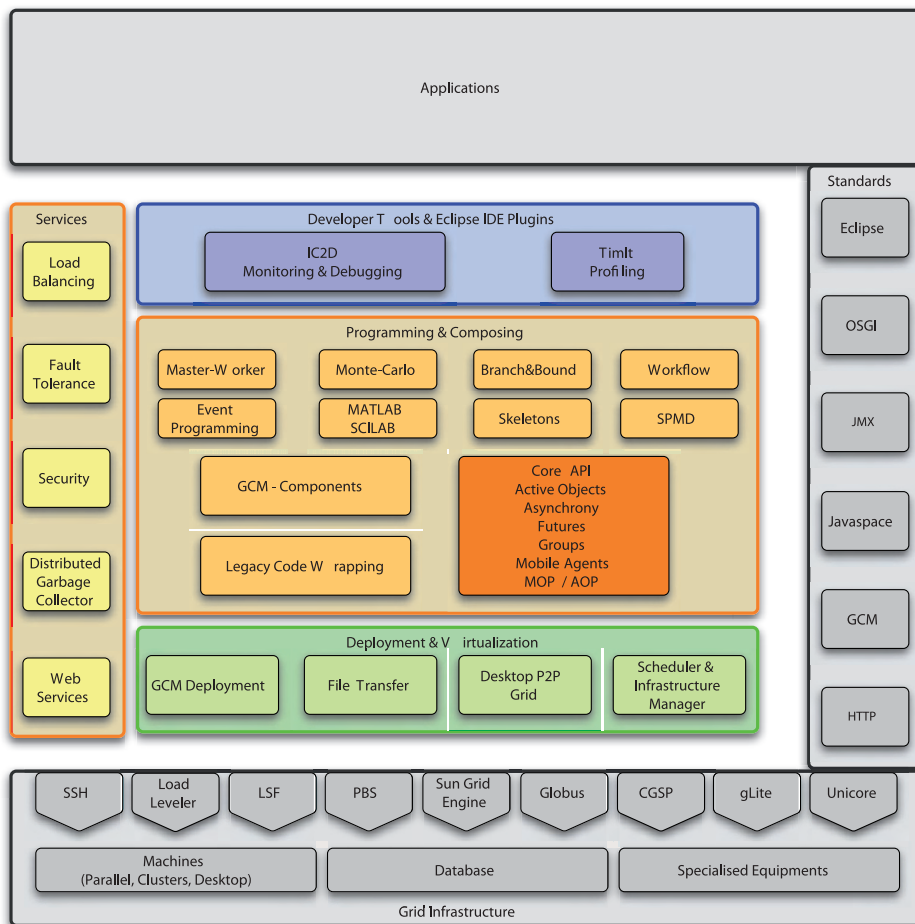
Figure 1: ProActive Parallel Suite architecture.

experiments, advanced modelling scenarios, genome matching, astronomical research). ProActive's mission is therefore to provide its users with:
• a uniform programming model that allows the development of powerful distributed applications
• a variety of programming paradigms through simplified and dedicated APIs (eg Branch'n Bound, Master-workers, SPMD)
• an easy deployment on heterogeneous resources in direct mode thanks to the XML deployment descriptor, or in scheduled mode thanks to the resource manager/scheduler tool
• a set of graphical tools that allows the application deployment and execution to be monitored and controlled at runtime.

The ProActive Parallel Suite® is composed of three key layers, and a transversal layer that provides value-added services such as security or fault tolerance.

ActiveEon offers packaged training courses, including both formal courses

and 'hands-on lab sessions', for industrial customers, users, educators, students and partners. In addition to training, the company provides consulting and professional support to professionals with some, little or no experience in parallel computing. ActiveEon is committed not only to providing open-source code (ProActive) for programming and execution of parallel applications, but also to offering services tailored to the client's needs.

Links:
http://activeeon.com
http://proactive.inria.fr/
http://gridcomp.ercim.org/
http://www.coregrid.net/mambo/images/stories/Deliverables/d.pm.04.pdf

Please contact:
Géraldine Cabannes
ActiveEon, France
Tel: +33 4 9238 5000
E-mail:
geraldine.cabannes@activeeon.com

SOFSEM 2008 – 34th International Conference on Current Trends and in Theory and Practice of Computer Science

by Viliam Geffert and Gabriel Semanišin

The 34th international SOFSEM 2008 conference was held in Nový Smokovec, High Tatras Slovakia on 19-25 January. It brought together professionals from academia and industry working in various areas of computer science and provided them an ideal framework for discussions, exchanging knowledge and practical experience and establishing personal contacts.

SOFSEM (originally SOFtware SEMinar) is an annual international conference devoted to the theory and practice of Computer Science. The 34th conference SOFSEM 2008 was organised by
• P.J. Šafárik University, Faculty of Science, Košice, Slovakia
• Slovak Society of Computer Science
• Institute of Computer Science, Czech Academy of Sciences, Prague, Czech Republic
• Czech Society for Cybernetics and Informatics.

It was held in High Tatras, one of the most beautiful regions of Slovakia.

The conference was financially supported by two principal sponsors: ERCIM and IBM Slovakia, as well as six IT companies Asseco Slovakia, DITEC, Hewlett-Packard Slovakia, Ness KDC, Siemens Slovakia and SOFTEC.

SOFSEM is usually organized in parallel tracks giving a unique opportunity to obtain quickly a representative overview of the areas that are selected as the topics of the year. These year tracks were:
• Foundations of Computer Science
• Computing by Nature
• Networks, Security and Cryptography
• Web Technologies
• Student Research Forum.

The programme consisted of ten of invited talks, given by prominent researchers, 57 contributed talks selected by the program committee from submitted papers, Working Sessions discussing work-in-progress, and the posters presented within Student Research Forum.

SOFSEM is especially suited for young computer scientists. Thanks to the help of the sponsors, including ERCIM, the organising committee was able to support especially students and young researchers participating at the conference.

The first volume of the conference proceedings was published by Springer- Verlag in the Lecture Notes in Computer Science (LNCS) series: LNCS 4910. It comprises 10 invited talks and 57 contributed talks that were selected from 162 submissions. The second volume contains twelve papers selected for the presentation in student research forum.

SOFSEM 2008 attracted about 140 participants from 22 countries. Besides the scientific programme they had an opportunity to take a part in a few social events, conference trip and sponsors' presentation evenings.

We are very glad that, according to the opinion of the most participants, SOFSEM 2008 continued a tradition of successful and faithful conferences that started in 1974.

More information:
http://www.sofsem.sk

EPOCH Final Event

by Franco Niccolucci

The final event of the EPOCH European Network of Excellence in Open Cultural Heritage, held in Rome, 25-26 February, presented the main achievements of the project during its four years of activity.

EPOCH is a network of about one hundred European cultural institutions collaborating to improve the quality and effectiveness of the use of Information and Communication Technology for Cultural Heritage. Participants include university departments, research centres, heritage institutions, such as museums or national heritage agencies, and commercial enterprises, together endeavouring to overcome the fragmentation of current research in this field. The network has been coordinated by Professor David Arnold of the University of Brighton, UK.

The project has produced a number of important research prototypes and applications, far too numerous to list here. Some of the main results have been in the area of visualization, where several groups of partners have been working. One team formed by ISTI-CNR and the Universities of Leuven and Bonn has produced a 3D Multimedia Kiosk, an integrated turnkey solution, specially tailored for the needs and requirements of 3D models in museums providing affordable and easy to use technologies from 3D capturing to 3D presentation authoring and visualisation. The Polytechnic of Zurich led a team on 3D procedural modeling, applying it to the reconstruction of ancient cities (Pompeii was on display at the event and can be seen on EPOCH's web site). This work has been integrated with the virtual humans produced by a group including the Universities of Brighton, East-Anglia, Geneva and the Polytechnic of Lausanne. Another team formed by ISME, CNRS and institutions from Portugal, UK and Austria has worked on underwater applications. The University of Bologna with Kent University has produced a toolkit for context-aware heritage applications; this was demonstrated at the exhibition complementing the Rome Conference. Less spectacular, but nevertheless of great potential, is the tool designed for mapping from differ-

ent data structures to the CIDOC-CRM ontology, based on an extensive analysis of standards currently in use in the heritage domain.

However, the results of the NoE have not been only software. Other significant outcomes include for example the "Research Agenda", listing priorities and describing research directions for IT applications to CH; the study of the socio-economic impact of IT applications, producing decision models for the use of heritage managers; and a number of training courses and summer schools, capitalizing the experience through the proposal of a syllabus for Digital Heritage studies supported by a number of European Universities. Other examples of the durable impact of EPOCH's activity are the London Charter, a guideline for the use of 3D visualization in the research and communication of our heritage, now supported by an independent organization

Virtual crowds populating the Pompeeii procedural modelling reconstruction.

(www.londoncharter.org); and EPOCH's substantial contribution to the MIBAC (Italian Ministry of Culture) good practice guidelines for 3D. All these results are described in detail on the EPOCH website where it is also possible to download software packages and demos.

However, perhaps the most notable achievement of EPOCH has been to succeed in a goal that was stated in its program but found many sceptics even among its proponents. It has created durable integration among most – if not all – of its partners, which now form a new trans-national research community. Stable research teams have been newly formed. Researchers have moved – temporarily or permanently – to partner institutions in other countries. New joint projects have been launched or are forthcoming. Thus, and despite its name, the Rome event does not celebrate an end: it celebrates also the beginning of a new, and perhaps more interesting, challenge in the integration between ICT and Cultural Heritage.

Link: http://www.epoch.eu/

Please contact:
Franco Niccolucci
STARC, The Cyprus Institute
E-mail: f.niccolucci@cyi.ac.cy

FMICS 2008 -
13th International ERCIM
Workshop on Formal Methods
for Industrial Critical Systems

Colocated with the ASE 2008 Conference,
L'Aquila, Italy, 15-16 September 2008

The aim of the ERCIM FMICS workshop series is to provide a forum for researchers who are interested in the development and application of formal methods in industry. In particular, these workshops bring together scientists and engineers that are active in the area of formal methods and interested in exchanging their experiences in the industrial usage of these methods. The FMICS workshop series also aims to promote research and development that will improve formal methods and related tools, facilitating their industrial application.

Topics include, but are not restricted to:

• design, specification, code generation and testing based on formal methods
• verification and validation of complex, distributed, real-time systems and embedded systems
• verification and validation methods that address shortcomings of existing methods with respect to their industrial applicability (eg, scalability and usability issues)
• tools for the development of formal design descriptions
• case studies and experience reports on industrial applications of formal methods, focusing on lessons learned or identification of new research directions
• impact of the adoption of formal methods on the development process and associated costs
• application of formal methods in standardization and industrial forums.

Deadline for paper contributions: 5 June 2008

ASE Conference
The FMICS workshop is colocated with ASE 2008, the International Conference on Automated Software Engineering which will bring together researchers and practitioners to share ideas on the foundations, techniques, tools, and applications of automated software engineering. ASE 2008 will be held on 15-19 September 2008.

The conference focuses on all aspects of automated software engineering, ie, how to automate or partially automate software engineering tasks to achieve significant improvements in quality and productivity.

More information:
http://www.dsi.unifi.it/fmics08/

ECDL 2008 - European Conference on Research and Advanced Technology for Digital Libraries

Aarhus, Denmark, 14-19 September 2008

ECDL2008 is the 12th conference in the series of European Digital Library conferences. ECDL has become the major European conference on digital libraries and associated technical, practical, and social issues, bringing together researchers, developers, content providers, and users in the field. ECDL2008 is jointly organised by the State and University Library and Aarhus University.

Conference Focus

ECDL2008 will provide an opportunity to present and discuss new research and development in areas supporting an ambition of the Ubiquitous Digital Library, a vision where information can be easily accessed in the user environment and where new objects can be produced by analyzing, processing and combining existing information.

Topics of contributions include:

- concepts of Digital Libraries and digital content
- collection building, management and integration
- system architectures, integration and interoperability
- information organisation, search and usage
- multilingual information access and multimedia content management
- user interfaces for digital libraries
- user studies and system evaluation
- digital archiving and preservation: methodological, technical and legal issues
- Digital Library applications in e-science, e-learning, e-government, cultural heritage, etc.
- Web 2.0 and associated technologies.

Contributions consist of peer reviewed papers, posters and demos. In addition the conference will feature tutorials, workshops, panels & themes, as well as doctoral consortium.

Doctoral Consortium

The ECDL Doctoral Consortium wil be held on 14 September and offers PhD students the opportunity to present, discuss, and receive feedback on their research in a constructive and collegial atmosphere. The consortium will be led by research experts in the field of Digital Libraries. The Doctoral Consortium is intended for students who have already settled on a specific research proposal and have some preliminary results, but still have enough time remaining before submitting their dissertation so that they can benefit from workshop feedback. The consortium language is English. Deadline for submission of abstracts is 1 June 2008

More information:
http://www.ecdl2008.org

CAISE08 - The 20th International Conference on Advanced Information Systems Engineering

Montpellier, France, 16-20 June 2008

The CAISE Conference is celebrating its 20th birthday! After these 20 years, Information Systems (IS) now support and underlie most, if not all, of our human activities. Considering the major economic and social development challenges now at stake, it is time to enter into the era of Sustainable Information Systems (SIS). As our world of interdependent activities and information technology continues to undergo profound changes and transformations, it is fundamental to maintain an adequate balance between activities and systems, and to promote their evolution in the context of sustainability.

Scope

CAiSE'08 aims to bring together practitioners and researchers in the field of information systems engineering. CAiSE'08 invites submissions on the development, evolution, requirements and usage of information systems. This year's special theme is "Sustainable Information Systems" (SIS) which are information systems with built-in support to handle evolution. Information systems are growing rapidly in scale and complexity. At the same time, information system evolution is a fact of life in today's organizations. Furthermore, nomadism and mobile communication lead to a process of continuous change of services provided by information systems. SIS should continuously simplify adequacy between system and enterprise requirements as well as assimilation of new supporting technologies. In addition, approaches for SIS should reduce the failure rate in IS development and allow for the definition of quality & maturity of IS development. An SIS must meet the needs of the present without compromising its ability to meet future requirements related to its context of use, and, consequently, must enable and facilitate innovative policies and practices at the activity level.

So the IS domain, with its sustainable aspects, becomes a new complex domain, which requires a lot of interdisciplinary approaches and a lot of multidisciplinary ways of thinking. Thus it seems legitimate to speak about a new Science: Services Science, where the strategies of enterprise, IT and IS are interwoven, and where "Service" is the cornerstone of the processes of innovation and of creation of value, inside enterprises.

Schedule

16-17 June 2008: Workshops
18-20 June 2008: Main Conference
19 pm and 20 am June 2008: Think Tank: Advancing Innovation Skills for Information Intensive Services in Europe.

More information: http://www.lirmm.fr/caise08/

Scientific Collaboration between CWI and INRIA

CWI and INRIA already have well-established relations, notably through ERCIM. In October 2007 associations were strengthened when the two research institutes signed a special cooperation agreement. In 2008 they will start joint research projects in the fields of software service evolution

Jan Karel Lenstra, general director CWI (left) and Michel Cosnard, president INRIA.

and learning and computational economics. Typical problems that will be investigated are transformation of existing software to trustworthy software services and the optimalization of cost-benefit analysis in for instance patient planning. CWI researchers in Amsterdam will closely work together with INRIA researchers based at the new research centre INRIA Lille-Northern Europe. The projects will initially be carried out at CWI, but as things progress the cooperation could be extended to joint projects in France as well.

Adam Dunkels receives Chester Carlson Prize

Dr. Adam Dunkels, senior scientist at the Swedish Institute of Computer Science, has been awarded the 2007 Chester Carlson Prize, the most prestigious prize for the information sciences in Sweden, for his prominent work on network-connectivity for small, low-cost embedded systems. The Chester Carlson Prize was founded in 1985 in memory of Chester Carlson, the Swedish-American inventor of the copying machine and founder of the Xerox Corporation. The prize winner is selected by Xerox and the Royal Swedish Academy of Engineering Sciences. The prize sum is 100,000 SEK (€10,600).

Over 98% of all microprocessors that are sold today are used in embedded systems, most of which have less than one millionth of the memory of a modern PC. By developing the lwIP and uIP embedded TCP/IP stacks and the Contiki operating system, Adam Dunkels has established that even such very small embedded systems can be connected to the Internet. He has released his research results as open source soft-

Adam Dunkels, winner of the 2007 Chester Carlson prize.

ware that today is used by hundreds of companies in products ranging from car engines and oil-pipeline monitoring equipment to airplanes and satellites.

The jury's motivation is: "For the development of operating systems and communication software that enables cost-effective Internet connectivity for new product classes, for example car engines, weather stations, and film production equipment." The prize ceremony was held at the Utsikt 2008 conference in Stockholm, Sweden, on 7 February 2008.
http://www.sics.se/chester-carlson-prize/

Günter Ziegler wins the Communicator Prize 2008

Günter Ziegler from TU Berlin received the €50.000 award of the Donors' Association for the Promotion of Sciences and Humanities in Germany (Stifterverband für die Deutsche Wissenschaft) and the German Research Foundation (DFG) for his outstanding achievements in relating his work (discrete mathematics) to the public. The jury acknowledged his successful efforts to paint a new, fresh picture of Mathematics. The Communicator Award was created in close cooperation between the DFG and

Prof. Günter M. Ziegler.

the Donors' Association to honour academics who, in a sustained and exceptional manner, have made efforts to communicate their work to the general public. Günter Ziegler is president of the German Mathematical Society, deputy chair of the Berlin Mathematical School, and a coordinator of the "2008 Year of Mathematics" celebrated in Germany.
http://www.math.tu-berlin.de/~ziegler/

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.

W3C ERCIM is the European Host of the World Wide Web Consortium.

AARIT
Austrian Association for Research in IT
c/o Österreichische Computer Gesellschaft
Wollzeile 1-3, A-1010 Wien, Austria
http://www.aarit.at/

CNR
Consiglio Nazionale delle Ricerche, ISTI-CNR
Area della Ricerca CNR di Pisa,
Via G. Moruzzi 1, 56124 Pisa, Italy
http://www.isti.cnr.it/

Crcim
Czech Research Consortium
for Informatics and Mathematics
FI MU, Botanicka 68a, CZ-602 00 Brno, Czech Republic
http://www.utia.cas.cz/CRCIM/home.html

CWI
Centrum voor Wiskunde en Informatica
Kruislaan 413, NL-1098 SJ Amsterdam,
The Netherlands
http://www.cwi.nl/

dana!m
Danish Research Association for Informatics and Mathematics
c/o Aalborg University,
Selma Lagerlöfs Vej 300, 9220 Aalborg East, Denmark
http://www.danaim.dk/

fonds national de la recherche
Fonds National de la Recherche
6, rue Antoine de Saint-Exupéry, B.P. 1777
L-1017 Luxembourg-Kirchberg
http://www.fnr.lu/

FWO
FNRS
FWO
Egmontstraat 5
B-1000 Brussels, Belgium
http://www.fwo.be/

FNRS
rue d'Egmont 5
B-1000 Brussels, Belgium
http://www.fnrs.be/

FORTH
Foundation for Research and Technology – Hellas
Institute of Computer Science
P.O. Box 1385, GR-71110 Heraklion, Crete, Greece
http://www.ics.forth.gr/

FhG Fraunhofer Gesellschaft
Fraunhofer ICT Group
Friedrichstr. 60
10117 Berlin, Germany
http://www.iuk.fraunhofer.de/

INRIA
Institut National de Recherche en Informatique
et en Automatique
B.P. 105, F-78153 Le Chesnay, France
http://www.inria.fr/

IUA Irish Universities Association
Irish Universities Association
c/o School of Computing, Dublin City University
Glasnevin, Dublin 9, Ireland
http://ercim.computing.dcu.ie/

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology, Mathematics and
Electrical Engineering, N 7491 Trondheim, Norway
http://www.ntnu.no/

PLERCIM Universitas Varsoviensis / Universitas Wratislaviensis
Polish Research Consortium for Informatics and Mathematics
Wydzia³ Matematyki, Informatyki i Mechaniki
Uniwersytetu Warszawskiego
ul. Banacha 2, 02-097 Warszawa, Poland
http://www.plercim.pl/

Science & Technology Facilities Council
Science and Technology Facilities Council,
Rutherford Appleton Laboratory
Harwell Science and Innovation Campus
Chilton, Didcot, Oxfordshire OX11 0QX, United Kingdom
http://www.scitech.ac.uk/

SpaRCIM
Spanish Research Consortium for Informatics
and Mathematics c/o Esperanza Marcos, Rey Juan Carlos University,
C/ Tulipan s/n, 28933-Móstoles, Madrid, Spain,
http://www.sparcim.org/

SICS SWEDISH INSTITUTE OF COMPUTER SCIENCE
Swedish Institute of Computer Science
Box 1263,
SE-164 29 Kista, Sweden
http://www.sics.se/

SARIT
Swiss Association for Research in Information Technology
c/o Professor Daniel Thalmann, EPFL-VRlab,
CH-1015 Lausanne, Switzerland
http://www.sarit.ch/

MTA SZTAKI
Magyar Tudományos Akadémia
Számítástechnikai és Automatizálási Kutató Intézet
P.O. Box 63, H-1518 Budapest, Hungary
http://www.sztaki.hu/

VTT
Technical Research Centre of Finland
PO Box 1000
FIN-02044 VTT, Finland
http://www.vtt.fi/

Order Form

If you wish to subscribe to ERCIM News
free of charge
or if you know of a colleague who would like to receive regular copies of ERCIM News, please fill in this form and we will add you/them to the mailing list.

Send, fax or email this form to:
ERCIM NEWS
2004 route des Lucioles
BP 93
F-06902 Sophia Antipolis Cedex
Fax: +33 4 9238 5011
E-mail: office@ercim.org

Data from this form will be held on a computer database.
By giving your email address, you allow ERCIM to send you email

I wish to subscribe to the

☐ *printed edition*   ☐ *online edition (email required)*

Name:

Organisation/Company:

Address:

Postal Code:

City:

Country

E-mail: