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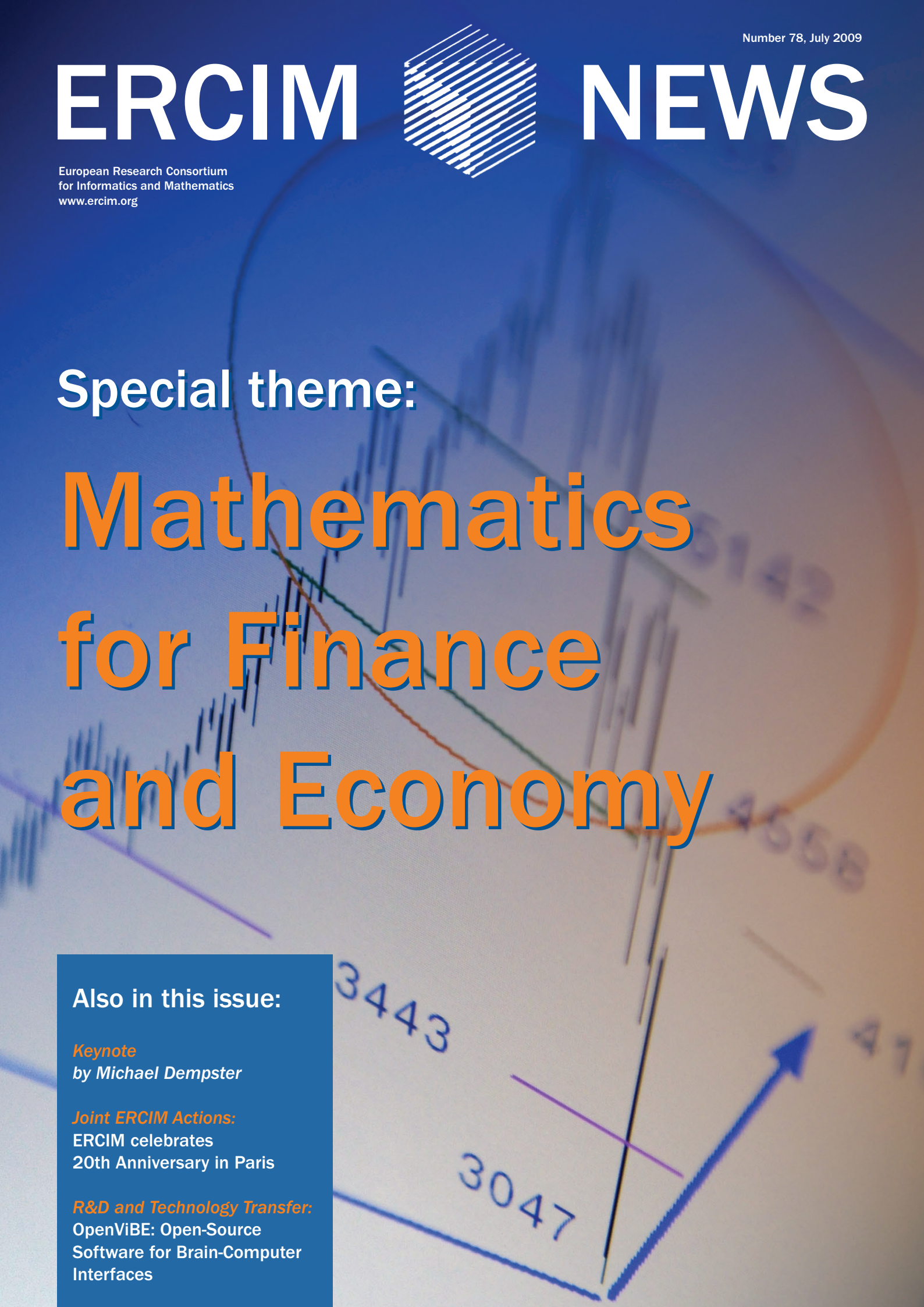

Special theme:

Mathematics for Finance and Economy

Also in this issue:

ERCIM News is the magazine of ERCIM. Published quarterly, it reports on joint actions of the ERCIM partners, and aims to reflect the contribution made by ERCIM to the European Community in Information Technology and Applied Mathematics. Through short articles and news items, it provides a forum for the exchange of information between the institutes and also with the wider scientific community. This issue has a circulation of 10,000 copies. The printed version of ERCIM News has a production cost of €8 per copy. Subscription is currently available free of charge.

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Quantitative Finance and the Credit Crisis

"Guns don't kill people, people kill people."
(US National Rifle Association).

The thoughts and research of a long line of social philosophers and economists attest to the fact that the current financial crisis is just the latest in centuries of frequently occurring events. Indeed, beginning with Adam Smith in the eighteenth century, Marx, Mill, Marshall, Wicksell, Fisher, Keynes, Schumpeter, Minsky and Kindleberger have all studied the causes and consequences of financial crises which have usually been appropriately 'global' in their time. While perhaps not yet generally agreed, the current truly global crisis, now hopefully in its final 'resolution" stage, fits virtually perfectly the stages of crisis discussed in Kindleberger's famous book in an historical context. Usually promoted by different communities and interests in isolation: 'globalization' in the form of financial imbalances between developing exporting and developed importing nations, improper regulation of macroeconomic policy and markets by governments and central banks, and greedy 'Anglo Saxon' bankers developing ever more complex derivative products in search of personal and corporate profits, have all been blamed for the current situation. The truth is that these three potential causes have all contributed to the current situation and all must be addressed appropriately in its resolution. As a mathematician who has worked with the global financial services industry over the past two decades, I wish to address the third issue here.

First, I would ask the reader to reflect on the fact that banking is the latest of the major industries to go 'high tech' in the sense of extensive day to day employment of mathematics and informatics. This follows military logistics in the second world war (operations research), the oil industry, aerospace, manufacturing, airlines, logistics, even film making (Lucas Labs). Although beginning with the breakdown of the Bretton Woods fixed currency exchange rate system and the precise valuation of equity options in the early 1970's, "modern" banking is at most a matter of the past twenty years.

In no case that I know of, including the nuclear industry, has government regulation – independent of whether or not it is justified – succeeded in reversing technological progress. Nevertheless people in high places are currently considering regulation based on the widely quoted opinions expressed by the world's most successful investor, Warren Buffet, Chairman of Berkshire Hathaway, 'Derivatives are weapons of mass destruction' and Lord Turner, Chairman of the UK Financial Services Authority, who blames 'excessive reliance on sophisticated mathematical models' for the crisis. The true explanation of the role of derivative products in its development is more complicated.

Michael A H Dempster
Centre for Financial Research, Statistical Laboratory,
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It should also be noted that these simple but popular opinions fly in the face of Mr Buffet's recent investment in Goldman Sachs and the widely acknowledged role of the Basel international capital requirements in the explosion of off balance sheet entities set up by the banks to securitize and structure credit derivatives, most of which ended in disaster. The law of unintended consequences in regulation remains a significant force to be reckoned with!

Good scientists know the truth of Box's maxim that "all models are wrong, but some models are useful". Financial models are no exception. The seminal contributions of Samuelson and his associates, Black, Scholes and Merton, in pricing equity options – albeit under somewhat unrealistic assumptions – is based on the concept of dynamic market equilibrium involving no arbitrage opportunities using a continuously rebalanced portfolio of cash and the underlying stock to replicate the option's value. This approach is the perfect example of Keynes' maxim that "it is better to be approximately right than precisely wrong" and is the principle upon which the pricing and hedging of current complex derivative products are based in the equity, foreign currency exchange and fixed income (government bond) markets. Moreover, the models involved have by and large continued to function properly throughout the crisis.

Alas this is not the case in the credit (mortgage, loan and corporate bond) derivative markets, which have grown over the past decade since their inception by the JP Morgan bank from a few tens of billions of US dollars to $160,000 billion today, nearly three times global GDP. Throughout, both academic and practitioners have been criticizing, as mere "curve fitting" to market data, the basic Gaussian copula model and its variants used to value over-the-counter (OTC) tranches of synthetic collateralized debt obligations (CDOs) written on indices of either European or US corporate bonds. As a result, hedging these widely traded derivatives in the absence of theoretical approximate hedges is notoriously difficult and shows that for these products more rather than less complication is need. The hedging problem for CDOs has lead to the unfortunate linking of the banking and insurance industries, involving firms such as AIG and the so-called "monoline" insurers, who wrote tens of billions of dollars of insurance in the form of credit default swaps (CDSs) on corporate bonds which in the end has had to be honoured by the US government.

The recent history of Citigroup, two years ago the world's largest bank and now effectively owned by the US taxpayer, under its previous CEO, Charles "while the music's still playing you've got to get up and dance" Prince, exemplifies the failure of top banking management to understand the true complexities of the structure of – and the risks being run by – their organizations. To quote the late Peter Bernstein, long time Wall Streeter, before the demise of the Bear Stearns investment bank in March 2007, "We have passed through a period where the appetite for returns was so voracious that considerations of riskiness were significantly downgraded" – the undeniable signature of a bubble. But there were even worse anomalies in the derivatives markets as a consequence of the top heavy incentive structures in banks ignored in the bubble period.

My own recent experience concerns valuing structured fixed income and FX products for litigation involving their trusted banks by continental European individuals, corporations and local authorities. It has been said that "30% of derivatives are 'bought', and 70% are 'sold'". The implication is that 30% of instruments are traded between 'consenting adults' who are technically equipped to evaluate the risks involved, but the other 70% are sold to investors "who have no idea what they are buying". The role in the larger proportion of OTC derivative trades of sales and structuring staff who set the parameters of new complex products – many now on the street – must be distinguished from the role of 'quants' who create their valuation and hedging tools in the first place. This egregious aspect of 'financial engineering' of derivatives needs to be examined going forward.

It is not as they say 'rocket science' to require by regulation the visual presentation of the risks involved to the client, which would have precluded purchase in the first place of many 'toxic' assets so revealed as grossly unfair. This of course might call into question the profitability of investment banking in the future – even if the Glass-Steagall act of 1933 separating commercial and investment banking were to be reinstated. With President Obama's current advisors – who were instrumental in the demise of the act in Bill Clinton's second term – this is currently an unlikely event. Nevertheless the proposed risk transparency might eventually lead to the support of true financial engineering, over product structuring at the client's expense, and encourage the widespread valid use of derivatives in reducing global risk.

Whatever happens one thing is certain, 'high tech' banking is here to stay!

Michael Dempster

Left column (from top): Cor Baayen, Philipp Hoschka, Dimitris Plexousakis. Right column: Wendy Hall, Gerard Berry, Michal Haindl. All photos by N. Fagot, © INRIA.

ERCIM Celebrates 20th Anniversary in Paris

by Peter Kunz

On 28 May, in conjunction with the ERCIM Spring Days meetings in Paris, ERCIM and INRIA organised ERCIM's 20th anniversary celebration. The anniversary was marked by a seminar including presentations by renowned personalities from research and industry, and representatives from the ERCIM community.

Set in the heart of the historical Le Marais district, 'Les Jardins du Marais' was the venue not only for the celebration, but also for the ERCIM Board of Directors and Editorial Board meetings, several ERCIM Working Group meetings and two European project meetings, namely InterLink and EuroIndia. In all, 180 attendees participated in ten meetings over three days.

Anniversary Seminar

The highlight of the anniversary celebration was the seminar held on the afternoon of 28 May. It was organised into three sessions: 'Science and Society', 'ERCIM Activities' and a 'historical round table'. Following the welcome speeches by the ERCIM President, Keith Jeffery and President d'honneur, Cor Baayen (a founding father of ERCIM), Wendy Hall (University of Southampton) gave the first talk. As President of the Association for Computing Machinery (ACM), a position to which she was elected in July 2008 as the first person from outside North America, Hall presented plans to create a European chapter of the ACM. She then talked about the new discipline known as 'Web Science', the main concern of the Web Science Research Initiative that she recently founded together with Tim Berners-Lee, Nigel Shadbolt and Daniel J. Weitzner. The goals of Web Science are to promote and encourage multidisciplinary collaborative research, to study the development of the Web, to provide a global forum enabling academia, government and industry to understand the scientific, technical and social factors that drive the growth of the Web, and to encourage innovation.

Mazin Yousif (Avirtec Inc., CEO and former-Intel executive and chair of the ERCIM Advisory Committee) talked about 'green computing'. When looking at the worldwide energy consumption of data centres, for example, the importance of this topic is obvious. The energy consumption of all data centres worldwide is similar to the entire energy consumption of a country like Argentina or The Netherlands. Reducing energy consumption relies on four pillars: new technology (new materials, virtualisation of computing facilities etc), efficiency (energy-efficient equipment, minimising resources executing workload etc), conservation (energy caps, resource consolidation, certificates) and operations (advanced cooling technology, best practices, holding IT accountable for cost etc). This is an area in which ERCIM could take the lead, promoting green computing in Europe, encouraging the establishment of a Green Computing Working Group, drafting a green computing research vision, encouraging green computing initiatives, and working with European standardisation bodies and the EU to expand the code of conduct.

Gerard Berry (INRIA) delivered a remarkable speech about his personal experience of teaching computer science to school children. Unlike the current generation of teachers and scientists, children today grow up with technology forming a natural part of their life. These days, there is little emphasis on teaching children the concepts of how computers work. Yet getting today's children enthused about scientific subjects such as computer science is crucial to ensuring a good cohort of engineers and scientists tomorrow. As Berry pointed out, what we must do is educate children in such a way that they choose to develop from consumers into creators.

Philipp Hoschka (W3C) spoke about the work of the W3C (of which ERCIM is the European host) and progress towards the Ubiquitous Web. Ubiquitous computing is now at an inflection point, where both hardware and software offer solutions for applications. Recent examples include the 'Sekai Camera' that can display and create 'floating air tags' when a user is navigating through a museum, and 'SixthSense', developed by the MIT Medialab, a wearable gestural interface that augments the physical world with digital information and lets us use natural hand gestures to interact with that information. W3C is currently working in fields such as geolocation, camera API and widgets. More work is needed on model-based user interface design and device-to-device communication. Hoschka concluded that mobile Web applications will play an important role for ubiquitous computing and that they are a good opportunity for European research and industry to get involved.

Walter Weigel, Director General of ETSI, the European Telecommunications Standards Institute, gave a talk entitled 'Standardisation of research results'. ERCIM and ETSI have developed a well-established cooperation, through five years of shared Grid technology experience, partnerships in European projects, and through the joint 'Infinity Initiative', a series of annual advanced seminars. Weigel explained the key challenges for successful innovation. With innovation cycles accelerating, market segmentation demands faster product and service takeoff and thus an increased investment in R&D. However, it is not sufficient simply to be innovative, or to master the innovation environment: the crucial question is how to ensure that an innovative advantage is not wasted. This is why work in standards is so important for transforming innovation leadership into market leadership. 'First movers' can set the standards and use them to impose their market leadership. Standardisation is also an important 'market access tool'. As Weigel explained, if we look at standardisation as a business process, successful innovation then needs to manage the increasing 'overlaps' in the 'research', 'test and development' and 'product' phases. A closer link is therefore needed between research and standardisation.

Top (from left):
Walter Weigel, Keith Jeffery, Alessandro Fantechi, Mazin Yousif.

Bottom left:
Seminar audience.

Bottom right:
Andreas Rauber.

"Historical round table" composed of two former representatives of ERCIM's Board of Directors, Executive Committee and Editorial Board members. From left: Alain Bensoussan, Paul Williams, Bob Hopgood, Georges Nissen, Henk Nieland and Siegfried Münch.

Opening the second session of the seminar, Alessandro Fantechi (University of Florence and ISTI-CNR) gave a presentation on the Formal Methods for Industrial Critical Systems (FMICS) Working Group as an example of an ERCIM success story. The Working Group was created in 1992 by Stefania Gnesi and Diego Latella (CNR), following an initial successful workshop in Pisa, Italy. Although model checking was then in its early days, the FMICS community was already aware of the great potential of formal verification techniques. Since then, the Working Group has advanced with the development of formal verification techniques and model checking in particular. The series of annual workshops, started in 1996, is now a well-established conference in the Formal Methods community. It has promoted an ongoing scientific discussion focused on identifying the most efficient verification techniques, with a keen eye on their industrial applicability. Most members of the FMICS community have strong links with industry; this has aided in the gradual introduction over the last decade of formal methods into the development cycle of industrial critical systems.

'Beyond the Horizon' (BTH) and INTERLINK are two examples of how ERCIM has affected EC strategy, and were presented by Dimitris Plexousakis (ICS-FORTH). BTH - Anticipating Future and Emerging Information Society Technologies, a project carried out in 2005-06, defined the major challenges and promising research directions in ICT-related strategic areas. Support for these was provided through a well-organised, extensive and systematic consultation of the relevant research community in Europe. The project was composed of six thematic groups investigating the topics 'Pervasive Computing and Communications', 'Nanoelectronics and Nanotechnology', 'Security, Dependability and Trust', 'Bio-ICT Synergies', 'Intelligent and Cognitive Systems' and 'Software Intensive Systems'. The intended impact was to enhance Europe's reactivity to emerging scientific and technological challenges, to build research communities and research networks in these fields, to encourage interdisciplinary research, and to increase industry's awareness of new trends, challenges and visions in information society technology-related research. As a result, a large majority of the proposals were adopted as proactive initiatives in the Future and Emerging Technologies Work Programme of the EU 7th Framework Programme.

INTERLINK - International Cooperation Activities - takes a similar approach. This project had several missions: to identify and address globally relevant basic research problems where significant added value is expected to be gained from worldwide cooperation; to establish communication and cooperation mechanisms within and beyond Europe to support the formation and functioning of a related scientific community; to identify complementarities in selected thematic areas among EU and non-EU countries that can give rise to knowledge and technology exchange; and to define joint basic research agendas, road-mapping activities and joint RTD initiatives. The thematic areas of INTERLINK are 'Software intensive systems and new computing paradigms', 'Ambient computing and communication environments', and 'Intelligent and cognitive systems'. The outcomes of project are comprehensive state-of-the-art reports and research roadmaps in the three thematic areas, as well as a number of new proposed research themes, including 'ensemble engineering' and 'socially-aware ambient intelligence'.

Left: Seminar participants.
Below (from left): Keith Jeffery, Alain Bensoussan, Cor Baayen and Gerard van Oortmerssen.

Both projects were carried out under the guidance of, and in collaboration with, the European Commission. As with the BTH project, it is expected that INTERLINK will have an impact on the European Commission's work programmes. It is also expected that the INTERLINK results will be noted by the research programs of the US Congress on Robotics and the Japanese Science Foundation on Cognitive Systems.

The session on ERCIM activities ended with presentations from Andreas Rauber (TU Vienna/AARIT) and Michal Haindl (Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic/CRCIM), who reported on their personal experiences and views of the Cor Baayen Award and the ERCIM Fellowship Programme respectively. Andreas was the 2002 Cor Baayen award winner; Michal was one of the first three ERCIM fellows in 1990, and since then has hosted an ERCIM fellow himself. In a very diverting and personal manner, they demonstrated how these two ERCIM activities contribute to an increase in scientific reputation, scientific community building and the establishment of international contacts.

The seminar ended with a 'historical round table' composed of two former representatives of ERCIM's Board of Directors, and members of the Executive Committee and Editorial Board, namely Alain Bensoussan, Paul Williams, Bob Hopgood, Georges Nissen, Henk Nieland and Siegfried Münch. They explained how ERCIM began in 1989, discussed the early achievements and visions and answered questions from the audience.

The celebration continued into the evening with a gala dinner to which the participants were welcomed by Keith Jeffery and Michel Cosnard, President of INRIA. The dinner set the scene for speeches from former ERCIM presidents Gerard van Oortmerssen and Cor Baayen, presenting what they have contributed to ERCIM as presidents, what has been achieved during their term of office, and their recommendations for the future.

More information:
http://paris2009.ercim.org

ERCIM Working Group Joint Meeting:

Dependable Embedded Systems and Formal Methods for Industrial Critical Systems

by Erwin Schoitsch

The ERCIM Working Groups Dependable Embedded Systems (DES) and Formal Methods for Industrial Critical Systems (FMICS) seized the opportunity at the 20th anniversary event of ERCIM to have a joint technical meeting. Experiences were exchanged, projects and scientific work were presented, and further cooperation was discussed, especially in light of the successful jointly edited special theme 'Safety-Critical Software' in ERCIM News 75. The meeting took place on 27 May 2009 in Paris.

The agenda covered the following issues:
- Radu Mateescu (INRIA): 'Specification and Analysis of Safety-Critical and Biological Systems'
- Jaco van de Pol (UTwente): 'High-Performance Model Checking for Embedded Systems'
- Wolfgang Herzner (ARC): 'Dependable Networked Embedded Systems Research at ARC: Overview on European Research Projects which are related to ERCIM DES WG Topics'
- Amund Skavhaug (NTNU): 'The Creation of a Special Interest Group for Embedded Systems at NTNU'
- Pedro Merino Gómez (UMA): 'Software Model Checking'
- Alessandro Fantechi (ISTI): 'Modelling Guidelines for Code Generation in Safety-Critical Systems'
- Erwin Schoitsch (ARC): 'ProSE – or How to Get Research Involved in Standardization'.

Possible cooperation in the editing of a book on safety-critical software was also discussed. The request for such a book came from Cambridge University Press following the above-mentioned special theme of ERCIM News 75.

The next workshops planned for the ERCIM DES Working Group are:
- 'Special Session: Dependable Embedded Systems' at Euromicro-SEAA, 27-29 August 2009, Patras, Greece. www.euromicro.org , http://seaa2009.vtt.fi/
- Session on 'Safety and security as a systemic challenge' at IDIMT 2009 (Interdisciplinary Information Management Talks), Jindrichuv Hradec, Czech Republic, 9-11 September 2009
- 'ERCIM/EWICS/DECOS Dependable Embedded Systems Workshop', SAFECOMP 2009 (15-18 September 2009, Hamburg). www.safecomp.org

The next FMICS Working Group workshop will be held in Eindhoven, The Netherlands, on 2-3 November 2009.

All members of ERCIM or ERCIM Working Groups are invited to participate.

Links:
http://www.inrialpes.fr/vasy/fmics/index.html
http://www.ercim.at/

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Introduction to the Special Theme

Modern Mathematics for Finance and Economics: From Stochastic Differential Equations to the Credit Crisis

by Ralf Korn

With so much science and so many applications focused on quantitative output, mathematics plays a key role in the design and evaluation of quantitative models. While in some cases simple or standard mathematics is enough to formulate models and support theories, sometimes methods are required that are very recent or even yet to be developed.

An application that falls into the second case is modern financial mathematics. From its first tentative steps in the early seventies it has undergone extensive development, via a great deal of hype in the eighties and nineties to the critical attention it is currently receiving in the face of the credit crisis.

Financial mathematics can be divided roughly into four areas:

- modelling of price movements (for stocks, commodities, interest rate products etc) and underlying factors (such as interest rates, exchange rates, inflation)
- portfolio optimization, ie the determination of an optimal investment strategy in a financial market
- option pricing, ie the determination of a price for a derivative, a security that consists of an uncertain future payment stream (such as simple call or put options or more complicated, so-called exotic variants)
- risk management, ie the measurement and management of risk connected with an investment in securities (such as credit risk, market risk or operational risk).

While the other three areas seem to be the more natural ones when one is thinking about mathematical applications in finance, it is option pricing which is the star area of modern financial mathematics. Here, the Black-Scholes formula for the prices of European call and put options earned Myron Scholes and Robert E. Merton the Nobel prize. On the theoretical side, the area is one of the rare cases in which very recent mathematical methods such as stochastic processes, stochastic calculus and stochastic differential equations are indispensable. What is more, option pricing actually motivated theoretical research in these areas of probability. On the application side, tools were developed that allowed the pricing – at least in principle – of all kinds of derivative securities, which could be shaped according to the demands of the market. This then called for efficient numerical methods for calculating option prices, and as there is a close relation between stochastic differential equations and parabolic partial differential equations, numerical mathematicians and physicists entered the scene.

For some years, therefore, the inventive activity of the market in creating new derivative products resulted in new option pricing problems. At the same time, the huge influx of researchers from other areas into financial mathematics led to new theoretical results and to more complicated models and valuation methods. The climax of this was the introduction in this decade of credit derivatives. These are nothing more than insurance against the defaults of creditors. With the reasons for a default already hard to model, the financial market made the problem even harder by putting many

credits together and then selling tranches of different riskiness in this package. This technique resulted in the now infamous collateralized debt obligation (CDO). In principle this is a package of credits, but it is divided into pieces: the equity tranche (the highly risky piece from which all default losses are paid as long as this tranche still exists), the mezzanine tranche (the mildly risky piece from which default losses are paid when the equity tranche has completely disappeared), and the senior tranche (relatively safe pieces that only suffer losses due to credit defaults if the other tranches are already used up).

As CDOs are very complicated securities, many investors bought them without fully understanding the mechanism how they work. In addition, the credits used in the packages were sometimes of questionable quality, the main issue that led to the current credit crisis. On the modelling side, determining the risk of a CDO investment requires an understanding of the correlation structure among the credits within it (at least the correlation when it comes to defaults). Here, very simplistic models became popular in the industry and, on top of that, were regarded as perfect images of the real world. This proved to be wrong as soon as the first defaults occurred, and as a consequence the values of CDOs dropped dramatically. Since credit derivatives and in particular CDOs had been enormously popular in recent years, the losses were huge and the consequence is the current financial crisis.

Examples of more off-the-shelf applications of mathematics in economics include operations research methods applied to revenue management problems, queuing theory applied to storage problems, and dynamical systems used in macro-economic theory.

Although financial mathematics has been the most popular application of mathematics in economics in recent decades, this special theme contains reports on a variety of applications. The contributions can be grouped in three blocks, plus three survey-type papers:

- an article by Paul Wilmott that sheds a slightly controversial light on 'Financial Modelling' and points out some important open problems
- a paper by Marlene Müller that surveys what modelling can do for the finance and insurance industry
- a block of papers on theoretical finance, with topics such as option pricing, scenario generation and price modelling
- a block containing applications of operations research in economics, dealing with topics such as revenue management, sales forecasting, CO2 emissions and fiscal fraud
- a block on software/hardware for applications in finance and economics, describing software projects and recent hardware design for problems in finance
- a closing paper by Pierluigi Contucci and Francesca Romiti that gives a statistical mechanics perspective of the application of mathematics in economics.

While reading these contributions, one should keep in mind a key difference between this area of applied mathematics and more classical physics and engineering. The quality of models in finance and economics is not fixed: their correctness can change with time, since it is not nature being modelled but the much more changeable and unpredictable interactions of humans .

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The Quality of Quantitative Finance

by Paul Wilmott

I'm not sure readers of this magazine are going to be pleased with the following statement, but here goes:

"There is too much mathematics in finance". Ooh, er!

Recently the Financial Times had a short article on quantitative finance and the current crisis, taking the position that what was needed was more mathematics. In any formal debate one side takes one position and the other side takes the opposite. Hence my statement above. In truth it's not so much about quantity of mathematics as quality. The Financial Times article simply seemed to think that more is better, without any thought for the type of mathematics involved. My position is therefore better stated as:

"The quality of mathematical modelling in finance is poor." And the quality has been decreasing for at least the last decade."

Twenty years ago people from all backgrounds, whether mathematics, science, economics, physics, etc. were welcomed into finance and were encouraged to contribute. There was a great deal of attempted technology transfer. Yes, most of it fell flat, that's inevitable, but the point is that their opinions and ideas were listened to with respect. Somewhere in the mid nineties the subject of quantitative finance became axiomatized, and very rapidly there became just the one way to do quant finance, and every other approach was dismissed. Even the physicists joining in had to adopt the 'accepted' way of thinking. Groupthink began to dominate.

"I think I know how this happened, and I certainly know why it is bad."

How? I blame the ubiquitous and overrated Masters programmes. Sadly such courses prey on the young and impressionable, usually those straight out of a first degree, leaving them heavily in debt and having to be re-educated once/if they get a job. These courses are almost invariably taught by academics with no practical experience. The courses are made abstract and overcomplicated because that's what the professors know. Final word on this: even Madoff only preyed on the rich and didn't exploit poor young students.

Bad? It is extremely bad because now there is an entire generation of quants and wannabe quants who really do believe that knowing mathematics is all that is needed. But they are incapable of questioning assumptions, or building their own models unless they are but a minor, trivial tweaking of somebody else's model. They cannot think outside any box. They have no awareness of the link between human behaviour and the markets, but that is what drives everything! I know all this because I am one of those people having to do the re-education.

I launched the Certificate in Quantitative Finance (CQF), see www.cqf.com, in 2003, it has become an antidote to the Masters programs. The CQF is fundamentally about the practice of quantitative finance. This still means that delegates must know about the mathematical methods and models, but they also learn how to criticize models, and build their own. This program has now grown to be the largest quant program in the world at that high level. Most people taking the CQF come from banks, and are people who appreciate the uneasy relationship between theory and practice in this subject.

Recently I was giving a talk about the CQF to an audience of people from all sorts of backgrounds. Afterwards one of them told me that he'd like to take the CQF but wanted to skip the first three modules on the grounds that he knew it all, having taken a Masters. And do you know what he meant by 'knowing it all'? Apparently he could 'derive the Black-Scholes equation'…and that was it! Well, sunshine, that's the trivial bit! What about when it breaks down, about its robustness, what about the popular 'improvements' that make it worse? No, he didn't know any of this. And I said to him "You can be a Nobel Prize winner and you still start the CQF at module one, because even in the first lecture there are things Nobel laureates don't know!"

Having set the tone I am going to spend the rest of this paper describing, in brief, some of the main problems with current quantitative finance modelling and suggest areas for research. In my view these are where people should concentrate their attention, not on yet another closed-form solution of a stochastic volatility model:

Real challenges of real quantitative finance

Lack of diversification

Despite the benefits of diversification being well known among the general public, and despite there being elegant mathematical and financial formulations of this principle, it is still commonly ignored in banking and fund management. This is partly due to the compensation structure within the industry whereby bonuses are linked simply to profit. The end result is that people will try to maximize the amount they invest or bet without any concern for risk.

Supply and demand

Prices are ultimately dictated by supply and demand. But 'price' is different from 'value.' Valuation is what quants do, to come up with a theoretical value of a product based on various assumptions. The role of the salesperson is then to sell the contract for as much above that theoretical value as possible, the difference being the profit margin. But then the quant, who rarely distinguishes price and value often gets confused. He sees a contract selling for $10, its price, and by confusing this price with the theoretical value of the contract deduces something about the mathematical model for that contract.

Jensen's Inequality arbitrage

The expectation of a non-linear function of a random variable and the function of the expectation are not the same. If the function is convex then the former is

greater. But options are just non-linear functions of something random, and the difference between the expectation of the function and the function of the expectation is where the value is in an option. The moral is do not assume things are deterministic when they are random, otherwise you will be missing value and mispricing.

Sensitivity to parameters

No one really knows what volatility will be in the future. So risk managers and quants do sensitivity analyses in which they assume a number for volatility, see what is then the value of a contract, change the volatility and see how the contract's value changes. This gives them a range of possible values for the contract. Wrong. They assume a quantity is a constant and then vary that constant! That does not give a true sensitivity, and is completely different from assuming at the start that volatility is a variable. Such analyses can easily give a false sense of security. Because the sensitivity of a value to another quantity is called a greek, I have christened sensitivities to parameters 'bastard greeks' because they are illegitimate.

Correlation

There are two problems with correlation. First it is not quite what people think it is and second it doesn't do a good job of modeling the relationship between two financial quantities. It's not what people think it is because when asked they talk about two highly correlated stocks trending in the same direction. But more often than not correlation to the quant is about the relationship between two random numbers, returns, for example, over the shortest timescale, and nothing to do with trending. And correlation is a very unsubtle tool for modeling the very subtle relationship between quantities.

Reliance on continuous hedging (arguments)

Derivatives theory is based almost entirely on the idea of continuous hedging eliminating risk. But in practice people don't and can't hedge continuously. They hedge every day for example. Such discrete hedging means that risk has not been eliminated and so all the theories based on risk elimination cannot necessarily be used. That's fine, as long as they openly admit that there is far more risk than they've been leading people to believe.

Feedback

For every buyer there's a seller. Correct. Therefore derivatives are a zero-sum game. Incorrect. One side, usually the option seller if it's an exotic, is also hedging the options by trading in the underlying asset. And this trading can move the markets. Such feedback is currently not adequately addressed in derivatives modelling or in trading, even though it has been blamed for the 1987 crash.

Reliance on closed-form solutions

There are good models and there are bad models. You'd think that people would choose models based on comparison with statistics, or maybe on some insight gained from fundamental economic considerations. No. Most popular models are chosen because they have simple closed-form solutions for basic contracts. This is seen especially in fixed-income models. Despite the ease of number crunching of most finance models quants still like to work with elegant models when they should be working with the most accurate models. Typical closed-form models used are the Vasicek- or Hull & White-model.

Valuation is not linear

Despite people's everyday experience of going to the shops, popular valuation models are almost all linear. The value of a portfolio of derivatives is the same as the sum of the values of the individual components. The relevance of the visit to the shops is that we have all experienced nonlinearity in terms of either discount for bulk, economies of scale, buy two get one free. Or the opposite, only one item per customer. There are several great non-linear quant models, with some fantastic properties.

Calibration

Calibration means making sure that the output of a model matches data in the market. It has been likened to the calibration of a spring. That is a completely misleading analogy. Springs behave the same way time and time again. Hooke's law is a very good model relating the tension in a spring and its extension, as long as that extension is not too great. Finance is not like this. Stock prices do not behave the same way, even probabilistically, time and time again because they are driven by human beings. For this reason calibration is fundamentally flawed.

Too much precision

Why bother with too much accuracy in your numerical analysis? First, you don't know whether volatility is going to be 10% or 20%. Second, you don't ever monitor individual contracts to expiration, together with cash flows and hedging instruments, to see whether you made a profit. Third, you lump all contracts together into one portfolio for hedging, and it's the portfolio that makes a profit (or doesn't). You make money from the Central Limit Theorem, so there's no point in pretending that you know the contract's value more precisely than you do.

Too much complexity

One can no longer see the wood for the trees in quantitative finance. Most researchers are so caught up with their seven-factor stochastic correlation model, with umpteen different parameters, calibrated to countless snapshots of traded prices, that they cannot see that their model is wrong. If the inventors and users of the model cannot see what is going on, then what hope has the senior management, and those who have to sign off on valuations and risk-management practices? Quant finance needs to get back to basics, to work with more straightforward models, to accept right from the get-go that financial models will never be perfect. Robustness is all.

Conclusions

Quantitative finance is one of the most fascinating branches of mathematics for research. But it is not fascinating because of the sophistication of the mathematics. Classical quantitative finance, unfortunately, as taught in universities only encompasses a relatively small amount of mathematical tools and techniques. No, quantitative finance is fascinating because of its potential to embrace mathematics from many different fields, a potential that has mainly not been realized. And fascinating because we are trying to model that which is extremely difficult to model, human interactions.

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Balancing Theory and Practice: Modern Financial Mathematics at Fraunhofer ITWM

by Marlene Müller

The financial mathematics department at the Fraunhofer Institute for Industrial Mathematics (ITWM) covers all important topics of modern financial mathematics which has been an extremely innovative research area during the last years.

The underlying mathematics is often new and at the same time very sophisticated, due to the complex structure of the modelling process. Financial mathematicians need to be familiar with stochastic processes, stochastic calculus and partial differential equations, as well as parametric and non-parametric statistics. The Financial Mathematics Department at the Fraunhofer Institute for Industrial Mathematics (ITWM) covers all the important topics of financial mathematics, in particular:

- option pricing using stochastic and local volatility models
- continuous-time portfolio optimization
- credit risk, Basel II, valuation of credit derivatives
- asset liability management, insurance mathematics, Solvency II.

In addition, risk management as an overall topic complements these more specific areas:

Option Pricing with Stochastic Volatility Models

Options are financial products with a price that depends on the price dynamics of one or several underlyings. A simple example is stock prices following a geometric Brownian motion and leading to the famous Black-Scholes formula for simple call or put options. Various other underlyings are possible, which include not only bonds, interest rates, commodities, exchange rates and investment funds, but also weather observations or CO_2 emissions.

Option pricing is one of the most popular fields in financial mathematics. Option trading is an important issue, particularly when market conditions are unfavourable. In order to hedge risks and to offer investors attractive products with a limited risk of loss, banks offer all kinds of derivatives with complex payoff structures; such as products with minimum capital guarantees or products that limit the gain via an upper bound. To calculate precise and market-conformal prices for such derivatives, it is necessary to choose a flexible and appropriate stochastic model for the underlying prices.

A popular generalization of the Black-Scholes model is the Heston (1993) stochastic volatility model. To calculate the price of a complex derivative as a discounted expected value of the payoff (under the risk-neutral measure), appropriate numerical methods (tree approaches, Monte Carlo, PDE methods) must be used. The price calculation is often complemented by the calculation of the 'Greeks', the sensitivities of the price to various model parameters.

The Fraunhofer ITWM has implemented the Heston model within an integrated option pricing software frame-

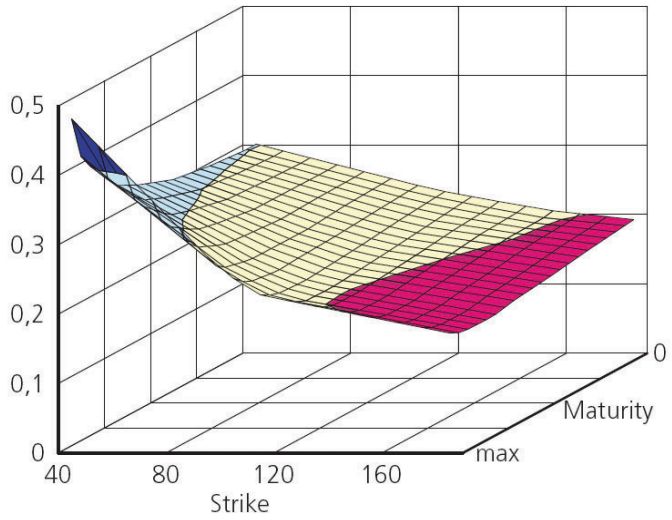

Figure 1: Implied volatility surface calculated from option prices on ht S&P 500 index.

work. Due to closed-form solutions for standard calls, this model offers a time-efficient calibration of the model parameters to actual market situations. In addition, the Heston model has the ability to reproduce the volatility smile observed in, for example, stock markets.

Credit Risk: Basel II and Credit Derivatives

Modelling of credit risks has been an important issue in recent years, for two reasons. The first is the implementation of the new capital regulations (Basel II) and their evaluation by the banking supervision, which is essentially completed now for many banks. The second is the development of several types of credit derivatives that have allowed banks to give away part of their credit risk. (This led to the subprime credit crisis and eventually also the current financial crisis.)

The Fraunhofer ITWM supports banks in their implementation of the Basel II regulations by providing expert knowledge in statistics, gained over the course of several successful research and consulting projects. A typical task is to assess the rating system from a statistical point of view, which means assessing the discriminatory and predictive power of the scoring method, possibly recalibrating the rating system, and validating specific terms, in particular score weights, default probability estimates or the estimated loss distributions. From a mathematical point of view, the main methods that we apply are classification and regression approaches with a special focus on the specific restrictions required by a rating system. In particular, the rating scores should be parametrically specified, additive and monotonic functions of the underlying risk factors, in order that their specification might be extrapolated to rating segments with no or few credit default observations.

In the field of credit derivatives, many standardized products have been developed during the last few years. An example of such a standardized product based on only one underlying subject is the so-called credit default swap (CDS). The attractiveness of this product comes from the fact that it allows the protection buyer to 'insure' against losses due to credit default of the underlying entity. CDSs are traded not only for large corporations but also for banks and sovereign states, which typically have very low default risk. When CDSs are traded on a sufficiently liquid market, their market prices can be used to calibrate a debtor's default probability (even if an assessment on the basis of historical data is almost impossible).

In addition to single-name-based CDSs, there are more complex types of credit derivatives that depend on several underlyings. Examples of these products are first-to-default swaps (FtD), Nth-to-default swaps (NtD), or the (now rather infamous) collateralized debt obligations (CDO). The valuation of these complex products places a significant demand on mathematical modelling and economical and financial knowledge, since existing models have not been able to characterize the market efficiently. In several research and consulting projects, the Fraunhofer ITWM has dealt with the implementation (particularly with the help of copula approaches) of different models for credit derivatives.

Continuous-Time Portfolio Optimization

Continuous-time portfolio optimization (ie the determination of optimal investment strategies in continuous-time models) is one of the main research areas of the Fraunhofer ITWM. It is one of our goals to demonstrate that such modern portfolio optimization methods can be applied to real-world problems (including transaction costs, nonlinear goods and worst-case bounds), and outperform the simplistic but still wide-

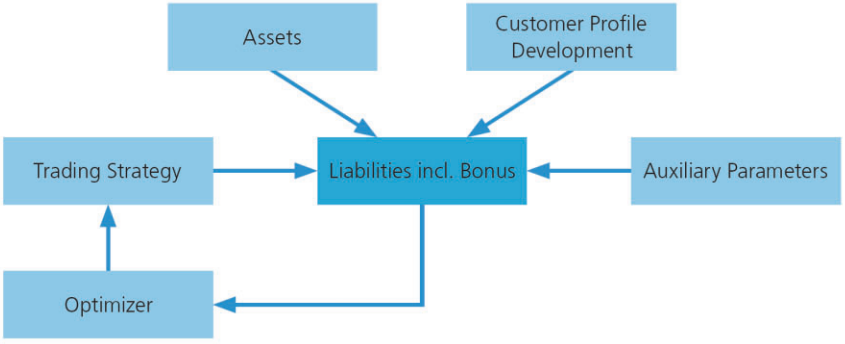

Figure 2: Asset Liability Management for pension funds: the long-term liabilities are in the focus of the optimization. The effects of different trading strategies, in particular their long-term risks can be studied by a simulation tool like ALMSim.

spread one-period Markowitz mean-variance approach.

Asset Liability Management, Insurance Mathematics, Solvency II

Asset liability management (ALM) forms an important part of running a company (especially a bank or insurance company), and it is usually company policy to carry it out regularly. The interdependence between assets and liabilities is about to become even more important, as Basel II (for banks) and Solvency II (for insurance companies) are now being implemented on national and international levels.

The Fraunhofer ITWM has developed the ALMSim simulation software tool to address this problem. Assets and liabilities can now be modelled individually with client-specific interdependences incorporated. ALMSim has already been used successfully by two pension funds. The software obtains the simulation model from a user-defined input file (ALMSim comprises an intuitive simulation language, very close to mathematical formulae), and then automatically recognizes and resolves logical model dependencies. ALMSim will then simulate the model using the appropriately chosen Monte Carlo methods and discretization step sizes. This enables a user (possibly without programming skills) to adapt the ALM simulation model as required. Model parameters, starting values and results are saved in ASCII format (.csv) such that input data can be imported from Excel, R/S-Plus, Matlab etc, and the results can be exported to these programs where they can be further processed and evaluated.

Link:
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Fundamental Modelling of Financial Markets

by László Gerencsér, Balázs Torma and Zsanett Orlovits

In modelling stock prices, two competing approaches exist: technical modelling and fundamental modelling. Technical models capture statistical phenomena observed directly in stock prices, while fundamental models consist of mathematical descriptions of the behaviour of economic agents that affect the stock price. Fundamental models incorporate minute details of the price generating process, and are thus more authentic than technical models. The development and analysis of multi-agent fundamental models has been the subject of research in the Stochastic Systems Research Group of SZTAKI since 2006.

Our model of market microstructures consists of various trading agents, and a stock exchange with order processing rules analogous to real exchanges such as the New York Stock Exchange. The agents observe the market price process, and determine the limit price and order amount in each trading period according to their trading strategy. Agents also consume or invest money. In combination, this gives us a non-linear stochastic feedback system as the mathematical model, with the stock exchange playing the role of the plant, and the agents playing the role of controllers.

Stock trading literature led us to identify three types of behaviour for trading agents. 'Trend followers' act aggressively in the direction of the current price momentum, meaning they buy more if prices rise sharply and sell when prices fall. 'Mean reverters' take the opposite action to trend followers in the hope that the stock price reverts to some mean value. 'Fundamentalists' develop a belief about the 'correct' price according to the information they receive; they then buy if the observed price falls below this level, and sell otherwise. The believed price process is itself generated by a stochastic price model, which they expect to adequately describe the value of a company.

According to well-known findings in behavioural finance, real traders tend to divert from their trusted trading strategies according to some random pattern. Randomness is also introduced when announcements or news about a company trigger analysts to pay more attention to that company and thus change its valuation. This in turn results in further analysts' announcements about that

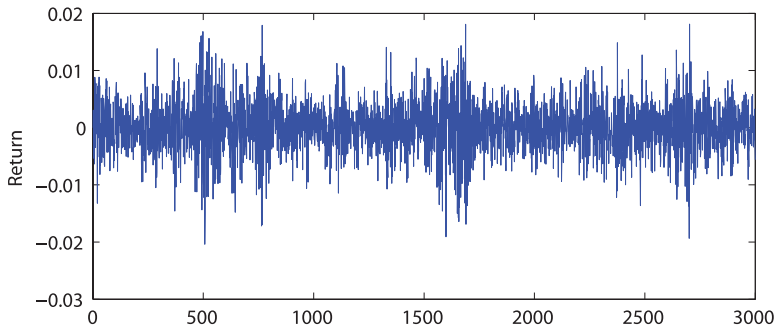

Figure 1: A simulated GARCH(1,1) process.

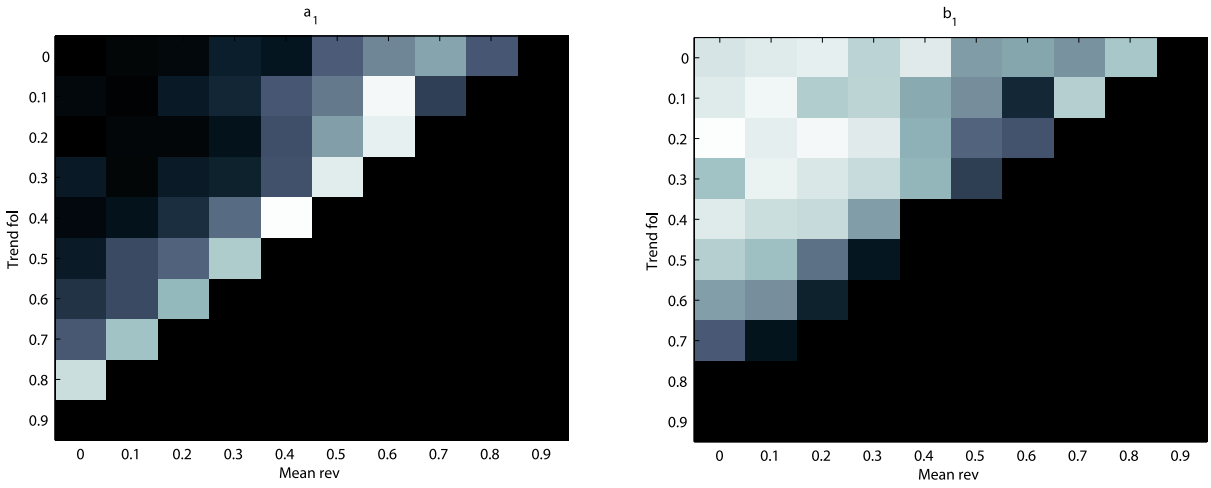

Figure 2a, 2b: Heat map of GARCH(1,1) parameters. Figure 2a (left) indicates that an increase in the relative weight of trend followers increases the volatility. Similarly, Figure 2b can be interpreted as saying that an increase in the relative weight of fundamentalists also increases the volatility.

company. This phenomenon can be represented mathematically using self-exciting point processes, which are incorporated in our model.

To validate our fundamental model we analysed the volatility characteristics of the generated stock price process using a widely accepted technical model, the so-called Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model. This model generates volatility via a stochastic, nonlinear, Wiener-Hammerstein feedback system, driven by log-returns. This model nicely captures a known volatility clustering phenomenon, as shown in Figure 1 using simulated data.

In fitting a GARCH model we relied on a preceding PhD reseach project on the statistical analysis of GARCH models, in particular the real-time estimation of its technical parameters. The theoretical basis of this work was the highly non-trivial application of an advanced theory of stochastic approximation allowing Markovian dynamics in the underlying state process. We have also developed a highly efficient numerical method for off-line estimation that improves the efficiency of the corresponding module of the MATLAB GARCH toolbox by a factor of 4.5. Simulations have shown that our fundamental model successfully reproduces the volatility properties of price processes generated by GARCH models.

An interesting research topic that we investigated is to analyse the relation between the structure of the artificial stock market and the price volatility; ultimately this was captured by fitting a GARCH model. The market structure is defined and parameterized by the relative weights of agents. These are calculated by dividing the number of agents of any of the three types given above by the number of all agents on the market. All agents are assumed to have the same initial endowment, so relative weights can be seen as the initial distribution of wealth among different groups of agents of a given type. In particular, we investigated the problem of detecting abrupt changes in the market structure, which may be an indicator of insider trading.

We have carried out extensive experiments in which we simulated stock price time series for different relative agent weights, and then fitted a GARCH model. The parameters of fitted GARCH models are highly dependent on the agent weights, as shown in Figure 2 for the case of GARCH(1,1) models with just two parameters. We indicate the relative weights of mean reverters and trend followers on the x and y axes respectively. Thus each box in the figure corresponds to a relative weight setting, defining a market structure. Shades of grey indicate the range of values of one of the two coefficients of the fitted GARCH model: the lighter the shade the higher the coefficient. This is known as a heat map. The figures above indicate a high correlation between agent weights and GARCH parameters. Using simple technical arguments, Figure 2a indicates that an increase in the relative weight of trend followers increases the volatility. Similarly, Figure 2b can be interpreted as saying that an increase in the relative weight of fundamentalists also increases the volatility. Both of these findings are in agreement with intuition.

We conclude that fundamental modelling of stock price processes is a realistic alternative to the widely used GARCH models. Given the advanced mathematical technology that is currently available to analyse stochastic, non-linear, Wiener-Hammerstein feedback systems we think our approach has great potential for future research in problems such as market stability and robustness.

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Macroeconomic and Financial Scenarios for Cost/Risk Analysis in Public Debt Management

by Massimo Bernaschi, Maria Francesca Carfora, Albina Orlando, Silvia Razzano and Davide Vergni

Sovereign debt management is the process of establishing and executing a strategy for managing government debt. Among the main goals of a sound public debt management are i) to fulfil the funding requirements; ii) to minimize the cost of the debt and the related risk; and iii) to set up and control an efficient market for government securities. Our research is aimed at providing the mathematical tools for a cost/risk analysis of the portfolio of securities issued every month by the Italian Treasury. The final goal is to provide public debt managers with a flexible, efficient and user-friendly decision support tool.

The Istituto per le Applicazioni del Calcolo 'Mauro Picone', part of the National Research Council of Italy, was founded in 1927 in Napoli by Prof. Mauro Picone as the first institute in the world devoted to the applications of calculus. Since 2002, the Institute has been involved in joint projects with the Italian Treasury that include high-level training on interest rate modelling for the Ministry staff. For the Department in charge of domestic public debt management, the Institute developed a software prototype that uses the simplex algorithm to determine, for a given scenario of interest rate evolution, the optimal sequence of public debt securities issuances. At the same time, this sequence must fulfil the constraints (imposed by the law or by market best practices) that Treasury must take into consideration. Figure 1 shows the block diagram for the optimization process.

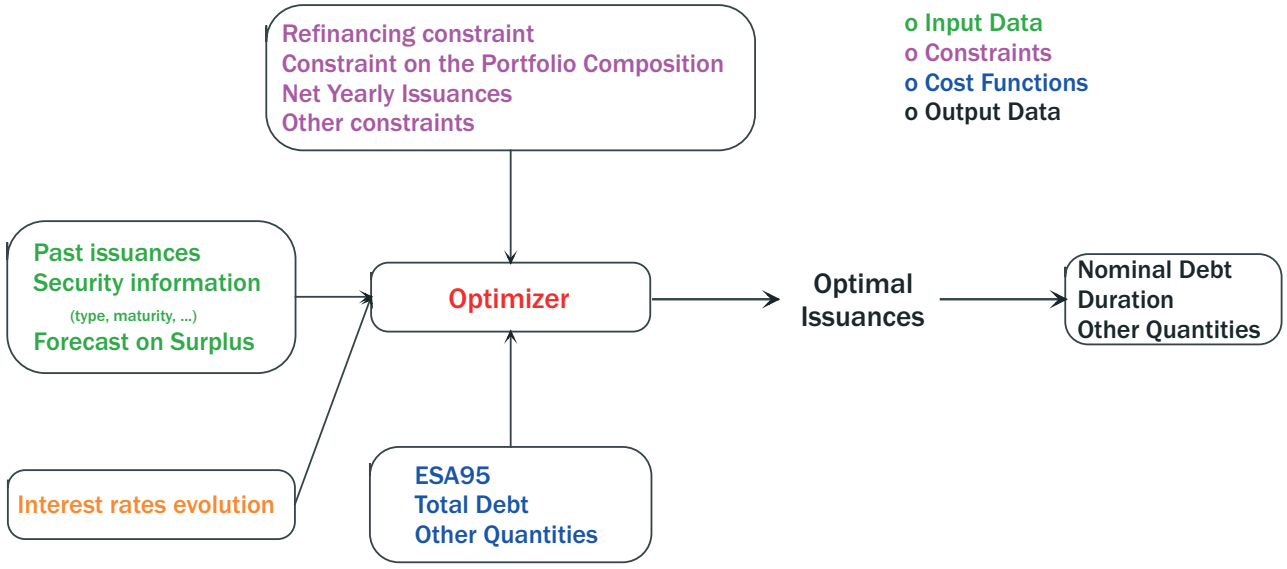
Recently a contract has been signed for the extension of this prototype with Consip S.p.A, a company of the Ministry of Economy operating on services for the Ministry itself. The prototype was presented in several international contexts (eg World Bank) and has received great attention and appreciation for its utility.

The final goal of the project is to determine the optimal sequence of public debt securities issuance. To this aim, we will develop methodologies to simulate realistic scenarios for the dynamics of interest rates, taking into account the effects of the main macroeconomic variables. This is crucial to support a robust cost/risk analysis that includes the impact of macroeconomic changes (variations in monetary policy, modifications in the economic cycle etc) on debt management.

The strong correlation between every rate (regardless of its maturity) and the official rate as fixed by the European Central Bank (ECB) leads us to assume the latter as a reference rate and to consider all other rates as generated by a combination of this reference rate with a characteristic, maturity-dependent fluctuation. On the other hand, the impact of expectations of the future economic trend on the choices made by the ECB cannot be neglected. We must therefore include in our control methodology a model describing the ECB rate dynamics as a function of the main macroeconomic variables.

The project is being developed through six modules:

1. Implementation of Markov Switching models to describe the dynamics of economic and inflation cycles, and subsequent validation on Italian and suitably aggregated European data. As far as inflation is concerned, we are comparing two options: modelling its dynamics by means of an exogenous variable relating the inflation cycle to the economic cycle (eg the output gap) and developing a bivariate model describing both cycles.
2. Development of a jump-diffusion model for the ECB rate. Our working hypothesis is that the ECB interventions can be modelled as a combination of a Poisson process describing



Optimization process for public debt management.

the intervention times of the ECB, and a Markov process accounting for the direction and width of such jumps. Such a model must be linked to the evolution of the economic cycle, by means of terms that vary depending on the recession or expansion phase.

3. As a complementary step with respect to the model in 2, implementation of a 'forward-looking' Taylor rule to model the ECB rate dynamics. Both the models in 2 and 3 will be introduced in the software tool to offer multiple choices for the simulations.
4. Evaluation, for both the models in 2 and 3, of the interest rate fluctuations with respect to the ECB official rate. The basic idea is that the ECB official rate is a reference rate and all the other rates are generated by a composition of this reference rate plus a characteristic maturity dependent fluctuation. Interest rates evolution will be described by means of different models (CIR, HJM, Nelson-Siegel). Powerful calibration techniques for the parameters will be implemented.
5. Extension of the current software tool through i) development of modules for the simulation of the dynamics of macroeconomic variables; and ii) stochastic programming techniques that allow the uncertainty in the evolution of the control variables of the system to be included in the optimal strategy.
6. Assessment of the risk associated with fluctuations in interest rates. Besides traditional risk measures such as Cost at Risk (CaR) and Expected Shortfall (ES), we are also exploring spectral measures and dynamic risk measures.

The final result will be an analysis with clear indications on the robustness of the securities emission strategy of the Italian Treasury.

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Rehabilitating Fractal Models in Finance

by Miklós Rásonyi

Despite of providing a good fit to financial data, asset price models with a fractal structure have often been rejected as they contradict a basic principle of economic theory: that arbitrage should be absent. In light of new results, their role must be reconsidered.

In the Stochastic Systems Research Group of SZTAKI, our current research in mathematical finance (in cooperation with Paolo Guasoni, Boston University, and Walter Schachermayer, University of Vienna) has a three-fold objective. We wish to incorporate certain market imperfections (ie features of the stock exchange that are neglected in idealized settings) in our modelling of the trading mechanism; to reintegrate an important class of 'fractal-like' stochastic processes into mainstream quantitative finance; and to develop further tools for treating these processes in a mathematical finance context.

Market imperfections include brokerage fees, taxes and liquidity constraints (where certain products are not available in the required quantities at a given time). These imperfections have been mostly neglected in the mathematical framework. We are focusing on models where proportional transaction costs are taken into account: each time the investor buys or sells an asset a certain percentage (eg 1% of the transaction value) must be paid to the broker. One of our aims was to achieve a deeper understanding of continuous trading in these more realistic models.

Identifying the right class of stochastic processes with which to model stock prices is of paramount practical importance. Ideally, a tractable class with a good fit to real data should be chosen. One family of stochastic processes, the so-called fractional Brownian motions, appears to be a promising candidate. These processes admit a fractal structure.

A fractal is generally thought of as a geometric object with rugged boundaries whose parts (however small they are) resemble the shape of the original, ie they show self-similarity. Most often they are recursively generated and hence ideal for computer implementations. There also exist stochastic processes with a self-similar structure, the prime example being Brownian motion. This is used to describe diffusive phenomena in physics and it serves as a basis for the overwhelming majority of current models in mathematical finance.

However, it is not the only fractal-like process of interest. Fractional Brownian motions are characterized by a number $H \in (0,1)$ (the so-called Hurst index), which is related to their self-similarity properties but also affects the roughness of the sample paths: as H decreases, the trajectories of the process appear wilder and more chaotic. Standard Brownian motion corresponds to the case H=1/2 and is thus only one particular point in an interval of possibilities!

Determining the 'right' value of H for stock prices is nontrivial, and there is evidence that it may well be different from 1/2. Despite this, models with $H \in 1/2$ have so far been rejected as unsuitable. The reason is that if the stock price followed such a process then agents in the market would have an arbitrage opportunity, meaning they could produce a positive return from zero investment by clever trading. As arbitrage contradicts economic equilibrium, these processes were not much used in option pricing.

In light of our recent progress, there is hope that the situation will soon change.

In cooperation with Paolo Guasoni (Boston University) and Walter Schachermayer (University of Vienna), we have shown that if proportional transaction fees are incorporated into the trading mechanism, stock prices can be modelled as fractional Brownian motion with any H. Not only does arbitrage then disappear, but one can also construct functionals to evaluate options.

We plan to go on with investigating these exciting models based on fractional Brownian motion and to develop option pricing techniques for them. One popular method is based on the preferences of investors: we wish to describe what strategy should be used to attain maximal satisfaction with respect to these preferences. This problem has strong links with optimal control, though it seems that the traditional approach (Bellmann principle) is useless for fractional Brownian motion models and we will need to apply alternative techniques.

We hope that these advances will lead to effective new methods for evaluating derivative securities in models that better approximate reality. In the near future, fractional Brownian motion may play a significant role in derivative pricing, which – as econometric investigations support – it deserves. We look forward to collaborating in these new developments.

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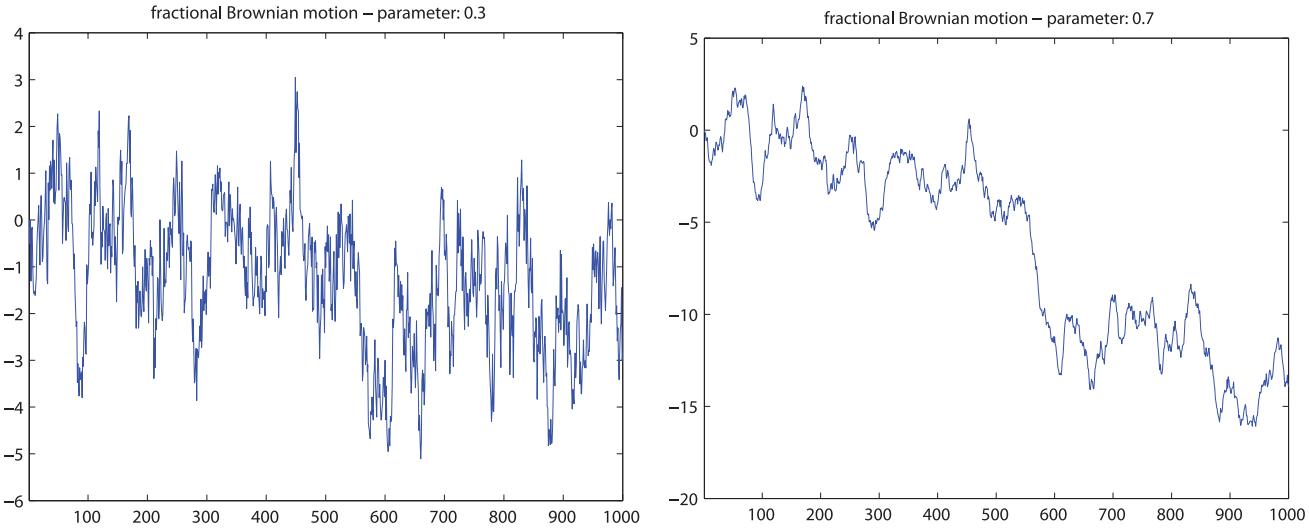


Two trajectories of fractional Brownian motion corresponding to the parameter values H=0.3 and H=0.7, respectively. The graphs were generated with the help of Tyrone Duncan (University of Kansas) and Balazs Torma (SZTAKI).

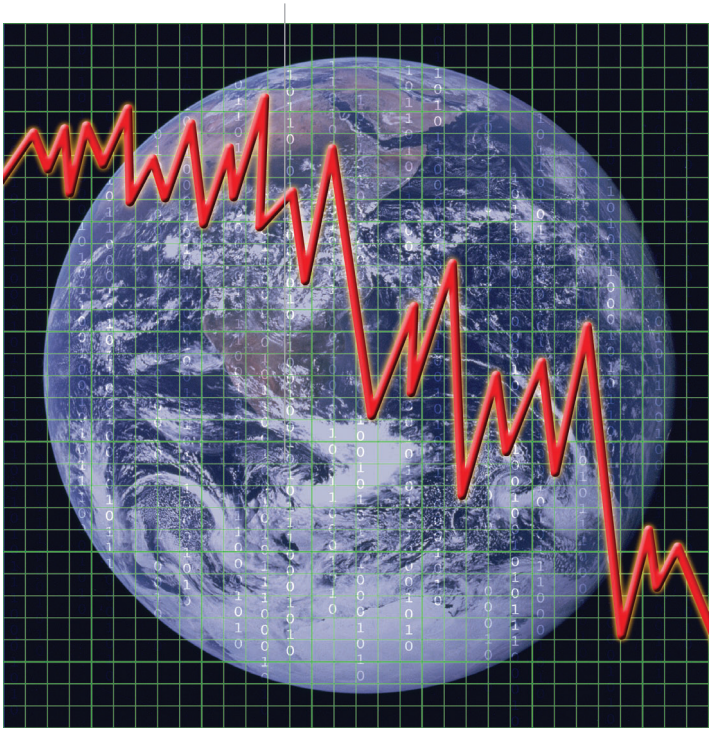
Improving Banks' Credit Risk Management

by Xinzheng Huang and Cornelis W. Oosterlee

The last year has seen financial institutions worldwide announce writedowns of hundreds of billions of dollars as a result of participating in the US mortgage market, in particular in subprime and other lower-rated mortgage-backed securities. Improving the practice of credit risk management by banks has thus become a top priority. Researchers Huang (Delft University of Technology) and Oosterlee (CWI) in the Netherlands focus on quantifying portfolio credit risk by advanced numerical techniques with an eye to active credit portfolio management. This work is sponsored by the Dutch Rabobank.

Credit risk is the risk of loss resulting from an obligor's inability to meet its obligations. Generally speaking, credit risk is the largest source of risk facing banking institutions. For these institutions, sound management involves measuring the credit risk at portfolio level to determine the amount of capital they need to hold as a cushion against potentially extreme losses. In practice, the portfolio risk is often measured by Value at Risk (VaR), which is simply the quantile of the distribution of portfolio loss for a given confidence level. With the Basel II accords (the recommendations on banking laws and regulations issued in 2004 by the Basel Committee on Banking Supervision), financial regulators aim to safeguard the banking institutions' solvency against such extreme losses.

From a bank's perspective, a high level of credit risk management means more than simply meeting regulatory requirements: the aim is rather to enhance the risk/return performance of credit assets.



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The global economy is the driver in a credit risk one-factor model.

To achieve this goal, it is essential to measure how much a single obligor in a portfolio contributes to the total risk, ie the risk contributions of single exposures. Risk contribution plays an integral role in risk-sensitive loan pricing and portfolio optimization.

Extrapolation of credit risk from individual obligors to portfolio level involves specifying the dependence among obligors. Widely adopted in the industry is the Vasicek model, on which is built the Basel II internal rating-based approach. It is a Gaussian one-factor model, with default events being driven by a single common factor that is assumed to follow the Gaussian distribution, and obligors being independent conditional on the common factor. Under certain homogeneity conditions, the Vasicek one-factor model leads to very simple analytic asymptotic approximations of the loss distribution, VaR and VaR Contribution. However, these analytic approximations can significantly underestimate risks in the presence of exposure concentrations, ie when the portfolio is dominated by a few obligors.

In their research, Huang and Oosterlee showed that the saddle-point approximation with a conditional approach is an efficient tool for estimating the portfolio credit loss distribution in the Vasicek model and is well able to handle exposure concentration. The saddle-point approximation can be thought of as an improved version of the central limit theorem and usually leads to a small relative error, even for very small probabilities. Moreover, the saddle-point approximation is a flexible method which can be applied beyond the Vasicek model to more heavily tailed loss distributions which provide a better fit to current financial market data.

The single factor in the Vasicek model represents generally the state of economy. More factors are necessary if one wishes to take into account the effects of different industries and geographical regions in credit portfolio loss modelling. For example, in the current crisis the financial industry is taking the hardest hit, while back in 1997 East Asian countries suffered most. Multiple factors can be used to incorporate these details, but they generally complicate the computational process, as high-dimensional integrals need to be computed. For this, the researchers proposed efficient algorithms of adaptive integration for the calculation of the tail probability, with either a deterministic multiple integration rule or a Monte Carlo type random rule.

In the Vasicek model the loss given default (LGD) – the proportion of the exposure that will be lost if a default occurs – is assumed to be constant. However, extensive empirical evidence shows that it tends to go up in economic downturn. A heuristic justification is that the LGD is determined by the value of collateral (eg house prices in the case of mortgage loans), which is sensitive to the state of the economy. To account for this, Huang and Oosterlee proposed a new flexible framework for modelling systematic risk in LGD, in which the quantities have simple economic interpretation. The random LGD framework, combined with the fat-tailed models, further provides possibilities to replicate the spreads of the senior tranches of credit market indices (eg CDX), which have widened dramatically since the emergence of the credit crisis to a level that the industrial standard Gaussian one-factor model can not produce even with 100% correlation.

This research provides useful tools to fulfill the needs of active credit portfolio management within banks. Banks can improve their insight into credit risk and take appropriate measures to maximize their risk/return profile.

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Fast Pricing of Hybrid Derivative Products

by Cornelis W. Oosterlee and Lech A. Grzelak

When the financial sector is in crisis, stocks go down and investors escape from the market to reduce their losses. Global banks then decrease interest rates in order to increase cash flow: this may lead to an increase in stock values, since it becomes less attractive for investors to keep their money in bank accounts. It is clear, therefore, that movements in the interest rate market can influence the behaviour of stock prices. This is taken into account in the so-called hybrid models currently being developed by researchers Grzelak (Delft University of Technology) and Oosterlee (CWI) from the Netherlands.

Looking in a dictionary, we see that hybrids are, for example, creatures combining body parts of more than one real species (such as mermaids or centaurs). The hybrid contracts from the financial industry are based on products from different asset classes, like stock, interest rate and commodities. Often these products have different expected returns and risk levels. Proper construction of a new hybrid product may give reduced risk and an expected return greater than that of the least risky asset. A simple example is a portfolio containing a stock with a high risk and return and a bond with a low risk and return. If one introduces an equity component into a pure bond portfolio the expected return will increase. If the percentage of the equity in the portfolio is increased, it eventually starts to dominate the structure and the risk may increase with a higher impact for a low or negative correlation.

Advanced hybrid models can be expressed by a system of stochastic differential equations (SDEs), for example for stock, volatility and interest rate, with a full correlation matrix. Such an SDE system typically contains many parameters that should be determined by calibration with financial market data. This task is challenging: European options need to be priced repeatedly within the calibration procedure, which should therefore be done extremely fast and efficiently.

At a major financial institution like a bank, one can distinguish a number of tasks that must be performed in order to price a new financial derivative product. First, the new product is defined as the market asks for it. If this is a derivative product, then there is an underlying, modelled by stochastic differential equations (SDEs). Each asset class has different characteristics, leading to different types of SDEs. To achieve a reasonable model that is related to the present market, one calibrates the SDEs. These products also form the basis for the hedge strategies used by the banks to reduce the risk associated with selling the new product.

A peculiar Dutch hybrid product.

Once the asset price model is determined, the new derivative product is modelled accordingly. The product of interest is then priced by means of a Monte Carlo simulation for the integral version of the problem, or by the numerical approximation of a partial differential equation. The choice of numerical pricing method is thus based on whether one is aiming for the model calibration, in which speed of a pricing method is essential, or for the pricing of the new contract, for which robustness of the numerical method is of highest importance.

Fourier-based option pricing methods are computationally fast, and can be used relatively easily for the hybrid models mentioned above. They are particularly well suited for the calibration process, as their efficiency is obvious for pricing basic option products. They work whenever the so-called characteristic function of the asset price process, ie the Fourier transform of the probability density function, is available.

The contribution of the Dutch group to pricing algorithms is the development of the COS option pricing method, based on Fourier cosine expansions. The basis of this method is that the Fourier-cosine expansion of a probability density function is directly related to the characteristic function. This not only allows probability density functions to be recovered but in addition, means highly efficient option pricing can be performed simultaneously for a large number of basic options. A unique property of the pricing method is that the pricing error decreases exponentially with the number of terms in the cosine expansion. Accurate pricing with the COS method therefore takes place in just a few milliseconds. Experience has been gained for a variety of stochastic processes for the modelling of the assets, like sophisticated hybrid models.

At present, the researchers are improving the applicability of their pricing method. They have already generalized it successfully to the pricing of options with early exercise opportunities, as well as to so-called swing options, which allow contract holders to buy or sell electricity at certain times in the contract. Another application, related to the recent credit crisis, is the calibration of credit default swaps, one of the problematic product classes of recent years, modelled by means of jump processes to the last year's market. A remarkable correspondence between model and market prices was achieved, and calibration could be performed within reasonable time, due to the use of the COS method.

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Modelling and Optimization of Fixed Income Investments

by Jacek Jakubowski and Andrzej Palczewski

Modelling fixed income securities and managing risk in their portfolios is a challenging mathematical task requiring models with an infinite number of risk factors. We have designed new methods of dealing with the risk of defaultable bonds and risk diversification in large bond portfolios.

The Financial Mathematics Group at the University of Warsaw was created in the early 1990s, when a group of mathematicians at the university became interested in financial mathematics. One of the main research interests of the group members is the modelling of fixed income derivatives and the optimization of bond portfolios. Fixed income markets are in certain aspects more complicated than stock markets due to a strong correlation between instruments. There is also no widely accepted 'standard' theory for all interest rate instruments.

Credit Risk

Investment opportunities in fixed income markets include both default-free and defaultable instruments. To model the credit risk of defaultable bonds, one relates the probability of default to the rating class of the issuer (rating classes reflect a firm's economic standing). To manage the financial risk of defaultable instruments, it is important to model not only asset prices in every rating class, but also a credit rating migration process. Investigations by our group are concentrating on a bond market model: this has a finite/infinite number of sources of randomness in the Heath-Jarrow-Morton (HJM) framework, driven by Lévy processes admitting discontinuous trajectories. The importance of models with an infinite number of risk factors has been stressed in recent papers, eg Carmona & Tehranchi, Ekeland & Taflin, Cont). In the model containing default-free and defaultable bonds with rating migrations driven by a Markov chain, we have found no-arbitrage conditions (generalized HJM conditions) for all basic types of recovery. This model has been further extended by defining a new class of stochastic processes: F-doubly stochastic Markov chains, used to model credit rating migrations. The extended model is used to valuate defaultable claims. The advantage of the new approach is twofold. First, the known two-state analysis of default/no-default is extended to a multi-state case. Second, we give a pricing formula for defaultable rating-sensitive claims in terms of characteristics of the rating migration process.

Optimal Investments in Bond Portfolios

The construction of a good combination of financial instruments involves an optimization problem: select the best investment portfolio from all admissible portfolios. The seminal paper by Markowitz formulates this as a risk-return trade-off. In its original formulation, it is in fact a mean-variance (MV) optimization, with the mean as a measure of return and the variance as a measure of risk. To solve this problem, it is necessary to know the distribution of random returns of risky assets. The solution procedure is then executed under the implicit assumption that we know both the mean and the covariance matrix. In fact, this assumption does not hold, and the estimation of the mean and covariance is an important part of the solution of the optimization problem.

Members of the Financial Mathematics Group have collaborated with an industrial partner to design an optimization method that uses a reasonable set of market data and produces 'good' optimal portfolios, ie portfolios that are well diversified and have asset shares that are stable with respect to estimation errors. The group has had an interesting

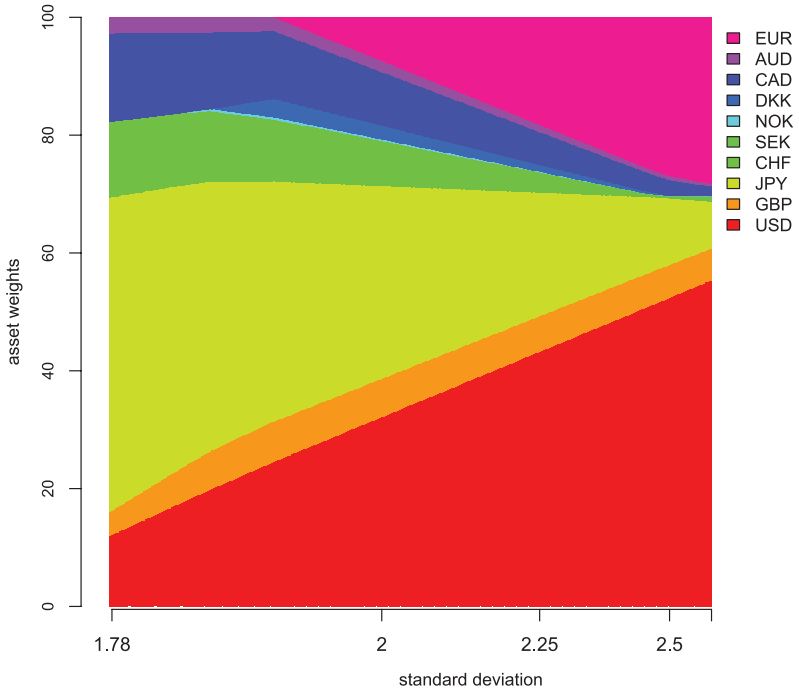

Figure 1: Optimal 10 currency bond portfolios. The figure shows assets weights as the function of portfolio risk measured by standard deviation (in percent). Observe that the portfolios are well diversified and there are no corner solutions (except very risky portfolios).

experience in the optimal tactical asset allocation for a multi-currency bond portfolio. As mentioned above, the main difficulty in implementing MV optimization is the estimation of parameters. While the existing literature points to the difficulty in estimating mean returns, this problem has been overcome using the Black-Litterman method. Our experience shows that the estimation of the covariance matrix is also a difficult task. Standard maximum likelihood estimators lead to unstable portfolios that are sensitive to small changes in data. In order to improve the portfolio stability we apply robust estimators (MCD-type estimators) and implement methods that account for a memory effect in the data. We have also performed a theoretical analysis of the sources of instabilities, and concluded that they are mostly due to small eigenvalues of the covariance matrix. Although this finding is not in itself a surprise, the extent of the instability incurred by small eigenvalues has exceeded our expectations. No remedy could be found in improved estimators; rather, the solution to the portfolio stability issue is to modify the objective function by adding a penalty term of a transaction cost type.

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Valuing CO_2 Emission Allowances with Stochastic Control

by Olivier Davidau, Mireille Bossy, Nadia Maïzi and Odile Pourtallier

The carbon market was launched in the European Union in 2005 as part of the EU's initiative to reduce its greenhouse gas (GHG) emissions. This means that industrial players must now include their GHG emissions in their production costs. We aim to model the behaviour of an industrial agent who faces market uncertainties, and we compare the expected value of an optimal production strategy when buying (or not buying) supplementary emission allowances. This allows us to compute the agent's carbon indifference price which defines its market behaviour (buyer or not). We aim to use the resulting indifference price to study the sensitivity of the carbon market to the shape of the penalty and the emission allowances allocation.

The global warming phenomenon and the related increase in GHG emissions are subjects of great concern in the international community. Developing international cooperation on GHG emissions reduction has led to the ratification of the Kyoto Protocol by most countries. For the European Union, it means an 8% reduction in its GHG emissions in comparison with 1990 levels, to be attained during the period 2008-2012. Such an objective is closely linked to carbon value determination over different time scales.

Determining the value of carbon is therefore an important economic issue and has led to a variety of research activities. It is at the heart of the prospective-based research effort underway at the Center for Applied Mathematics (CMA), at Mines ParisTech. In collaboration with the French Environment and Energy Management Agency (ADEME) and CMA, specialists in stochastic modelling and numerics from the TOSCA and COPRIN teams at INRIA are working on a short-term carbon value derived from the so-called financial 'carbon market', the European Union Emission Trading Scheme (EU ETS).

The EU ETS is a framework for GHG emissions reduction in European industry. It covers specific industrial sectors including energy production, cement, iron and steel, and oil refineries. In February, the beginning of the annual trading period, each production unit receives a certain quantity of emissions allowances. By April, the unit must possess at least the same level of allowances as its emissions during the previous year. Meanwhile, the producer is allowed to sell or buy allowances on the carbon market. If allowances do not cover emissions, the producer must pay a penalty. Such a market is called a compliance or 'cap and trade' market.

We aim to evaluate the consequences of the design of the allowance allocations and penalties on industries' behaviour and GHG emissions reduction. Our approach is based on 'indifference price' evaluation methodology, used to price complex Over The Counter (OTC) financial contracts. We propose to study the EU ETS indifference price according to a given sector's players aggregation.

We model an agent (the producer) taking part in the EU ETS and seeking to optimize its production planning and CO_2 allowances trading strategy for one period of the carbon market. The agent faces uncertainties in product sales and in production costs (energy, commodities etc); these are modelled using stochastic processes. The agent then chooses an adequate policy for production, investment and carbon trading in order to maximize the expected utility, a function of its final wealth which represents its preferences. For example, an electricity producer can dynamically switch between coal, gas or hydro power plants, and/or buy/sell emission allowances. To determine whether or not the agent enters the carbon market, we compare the optimal expected utility when buying or selling extra emission

With the European carbon market, electricity producer must include their greenhouse gas emissions in their production costs. Photo: Vattenfall.

allowances at a given price, with the optimal expected utility without a carbon market. The indifference price is the price at which the two utilities become equal. A comparison of the current carbon price with the indifference price shows whether it is more or less financially advantageous for the producer to cover its GHG emissions. That is, when the market (buying) price is higher than the (buying) indifference price, the producer will cover its emissions; otherwise it prefers to pay the penalty. This indifference price gives us information on the investment level the producer will deploy to reduce its GHG emissions.

Mathematically, this optimization problem is a stochastic control problem, where the state variables are accumulated wealth and CO_2 emissions, revenue from product sales and production costs. The optimal expected utility is the solution of a Hamilton-Jacobi-Bellman equation. Computing this price and studying its sensitivity to the shape of the allowances allocation and penalty leads us to solve this equation and eventually to invert the resulting value function. We then compute the derivatives of this solution with respect to the level of penalty/allocation. From a mathematical point of view, this leads us to developing efficient numerical schemes. An approach based on backward stochastic differential equations may provide alternative representations, qualitative information on regularity, and derivatives of the solutions and numerical tools.

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Revenue Management in the Parking Industry: New Business Opportunities

by Rob van der Mei, Kevin Pak, Maarten Soomer and Ger Koole

Revenue Management (RM) techniques provide a powerful means of increasing revenue, creating new business opportunities for companies in a wide variety of business areas. Recently, the authors have successfully applied RM techniques for one the world's largest parking companies, creating millions in additional yearly revenue.

Suppose you are sitting in a plane and you ask the person next to you what price he paid for his ticket. It is likely that it will be different from the price you paid for the same ticket. This price differentiation is a result of Revenue Management (RM). While the use of RM techniques is now common practice in the airline industry, these techniques have recently started to create new business opportunities in the parking industry. In a joint effort between CWI, the Dutch company ORTEC and VU University in the Netherlands, the authors have successfully applied RM for one of the world's largest parking companies. This has boosted the company's annual revenue and given it a new competitive edge.

RM is a method for increasing revenue whereby available capacity (for example an airplane seat or a parking spot) is sold in a smart manner by

offering different prices to different customers. In order to determine how much capacity can be offered at what moment and at what price, statistical methods and optimization models are to be used.

RM emerged in the 1980s in the airline industry. Today, for many airlines RM makes the difference between profit and loss. For each flight, airlines determine in detail how many seats will be offered at a given moment and price. The commercial success of RM has triggered the interest of other business areas, such as hotels, tour operators and car rental companies.

RM can be used to stimulate demand by offering services at lower prices in a controlled manner during periods when the demand is relatively low. It can be applied to products or services where the amount of capacity is fixed and has only a limited lifetime: the number of seats in an aircraft is fixed and cannot be extended if demand happens to exceed capacity. On the other hand, an empty seat cannot be sold once the aircraft has departed.

In order to be profitable, the available capacity should be offered at different prices. For each flight, the airline determines what fraction of the (remaining) seats are to be offered at what price. Of course, price differentiation is only useful when different groups of customers exist who are willing to pay different prices. These customer groups must also be distinguishable by the selling channel they choose, the time of reservation, or their choice of additional features (such as possibilities for cancellation).

To illustrate the use of RM for airport parking, let us assume for simplicity that a parking company offers a regular price of $10 per hour, but also wants to offer a discount rate at $6 per hour. The company must then identify how many parking spots are likely to be sold at the discount rate. To this end, it is crucial to have good forecasting models that can accurately predict the demand for any given day for the different customer classes based on both historical and current data.

The next step is to use these demand forecasts to optimize the expected revenue. To this end, one needs to determine the maximum number of seats to be sold at the discount rate of $6. This is done by the so-called Expected Marginal Seat Revenue Model (EMSR), which is based on comparing the revenue of one additional parking spot at the regular rate multiplied by the probability of filling that spot against the discount rate. As long as the first exceeds the second, the parking company should reserve this parking spot for customers willing to pay the regular rate; otherwise, the spot should be sold at the discount rate. In this way, it can be easily determined how many parking spots should be reserved for customers willing to pay the regular price.

Source: Shutterstock

Figure 1: Revenue management in the parking industry: who is paying what?

For one of the world's leading parking companies, we have developed and implemented prediction models and EMSR-based revenue optimization, in combination with smart price differentiation and market segmentation. This has led to a multi-million dollar increase in annual revenue, strongly enhancing the competitive edge of our customer.

To summarize, the use of RM techniques in the airline industry has been successfully applied for one of world's leading parking companies. This case demonstrates the existence of tremendous business opportunities in the parking industry.

The authors are the founders of PreMa, the Dutch national network for Pricing and Revenue Management, in a joint effort of CWI, VU University Amsterdam and the Dutch company ORTEC. The goal of PreMa is to bring together practitioners and researchers to exchange knowledge and experience in the area of RM.

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SNIPER: A Data Mining Methodology for Fiscal Fraud Detection

by Stefano Basta, Fosca Giannotti, Giuseppe Manco, Dino Pedreschi and Laura Spinsanti

An effective audit strategy is a key success factor for 'a posteriori' fraud detection applications in fiscal and insurance domains. 'Sniper' is an auditing methodology with a rule-based system, which is capable of dealing with conflicting issues such as maximizing audit benefits, minimizing false-positive audit predictions and deterring probable future fraud.

Fraud detection represents a challenging issue in several application scenarios, and the automatic discovery of fraudulent behaviour is crucial in many real-life situations. In this context, the Value Added Tax (VAT) fraud detection scenario is receiving increasing interest for both its practical and theoretical issues. Like any tax, the VAT is open to fraud and evasion. There are several ways in which it can be abused, e.g. by underdeclaring sales or overdeclaring purchases. In addition, opportunities and incentives to fraud are provided by the credit mechanism that characterizes VAT: tax charged by a seller is available to the buyer as a credit against his liability on his own sales and, if in excess of the output tax due, refunded to him. Thus, fraudulent claims for credit and refunds are an extensive and problematic issue in fiscal fraud detection. From this perspective, a mathematical modelling methodology capable of producing a predictive analysis tool is of great significance. The tool should be able to identify the taxpayers with the highest probability of being VAT defrauders, in order to support the activity of planning and performing effective fiscal audits.

There are several issues that make the problem difficult to address. First, each government agency has a limited auditing capability, which severely restricts the amount of audited data available. In Italy for example, audits are performed on only 0.4% of the overall population of taxpayers who file a VAT refund request. This restriction inevitably raises a sample selection bias: while auditing is the only way to produce a training set upon which to devise models, auditors focus only on subjects who according to certain criteria seem particularly suspicious. As a consequence, the proportion of positive subjects (individuals who are actually defrauders) in the training set is vast compared with that in the overall population.

The limited auditing capability of a generic revenue agency poses severe constraints also in the design of the scoring system. Auditing is a time-consuming task involving several investigation and legal steps, and which ultimately requires a significant commitment of human resources. Hence, the scoring system should concentrate on a user-defined fixed number of individuals (representing the auditing capability of the agency), with high fraudulent likelihood and with a minimum false positive rate.

The situation is further exacerbated by the quest for a multi-purpose modelling methodology: in general, several objective functions characterize the fraud detection scenario, and a traditional classification scheme may fail in accomplishing such a multi-purpose task. Typically, experts are interested in scoring individuals according to three criteria:

- *Proficiency:* scoring and detection should not rely only on a binary decision boundary separating defrauders from non-defrauders. Rather, higher fraud amounts make defrauders more significant. For example, it is better to detect a defrauder whose fraud amounts to $1000 than one whose fraud amounts to $100.

- *Equity:* a weighting mechanism should highlight those cases where the fraud represents a significant proportion of the business volume. For example, an individual whose fraud amounts to $1000 and whose business volume is $100,000 is less interesting than an individual whose fraud amounts to $1000 but whose business volume is only $10,000.

- *Efficiency*: since the focus is on refunds, scoring and detection should be sensitive to total/partial frauds. For example, a subject claiming a VAT refund equal to $2000 and entitled to $1800 is less significant than a different subject claiming $200 who is entitled to nothing.

There are several mathematical tools based on machine learning and statistics, which can be adopted to address

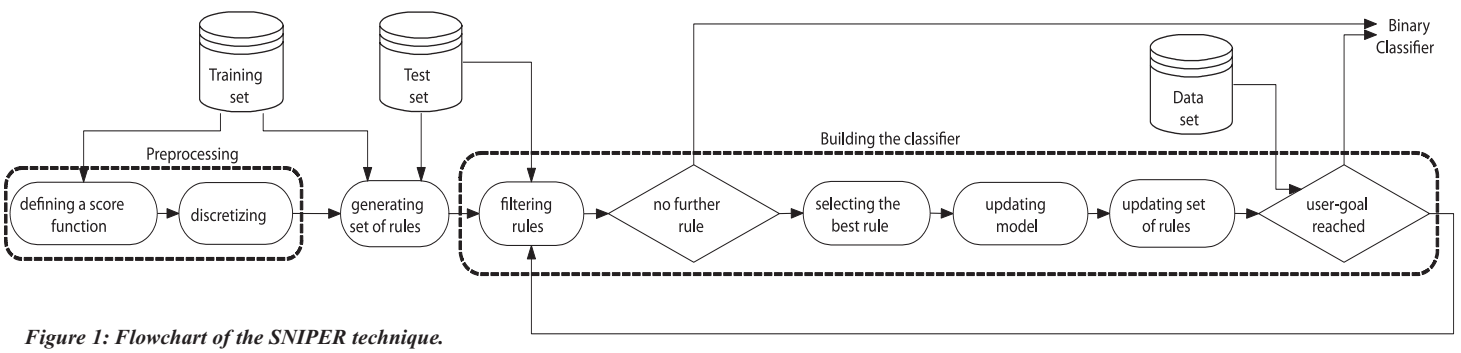

Figure 1: Flowchart of the SNIPER technique.

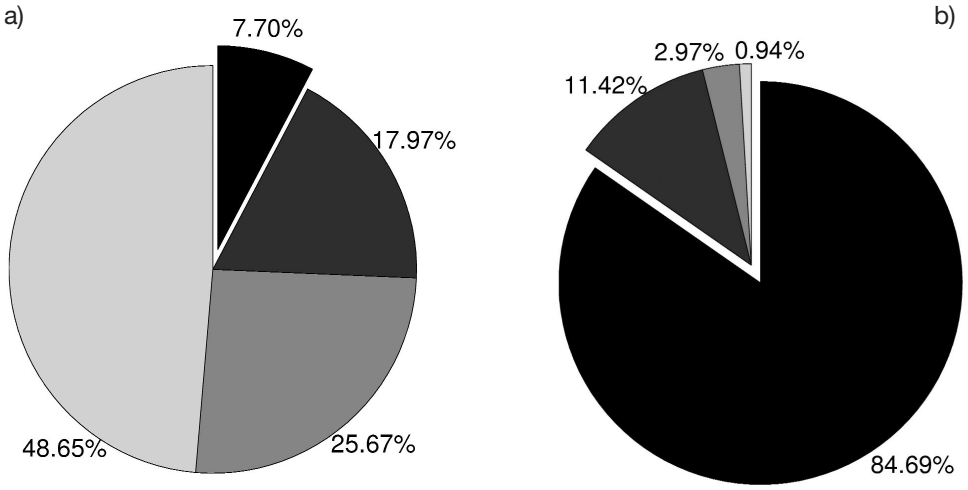

Figure 2:
(a) Subject portioning - An example segmentation of the audited subjects on the basis of their relevance to the scoring function. Specifically, from the lighter to the darker-coloured slice, the figure reports the percentage of subjects in four segments.
(b) Retrieved fraud - the percentage of total amount of fraud associated to these segments.

the above issues. Approaches based on the estimation of the underlying distribution and a direct modelling of the fraudulent behaviour exhibit shortcomings due to both the complexity of the domain under consideration and the presence of noise which prevents suitable model fitting. In general, supervised techniques (using a training set of known fraudulent cases) based on hybrid or cost-sensitive classification suffer from low interpretability, which makes them inadequate for the problem at hand. In addition, the aforementioned problem of sample selection bias makes it difficult to devise a proper training set. Recently, semi-supervised and unsupervised methods have been proposed to partially overcome these drawbacks. Unfortunately, these techniques fail to provide interpretable explanations of the 'outlierness' of a fraudster.

Rule-based approaches are preferable from a socio-economic point of view. Intelligible explanations of why individuals are scored as fraudulent are far more important than the scores themselves, as the former allow auditors to thoroughly investigate the behavioural mechanisms behind a fraud. Unfortunately, rule-based classifiers exhibit poor predictive accuracy when the underlying data distribution is inherently characterized by rarity and primary aspects of the concept being learnt are therefore infrequently observed.

In this context, we developed Sniper, a flexible methodology devised to accommodate all the above-mentioned issues in a unified framework. Sniper is an ensemble method that combines the best of several rule-based baseline classification tools, each of which addresses a specific problem from among those described above. The idea of the approach is to progressively learn a set of rules until all the above requirements are met. The approach is summarized in Figure 1.

Sniper devises a scoring function that associates an individual with a value representing degree of interest according to the proficiency, equity and efficiency parameters. Clearly, the training set of audited subjects allows the computation of such a function and its analytical evaluation over those known cases. Tuning the function allows different aspects of VAT fraud to be emphasized, from which baseline classification tools can then be trained in order to associate class labels to individuals according to their relevance to the aspect of interest. Figure 2a reports an example segmentation of the audited subjects on the basis of their relevance to the scoring function. Specifically, from the lighter to the darker-coloured slice, the figure reports the percentage of subjects in four segments. Conversely, Figure 2b reports the percentage of total amount of fraud associated to these segments.

Baseline classifiers can thus be used to filter out rules that degrade the overall accuracy of the system. This is an iterative step, which selects the best subset of rules from that obtained by the baseline classifiers. The result is a final binary classifier capable of selecting subjects to be audited. Experimentally, Sniper has proven to be simple and effective, producing a prediction model that outperforms those models generated by traditional techniques.

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Enterprise Network Dynamics Explored through Computational Modelling

by Marco Remondino and Marco Pironti

We apply computational modelling and simulation to enterprise economics and the underlying network dynamics. Here, we briefly describe a comprehensive framework.

At the e-Business L@B at the University of Turin, Italy, we are developing a computational method based on iterative agent-based simulation to analyse patterns and trends in enterprise clusters. Clustering is definable as the tendency of vertically and/or horizontally integrated firms in related lines of business to concentrate geographically, or, to a more general extent, virtually. Our goal is to create a comprehensive framework that can be used as a tool to study the dynamics of network and cluster formation and modification, when specific events occur. The aim is to be able to explore the qualitative and quantitative results deriving from the application of different strategies and different exogenous parameters (such as infrastructure quality, market complexity, the introduction of technological innovation, market shocks etc). Our model is at an advanced stage of development, but at present employs reactive agents: future plans include cognitive agents and real-world case analysis.

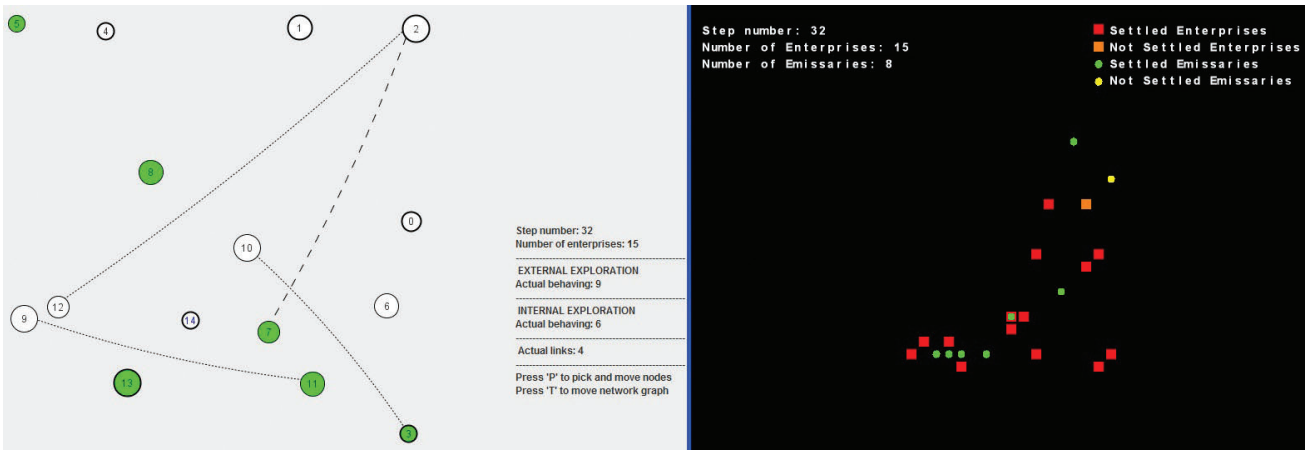
The development of a firm depends on its ability to expand its capabilities and resources and introduce its products into the market. Two main kinds of exploratory strategy are involved when developing new skills. The first is internally focused: firms can try to develop new competence through research and development activities. Alternatively, externally focused firms may look for partners with whom they can create links and exchange skills. The results will depend on the strategy employed, and this will have an impact on the topology of the enterprise's network.

Our model proposes three categories of agent: the enterprises, the emissaries and the environment (E^3). We introduce the 'heat' metaphor to represent the advantage of an enterprise having competence. Enterprises are rewarded with a quantum of heat for every competence. If the competence is internal (ie, developed by the enterprise and not outsourced) this value is higher. The goal of each enterprise is to remain above a certain heat threshold: below this it will cease activity and disappear from the grid. It achieves this by increasing its competence, both through internal and external exploration.

In the model, the environment is metaphorically represented by a lattice with dimensions n∗m and each cell of this grid is assigned a heat value. A set of enterprises is uniformly distributed in the environment. Each enterprise can use its own emissary, also scattered in the environment; these represent probes that are able to move around and report information to the parent enterprise during an external exploration phase. Each enterprise is represented by a vector whose length defines the complexity of the industry in which the enterprise operates. This vector metaphorically defines the competences possessed (both internal and outsourced). Each element C_l of the vector is a Boolean variable (where 1 means that the l^{th} competence is possessed, while 0 means that it is not).

At each step, the cells are updated to reflect the heat produced by the enterprises according to the competences possessed and the dispersion effect managed by the environment itself. The heat of each enterprise is a function of the competences it possesses and hence of its previous behaviour (ie, its success or otherwise in creating new competences). When idle, an enterprise can decide, at each step, which strategy to choose (externally or internally explorative). Each strategy will take several steps to complete, during which the enterprise cannot carry out any other action. In addition to the physiologically scattered heat, the enterprise consumes additional energy (used by the emissary, during external exploration, or by the research and development process, during internal exploration).

If a given action is successful, the end of a phase of internal or external exploration will see the enterprise possess a new competence. An action is unsuc-



Graphical Output from the Model, Showing the Network Dynamics (left), and the Geographical Dynamics (right).

cessful if, after several steps of research and development (internal exploration) or external searching to find a partner (through the emissary), nothing new is found and the l^{th} competence remains set to zero. While internal competences are rewarded more than external ones, they are more expensive and difficult to produce. However, internal exploration is important, since it also permits the exchange of innovative competences during the external exploration phase, with a link being created every time at least one competence is exchanged between two enterprises. At each time-step, the set of links connecting enterprises is updated according to the competences exchanged among the enterprises.

As a result, the model defines the dynamics of link creation among enterprises. Many parameters are definable by the user at the beginning of the simulation; the framework is comprehensive and still under development. At present, the agents are reactive or stochastic, meaning their behaviour is determined by predefined rules based on the stimulus-reaction paradigm, or by a probability distribution, but we are developing cognitive strategies for them. In particular, agents will act realistically, by considering past data through a trial and error technique based on reinforcement learning. In order to simulate as far as possible the behaviour of humans in the real world, the agents will not be totally rational; they will have an internal bias that will affect the way they cognitively form their own actions for the next step.

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A New Approach to Explicable Sales Forecast Models for the German Automobile Market

by Marco Hülsmann, Christoph M. Friedrich and Dirk Reith

The Fraunhofer-Institute for Algorithms and Scientific Computing (SCAI) has developed a software tool for sales forecasts using a methodology that consists of a combination of time series analysis and data mining techniques.

Successful corporate management depends on efficient strategic and operative planning. In this context, reliable forecasts make an important contribution. As the automobile industry is one of the most important sectors of the German economy, its development is of the utmost interest. Developments in both mathematical algorithms and computing power have increased the reliability of forecasts enormously. Enhanced methods such as data mining, and advanced technology allowing the storage and evaluation of large empirical data sets, mean that forecasts are more reliable than ever before. At the same time, the explicability of a forecast model is as important as its reliability. In cooperation with the service company BDW Automotive, which consists of market experts in the automobile industry, the Fraunhofer-Institute for Algorithms and Scientific Computing (SCAI) has developed a software tool for sales forecasts, wherein the methods applied are highly accurate and at the same time easily explicable.

Data

The data for this model consists largely of registrations of new automobiles as well as economic exogenous parameters

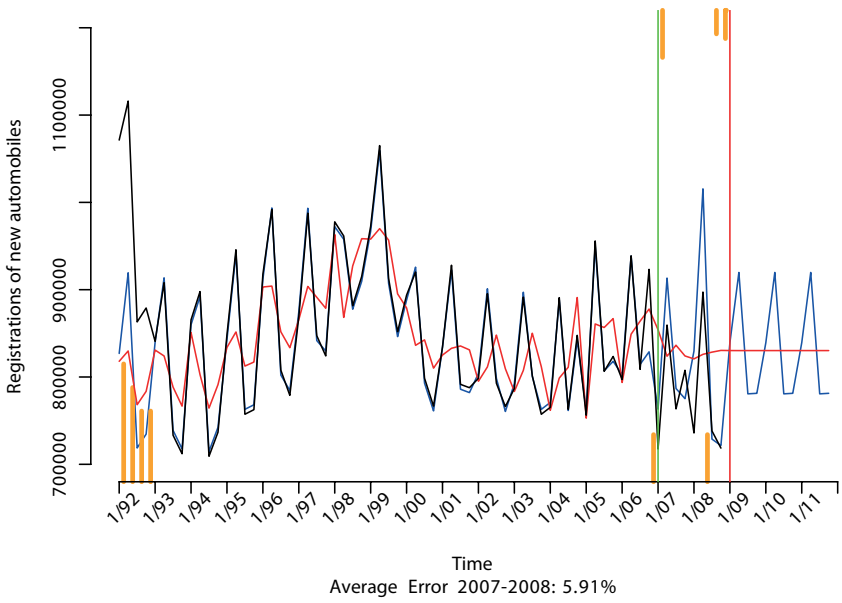

Figure 1: Model evaluation and forecast for quarterly data. In the training period (1992-2006), the blue line indicates the time series model; in the test period (2007/2008), it shows the predictions based on this model. Using a Support Vector Machine as multivariate trend estimator, this leads to an average error of 5.91% in the test period, and a forecast up to the year 2011 was performed. The decrease of automobile registrations due to the financial crisis in the last two quarters of 2008 is depicted correctly. However, this is only because perturbations indicated by the orange rugs were considered. Lower rugs represent positive and upper rugs represent negative perturbations.

like the Gross Domestic Product, the Consumer Price Index, the Unemployment Rate, the Interest Rate and the Industrial Investment Demand: these are available from the Federal Statistical Office and the German Federal Bank, mostly as monthly or quarterly data. In addition, market experts provide domain-specific economic factors like Latent Replacement Demand and Model Policy. Our software tool is able to generate forecasts for monthly, quarterly and yearly time intervals; if the data is not published at the required time interval, conversions are performed. As the German automobile market increased extraordinarily due to the reunification of the two German states in 1990, this could only be treated as a massive shock event, which caused all data prior to 1992 to be discarded. We therefore used yearly, monthly and quarterly data from 1992 to 2008 for our software tool. This has led to a model based on the past that is considered capable of making reliable predictions for the future.

Methodology

The methodology consists of a combination of time series analysis and data mining techniques. New car registrations are considered as a time series composed additively of trend, seasonal and calendar components, which are assumed to be independent. The seasonal and calendar components are estimated by standard time-series analysis methods, whereas the trend component is multivariate, ie it depends on economic exogenous parameters and is therefore estimated by data mining techniques. The simplest method applied in this context was multivariate linear regression. However, it delivered poor results, as the trend could not be assumed to be roughly linear. Hence, nonlinear trend estimators were used, which yielded much more reliable results, eg a Support Vector Machine with a Gaussian kernel, Decision Trees, K-Nearest-Neighbour and Random Forest.

Model Evaluation and Limitation of Forecasts

In order to evaluate the model, a training period and an adjacent test period must be defined. In the former, the model is built by estimating trend, seasonal and calendar components, and for the latter, a forecast is made, with the predicted registrations of automobiles being compared to real data. Taking the period from 1992 to 2006 as the training period and 2007/2008 as the testing period, the average error on the predicted registrations is very low (0.1-1% for yearly, 4-6% for quarterly and 6-7% for monthly data) using high-performance nonlinear data mining techniques. These low error rates represent a very good performance of our forecast tool.

Due to the expertise of BDW Automotive, external perturbations can be taken into consideration. For example, the rise in the German sales tax in 2007 from 16% to 19% led to increased sales in 2006, and the recent financial crisis led to a decrease in the last two quarters of 2008. It should be pointed out that forecasts are always limited by uncertainties caused by perturbations in the future, which are not predictable or whose effects cannot be assessed. The current grant of the scrapping bonus in Germany, which led to higher sales in the year 2009, is another such occurrence. As a result, reliable trend forecasts can always be achieved but more detailed forecasts must be interpreted with care, as they cannot handle random events.

Future Work

The focus now lies on applying our software tool to other traditional major markets, eg France, Japan and the USA. This will require different exogenous parameters to be considered along with different economic perturbations.

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Multiple Dimensions in Resource Allocation and Investment Decisions

by João Oliveira Soares

Diverse case studies carried out at CEGIST (Centre for Management Studies) at the Technical University of Lisbon have a common root: the support and analysis of investment decisions made by public authorities, banks and private firms. The approach comprises multiple dimensions and reflects on the use of statistical and quantitative methods along with qualitative criteria and judgment-based procedures. Recent work also adds flexibility and risk issues to this multidimensional context.

Daily we face numerous decisions. Many of these decisions are not subject to a formal process of analysis, but may implicitly incorporate multiple criteria and frequently involve uncertainty. A classical example is the choice of what to wear each day, which depends on the weather forecast, the agenda for the day, comfort and the image we wish to project. Despite this being a familiar occurrence to all of us, most of the decision models for investment analysis and resource allocation still try to capture the complex nature of decision processes with very simplified rules and one sole criterion. Our research at CEGIST goes in the opposite direction.

Let us start with an example at a macroeconomic level: the allocation of regional funds within the European Union. These funds represent a significant fraction (1/3) of the European budget, but are distributed based on a single indicator (GDP per head), which is used to segment the European regions (NUT 2). Such segmentation leads to very heterogeneous regions, and is insufficient for characterizing the types of dissimilarity among regions, which is necessary to design solutions tailored to the different needs within the EU territory. Our work has been to develop

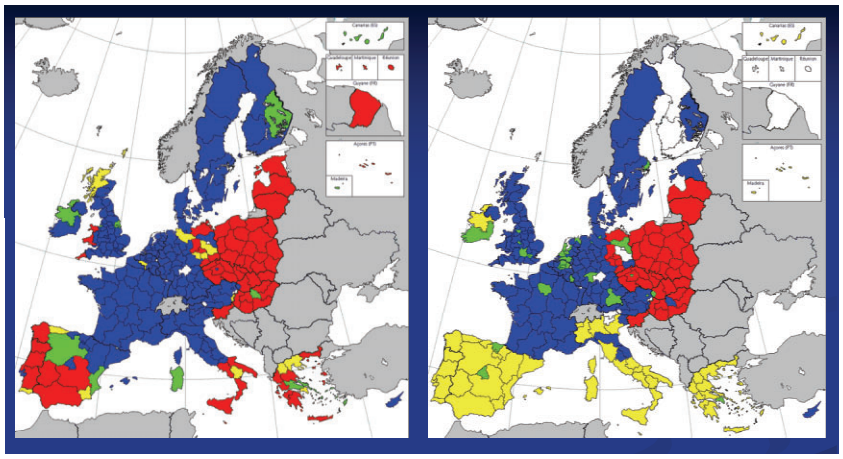

Figure 1: The European Regional Policy and the Socioeconomic Diversity of European Regions: A Multivariate Analysis.
Left: EU-25: convergence and competitiveness objectives, 2007-2013 - EC classification.
Right: EU-25: clusters of socio-economic similarity.

approaches based on multivariate statistical techniques that allow the identification of the different axes of socio-economic development and, subsequently, the segmentation of regions into more coherent and homogeneous clusters.

Credit Risk Analysis

Segmentation, classification and multivariate statistical methods are also used in credit risk analysis, namely to help credit-granting decisions. For some types of loans, however, the modelling procedure must permit the inclusion of expert judgements, since qualitative criteria, particularly management's experience and reliability, show significant negative correlation with banks' default records. Within this context, we extended our work to the use of multicriteria decision analysis models as a way of assessing credit risk by integrating both qualitative and quantitative data.

Similarly, we developed a multicriteria value model for selecting and managing portfolios of financial assets. It consists in defining a benchmark portfolio and scoring its different stocks according to expected return criteria. A procedure is then proposed to suggest adjustments to the proportions of stocks in the portfolio. Finally, the risk is taken into consideration in an optimization module that includes constraints concerning the limits of variation for the proportion of each stock.

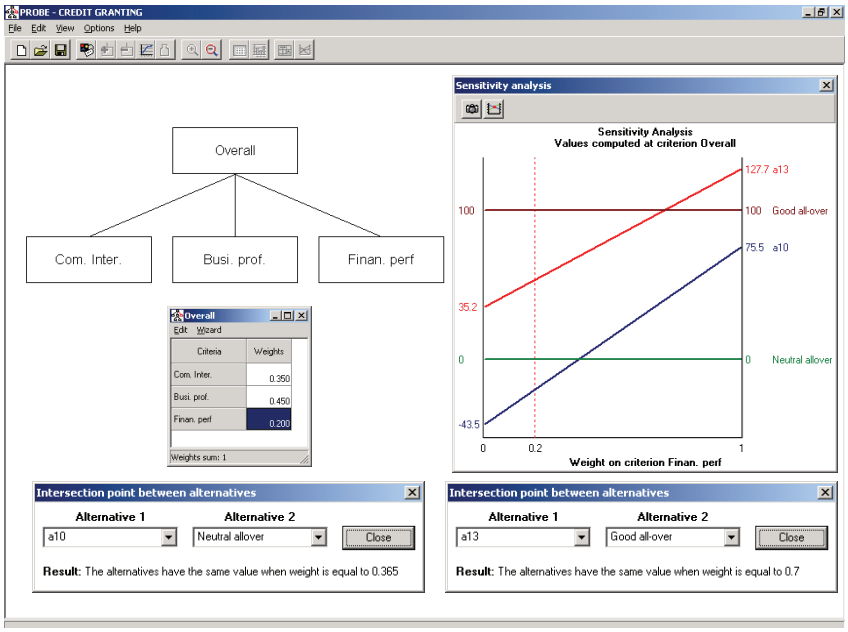

Figure 2: Credit Scoring - the software PROBE is used to perform sensitivity analysis on the weight of a component.

This approach is different from others found in the literature, eg mono-objective optimization with constraints associated to the different factors; and multi-objective and goal programming. The reason is the ambiguous nature of some indicators. Think of the interpretation of a usual market indicator: P/E, the price-to-earnings ratio. A high value of P/E, for instance, can indicate that the market expects future earnings to grow fast or that the company has a low risk. However, it can also reveal that the stock is overpriced. The question then is not whether the ratio is high or low, but whether or not one believes the market is correctly (efficiently) pricing the asset. A multicriteria value approach is well suited to the subjective (and complex) nature of investors' judgments on quantitative and qualitative criteria.

The final link in our conceptual chain adds multiple dimensions with flexibility and risk. The focus is again on the support of investment decisions, now in terms of real assets. Imagine that the decision to invest on a new industrial unit might be postponed, waiting for more information about the expected market behaviour. This postponement option as a value that can be estimated by adapting the usual financial option models to real assets. In this case, the volatility is assumed to be represented by the variation in prices of the subjacent asset (shares of the firm). However, projects are subject to multiple risks: variation in output price, variation in input prices, and among other things, uncertainty in the future prices of CO_2 licences. These multiple sources of risk are not contemplated in option models. The solution we are working on is to use Monte Carlo methods to generate different streams of cash flow and to use their variance as a proxy for the volatility of the real options. Finally and in parallel, we are working on the development of multicriteria models to incorporate sustainable development concerns into the investment decisions framework.

Link:
https://fenix.ist.utl.pt/investigacao/ceg-ist/inicio

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Premia: A Numerical Platform for Pricing Financial Derivatives

by Agnès Sulem and Antonino Zanette

PREMIA is a computational platform designed to set up a technology watch for numerical problems related to the evaluation of financial derivative products and the management of pertinent risks. It is developed by the MATHFI research team at INRIA.

Efficient computation of prices and hedges for derivative products is a major issue for financial institutions. The development of increasingly complex financial products requires advanced stochastic and numerical analysis techniques. The software 'PREMIA' offers numerical solutions to the problems of pricing and hedging financial derivatives, with a collection of algorithms stemming from recent research in financial mathematics.

Premia has been developed in the framework of the MATHFI research team, which gathers researchers in probability and mathematical finance from INRIA, ENPC (Ecole Nationale des Ponts et Chaussées) and the University of Paris-Est Marne laVallée. The development of Premia started in 1999.

This project keeps track of the most recent advances in the field of computational finance. Premia contains various numerical algorithms: deterministic methods (finite difference and finite element algorithms for partial differential equations, wavelets, Galerkin, sparse grids etc), stochastic algorithms (Monte-Carlo simulations, quantization methods, Malliavin calculus-based methods), tree methods and approximation methods (Laplace transforms, Fast Fourier transforms etc). These algorithms are implemented for the evaluation of plain vanilla and exotic options on equities, interest rates, inflation, credit and energy derivatives. For equity derivatives for example, the multi-dimensional Black-Scholes is available as well as stochastic volatility (Heston, Hull-White, Fouque-Papanicolau-Sircar) and various Lévy models with jumps (Merton, Kou, Variance Gamma, normal-inverse Gaussian (NIG), Tempered stable). The most recent Monte-Carlo algorithms are implemented for high-dimensional American options. Various models of interest rate derivatives are included, as for example affine models, quadratic term structure models, Heath-Jarrow-Morton model and the Libor Market Model. Moreover, Premia provides a calibration toolbox for the Libor Market model, using a database of swaptions and cap implied volatilities and a toolbox for pricing credit derivatives (credit default swaps (CDS) and collateralized debt obligations (CDOs)) using the most recent algorithms.

The Premia software provides a collection of C/C++ routines and scientific documentation in PDF and HTML, and is available for both Windows and Linux operating systems. Interfaces for Excel and NSP/Scilab are available. More precisely, Premia is composed of (i) a library designed to describe derivative products, models and pricing methods, and which provides basic input/output functionalities; (ii) a unified numerical library (Premia Numerical Library (PNL)) available for contributors; (iii) a collection of pricing routines which can easily be plugged, if necessary, into other financial softwares; and (iv) a scientific documentation system.

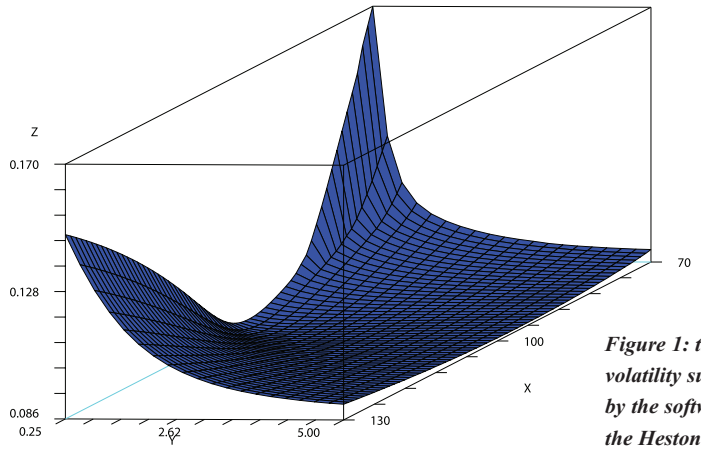

Figure 1: the implied volatility surface computed by the software Premia in the Heston model.

The development of Premia is being undertaken along with a consortium of financial establishments. Consortium Premia is presently composed of CALYON, Natixis, Société Générale, Bank of Austria and RZB ((Raiffeisen Zentralbank Österreich). The participants in the consortium contribute to finance the development of Premia and help to determine the directions in which the project evolves. Every year, a new release is delivered to the consortium members. All algorithms implemented in Premia are provided with their source codes, solid research documentation and extended references. A restricted, open-source version of Premia is also available on the Premia Web site and can be downloaded with a special licence for academic and evaluation purposes.

Premia aids research and promotes technology transfer, creating a bridge between academic researchers and professional R&D teams. It supplies a benchmark for new numerical pricing methods and provides a useful teaching support for graduate students in mathematical finance.

Links:
http://www.premia.fr
http://www-rocq.inria.fr/mathfi/

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Accelerating Applications in Computational Finance

by John Barr

The computational power required to participate successfully in today's financial markets is growing exponentially, but the performance of commodity processors is not keeping pace. How can firms harness innovative technology to achieve success?

Two financial and two technology issues are combining to force a radical rethink of how financial algorithms are computed.

First, the trading landscape is changing. The 'Markets in Financial Instruments Directive' (MiFID) regulation in Europe has encouraged the creation of a raft of new execution venues. Combined with the growth of automated and algorithmic trading, the amount of market data that must be processed - and the speed with which that must be accomplished in order to deliver profitable trades - means that at every stage of the trade lifecycle, high-performance computation is required to deliver low-latency results.

Second, in the aftermath of the credit crunch there is a requirement for more sophisticated risk calculations, both from trading firms themselves and from regulators. Overnight risk calculations are no longer sufficient, with intra-day risk runs tending towards real-time calculations, covering multiple departments and asset classes in addition to counterparty and liquidity risk.

On the technology side, processor clock-speed, which for many years advanced in line with Moore's Law, has stalled at around 3 GHz as chips running faster than that consume over 150 Watts. In addition, the pressure to reduce our carbon footprint forces us to explore alternatives in many areas of life, particularly in transport and in IT.

A first approach to dealing with these issues is to exploit multicore by parallelizing applications. While this is a good option, it is non-trivial and doesn't fix all of the issues raised above. Compilers will only automagically parallelize a very small class of applications; some will be unable to exploit multicore at all, while others will require a significant (possibly a total) rewrite. In addition, if we look forward five years or more we need to consider not just dual or quad core, but dozens of cores with heterogeneous architectures.

An alternative to this is to deploy specialist architectures. Many examples exist of appliances, driven by exotic processing technology, being deployed to handle one or more specific functions such as latency monitoring and analysis, market data feed handling, ticker plant management, message acceleration or risk analysis. The processors used include Field Programmable Gate Arrays (FPGA), Graphic Processing Units (GPU) and the IBM Cell Broadband Engine (a heterogeneous high-performance computing architecture used in the Sony Playstation 3 games console).

FPGAs, in which the personality of the chip must be programmed by the developer, are not as good for computationally intensive workloads but are well suited to the processing of streaming data. Examples of FPGA use in support of financial markets include:

- Endace for latency monitoring
- Celoxica for data feed handling
- Exegy for ticker plant acceleration
- ActivFinancial for market data processing
- Solace, Tervela and Tibco for message acceleration
- TS Associates and Vhayu for data compression.

FPGAs run at low clock speeds and deliver high performance through pipelining and parallelization. Due to this complexity, their use by mainstream developers is very limited, but their value in appliances where they can be programmed once - and used broadly - is significant. A single FPGA-based appliance can replace a rack of commodity servers, significantly reducing up-front cost, power and cooling charges, and saving potentially very expensive rack space in colocation facilities shared with stock exchanges.

Both GPUs and IBM Cell have been used successfully in performance experiments with financial applications. IBM Research has demonstrated excellent performance of computationally intensive risk analytics applications, and particularly good scaling results when increasing the number of Cell processors targeted. The InRush ticker plant appliance from Redline Trading uses the IBM Cell as an acceleration co-processor. Professor Mike Giles' group at Oxford University has developed a series of demonstrators for financial applications based on Nvidia CUDA GPUs with up to 240 cores, generally delivering between 50 and 100 times speed-up compared to a single Xeon core.

One obvious conclusion is that numerically intensive compute performance for financial applications running on future platforms will be delivered through the complexity of parallelism and heterogeneity. In order that the performance is accessible to a broad range of developers it is crucial that appropriate programming paradigms and tools, together with portable libraries and simple APIs, are developed. One example of this is the C library of mathematical functions from the Numerical Algorithms Group that supports the IBM Cell processor (in addition to many others). Another is the Fortran and C compilers from The Portland Group that support multicore x86 processors as well as GPUs from AMD/ATI and Nvidia. For multicore and other, more exotic processor technologies to be successful in meeting the performance needs of financial markets, new programming paradigms, languages, tools and libraries must follow.

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Simulating Large Portfolios of Credit: The CreditCruncher Project

by Gerard Torrent

Financial institutions need tools to simulate their credit portfolios in the same way that they simulate their equity portfolios. CreditCruncher allows each payment in a massive loan portfolio to be simulated, taking into account the probability of default for each creditor and the correlations between them.

While the portfolios of loans given to SMEs and portfolios of corporate bonds do not have the glamour of the equity or foreign exchange markets, they are nevertheless the core business of many financial institutions. Such portfolios tend to have values of thousands of millions of dollars and may be composed of tens of thousands of small loans.

At first glance, credit portfolios may seem harmless because payments are based on pre-agreed dates. Nothing could be farther from the truth. Defaults frequently occur in clusters, affecting entire sectors of industry. The correlation between defaults is the main difficulty in risk assessment, and this is the rationale behind many of the approaches to credit risk valuation. The impact of the correlation on the loss distribution function is notorious, and causes an asymmetrical distribution function with long tails.

CreditCruncher is an open-source project for the simulation of massive portfolios of loans where the unique risk is the default risk. It is addressed to financial institutions searching for a well-documented and efficient tool. It consists of an engine that runs in batch mode and is designed to be integrated into the risk management systems of financial institutions for risk assessment and stress testing. The method used to determine the distribution of losses in the portfolio is the Monte Carlo algorithm, because it allows us to consider the majority of variables involved, such as the date and amount of each payment. This approach is conceptually equivalent to the valuation of portfolios of equities and derivatives using the Monte Carlo method. In the case of market risk, the price of the underlying assets is simulated using a geometric Brownian motion with a given volatility and trend. In the credit risk case, borrowers' defaults are simulated using a copula with given survival rates and correlations.

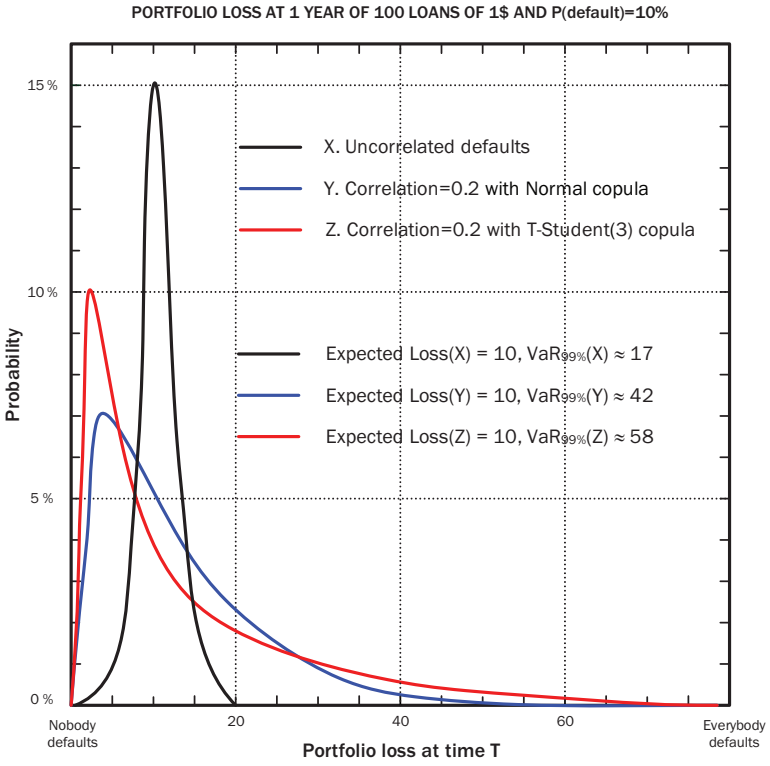
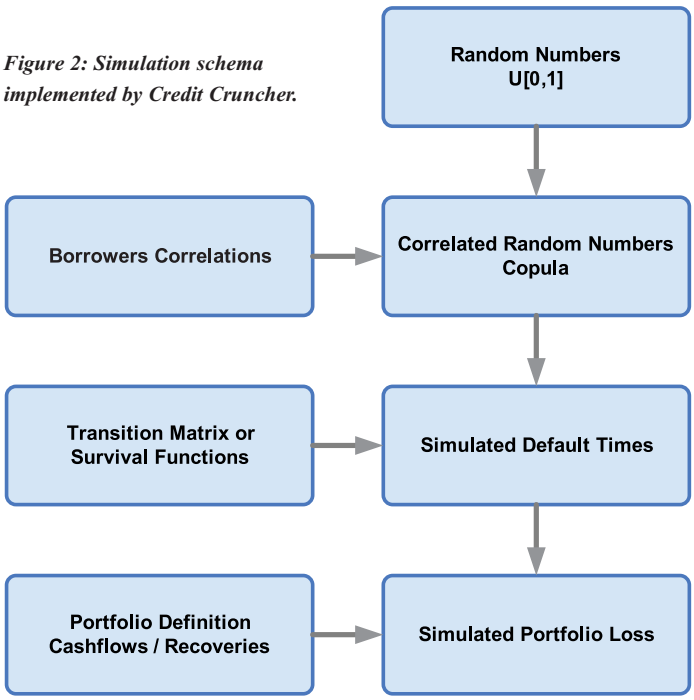


Figure 1: Impact of correlation and copula selection on portfolio loss distribution.

Figure 2: Simulation schema implemented by Credit Cruncher.



Sklar's theorem states that any multivariate distribution can be decomposed into two parts, the marginal distributions and a copula that reflects the structure of dependencies between components. This result is important because it allows us to separate the default probabilities from the default correlations.

CreditCruncher implements two of the most commonly used copulas in finance, the Normal and T-Student copulas. Because the default time of each borrower is modelled as a random variable, the size of the copula can be over 50,000, where each component represents a borrower. Simulating low-dimensional copulas poses no problem, but many of the algorithms operating in low dimensions are unsuitable for large dimensions. To solve this problem, the Cholesky decomposition was adapted to operate with a large correlation matrix composed of blocks, in order to reduce the memory space and the number of operations involved.

Each Monte Carlo run simulates the default time for each debtor by combining a copula sampling with the survival functions. This default time is used to determine the loss caused by the default, mitigated by an estimated recovery at a given time. The default amount is discounted to the present value using the interest rate provided by the yield curve. The sum of all losses provides the loss value of the portfolio for that simulation. The completion of thousands of simulations allows us to obtain the loss distribution function and compute the usual risk indicators, such as the Value at Risk or Expected Shortfall. Depending on the portfolio size and the required accuracy, the computational cost may be high; CreditCruncher is therefore compatible with execution in parallel computers.

CreditCruncher is currently a one-man project with no financial support, and is looking for collaborators with expertise in applied and/or theoretical financial mathematics to participate in a GPL (GNU General Public License) structure. The CreditCruncher system has been tested against both simple hand-made portfolios and large automatically generated portfolios. Future work is being considered to add stochastic recovery rates, pure risk operations like bank guarantees, and the creation of a graphical interface to make the tool available to the public, such as portfolio bond managers.

Links:
http://www.generacio.com/ccruncher/
http://sourceforge.net/projects/ccruncher/

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Mathematics for Economics: A Statistical Mechanics Perspective

by Pierluigi Contucci and Francesca Romiti

Will the noble (and sometimes snobbish) queen of sciences mathematics have a role in the future study of economics? Will the role it plays (if any) be as crucial as in the physical sciences? We argue that mathematics will very likely have a pivotal beneficial mutual exchange with economics, particularly through the study of statistical mechanical models of complex systems.

In recent times, we have witnessed a large-scale economic turmoil whose future is hard to predict. The crisis has so deeply involved the world's population that it is mentioned constantly in the media and is having a daily influence on government agendas. People's reactions and opinions are as diversified as their experience of these difficult matters.

How can mathematics be of help in such a situation? The spectacular success of mathematics in the physical sciences is based on a long interaction between theory and experiment, with trial and error procedures and multiple cycles of feedback. Reality is quantitatively 'understood' when a theory (whose language is mathematics) is able to deduce observed phenomena from a small number of simple principles and predict the output of new experiments. When even a single experiment contradicts the theoretical predictions, the whole machinery must be modified at the cost of replacing some of the principles with new ones.

Economics, however, has followed an apparently different path. On the one hand, the large amount of available data has only begun to come under serious consideration in the last century. The discovery that the tails of the probability distributions of price changes are generally non-Gaussian is quite a recent achievement. On the other hand, the axiomatic method of deductive science has been applied without performing proper feedback checks with observations: the principles of rationality of economic agents, market efficiency etc, have prospered within some schools of economics more like religious precepts than scientific hypotheses.

Yet testable and predictive theories have appeared in economics. The study by D. McFadden (2000 Nobel Laureate in Economics) on the use of the San Francisco BART (Bay Area Rapid Transit) transportation system is a celebrated example. It is interesting to notice that from a mathematical point of view, this work is equivalent to the Langevin theory of a small number of types of independent particles. However, when applied to cases in which the particles or agents interact and the resulting peer-to-peer effects play a more substantial role, that theory turns out to be inefficient.

There are several factors responsible for the delay in the advent of the scientific

method within the economical sciences. The intrinsic difficulty of its topics and the gap between these and the available mathematical techniques is one. Until a few decades ago, mathematics only treated simple models with translation or permutation invariance. From the point of view of statistical mechanics, mechanics to extend the McFadden theory to include interacting systems. There are good indications that this approach could lead to interesting results. First, it has the potential to include sudden changes in aggregate quantities even for small changes of the external parameters, as happens in an problem solution is structurally linked to the monotonic behaviour of observed quantities with respect to parameters (Link 5).

For the time being, the simple economics models considered in mathematics and derived from theoretical

Will mathematics have a role in the future study of economics?

only uniform interactions were understood. However, as the physicist Giorgio Parisi likes to phrase it, science has become more robust and the theory of complex systems has made enormous progress. Among the things that have been learned is how to treat systems in which imitative and counter-imitative interactions occur, and where interactions themselves are generally random variables and are related to novel topological properties.

The challenge we now face is to fill the gap between phenomenological and theoretical approaches. Data analysis must increase in depth and in particular must follow a theoretical guide. Performing an extensive search of data without having an idea of what to hunt for is an illusion no less dangerous than the search for principles without regard for experiments. In the same way, the refinement of the theoretical background of economics must work in parallel towards data searching and analysis. The group of the Strategic Research Project in Social and Economical Sciences at the University of Bologna is working on these themes (see Link 1). Among the approaches being explored is the use of statistical economic crisis (Link 2). Second, it may eventually make use of the complex systems theory of spin glasses, whose applicability to economics is well understood (Link 3). Third, it has built into it the capability to include acquaintance topologies, especially those that have been observed in network theory like the small-world and scale-free (Link 4).

Mathematics can provide a substantial contribution in the crucial phase of checking that questions are well posed and then solving them. It is obvious that new mathematical instruments will be necessary and that the process of developing them will be lengthy. An early phase in which mathematics will be involved is the so-called 'inverse problem'. Unlike physics, where interactions between agents have generally been established by pre-existing theories, in the realm of economics effective interactions should be deduced from data, possibly at a non-aggregate level. From a mathematical point of view, the computation of interaction coefficients from real data is a statistical mechanics inverse problem, a research setting to which many fields of science are turning their attention. The inverse physics look like rough metaphors of reality. Nevertheless, they are able to describe some features of the observed phenomena and are in any case a necessary step towards a more refined approximation of reality.

Finally, the attempt to provide soluble and tractable mathematical models for economics will be an important opportunity to fertilize mathematics itself with new paradigms and to develop new parts of Galileo's 'language of nature'.

Links:
(1) http://www.dm.unibo.it/~contucci/srp.html
(2) http://arxiv.org/abs/0810.3029
(3) http://arxiv.org/abs/0904.0805
(4) http://arxiv.org/abs/0812.1435
(5) http://arxiv.org/abs/cond-mat/0612371

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The ASPIRE Project – Sensor Networks for Immersive Multimedia Environments

by Athanasios Mouchtaris and Panagiotis Tsakalides

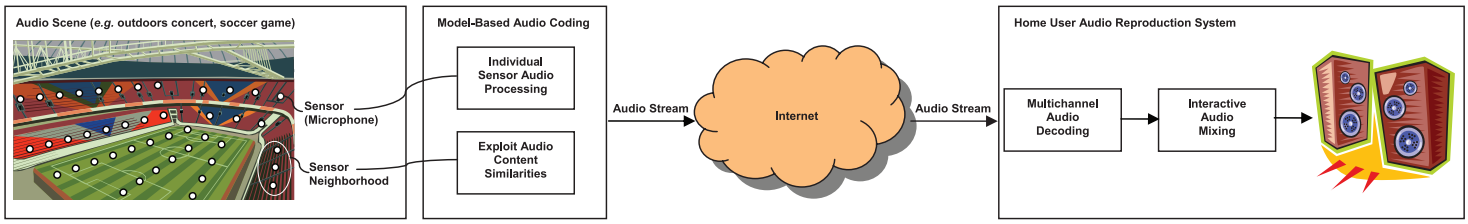
Art, entertainment and education have always served as unique and demanding laboratories for information science and ubiquitous computing research. The ASPIRE project explores the fundamental challenges of deploying sensor networks for immersive multimedia, concentrating on multichannel audio capture, representation and transmission. The techniques developed in this project will help augment human auditory experience, interaction and perception, and will ultimately enhance the creative flexibility of audio artists and engineers by providing additional information for post-production and processing.

Realizing the potential of large, distributed wireless sensor networks (WSN) requires major advances in the theory, fundamental understanding and practice of distributed signal processing, self-organized communications, and information fusion in highly uncertain environments using sensing nodes that are severely constrained in power, computation and communication capabilities. The European project ASPIRE (Collaborative Signal Processing for Efficient Wireless Sensor Networks) aims to further basic WSN theory and understanding by addressing problems including adaptive collaborative processing in non-stationary scenarios; distributed parameter estimation and object classification; and representation and transmission of multichannel information. This highly diverse field combines disciplines such as signal processing, wireless communications, networking, information theory and data acquisition.

In addition to basic theoretical research, ASPIRE tests the developed theories and heuristics in the application domain of immersive multimedia environments. The project aims to demonstrate that sensor networks can be an effective catalyst for creative expression. We focus on multichannel sound capture via wireless sensors (microphones) for immersive audio rendering. Immersive audio, as opposed to multichannel audio, is based on providing the listener with the option of interacting with the sound environment. This translates to listeners having access to a large number of recordings that they can process and mix themselves, possibly with the help of the reproduction system using some pre-defined mixing parameters.

These objectives cannot be fulfilled by current multichannel audio coding approaches. Furthermore, in the case of large venues which are possibly outdoors or even underwater, and for recording times of days or even months, the traditional practice of deploying an expensive high-quality recording system which cannot operate autonomously becomes impossible. We would like to enable 'immersive presence' for the user at any event where sound is of interest. This includes concert-hall performances; outdoor concerts performed in large stadiums; wildlife preserves and refuges, studying the everyday activities of wild animals; and underwater regions, recording the sounds of marine mammals. The capture, processing, coding and transmission of the audio content through multiple sensors, as well as the reconstruction of the captured audio signals so that immersive presence can be facilitated in real time to any listener, are the ultimate application goals of this project.

So far, we have introduced mathematical models specifically directed towards facilitating the distributed signal acquisition and representation problem, and we have developed efficient multichannel data compression and distributed classification techniques. In the multisensor, immersive audio application, we tested and validated novel algorithms that allow audio content to be compressed and allow this processing to be performed on resource-constrained platforms such as sensor networks. The methodology is groundbreaking, since it combines in a practical manner the theory of sensor networks with audio coding. In this research direction, a multichannel version of the sinusoids plus noise model was proposed and applied to multichannel signals, obtained by a network of multiple microphones placed in a venue, before the mixing process produces the final multichannel mix. Coding these signals makes them available to the decoder, allowing for interactive audio reproduction which is a



As immersive spatialised sound and user controlled interactivity depend on enhanced audio content, the ability to efficiently capture, process, transmit, and render multiple recordings containing numerous sound sources is of crucial importance.

necessary component in immersive applications.

The proposed model uses a single reference audio signal in order to derive an error signal per spot microphone. The reference can be one of the spot signals or a downmix, depending on the application. Thus, for a collection of multiple spot signals, only the reference is fully encoded; the sinusoidal parameters and corresponding sinusoidal noise spectral envelopes of the remaining spot signals are retained and coded, resulting in bitrates for the side information in the order of 10 kbps for high-quality audio reconstruction. In addition, the proposed approach moves the complexity from the transmitter to the receiver, and takes advantage of the plurality of sensors in a sensor network to encode high-quality audio with a low bitrate. This innovative method is based on sparse signal representations and compressive sensing theory, which allows sampling of signals significantly below the Nyquist rate.

In the future, we hope to implement exciting new ideas; for example, immersive presence of a user in a concert hall performance in real time, implying interaction with the environment, eg being able to move around in the hall and appreciate the hall acoustics; virtual music performances, where the musicians are located all around the world; collaborative environments for the production of music; and so forth. A central direction in our future plans is to integrate the ASPIRE current and future technology with the Ambient Intelligence (AmI) Programme recently initiated at FORTH-ICS. It is certain that the home and work environments of the future will be significantly enhanced by immersive presence, including entertainment, education and collaboration activities.

ASPIRE is a €1.2M Marie Curie Transfer of Knowledge (ToK) grant funded by the EU for the period September 2006 to August 2010. The University of Valencia, Spain and the University of Southern California, USA are valuable research partners in this effort.

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OpenViBE: Open-Source Software for Brain-Computer Interfaces

by Anatole Lécuyer and Yann Renard

Brain-computer interfaces enable commands or messages to be sent to computers by means of brain activity. Created by a consortium of academic and industrial partners, OpenViBE is free and open-source software, which makes it simple to design, test and use brain-computer interfaces.

Brain-Computer Interfaces (or BCI) are communication systems that enable a user to interact with a computer or a machine using only brain activity. The brain activity is generally measured by electroencephalography (EEG). BCI is a rapidly growing area of research and several impressive prototypes are already available. The aim of the OpenViBE consortium was to develop open-source software for brain-computer interfaces, which is expected to promote and accelerate research, development and deployment of BCI technology. Key features of the resulting software are its modularity, its high performance, its multiple-users facilities and its connection with high-end virtual reality displays. The development of OpenViBE involved six academic and industrial French partners (INRIA, INSERM, FRANCE TELECOM R&D, CEA, GIPSA-LAB and AFM). Applications of OpenViBE are initially concerned with the provision of access for disabled people to multimedia and telecommunication services.

The OpenViBE partners have conducted innovative research and published around forty papers covering the entire spectrum of the BCI field: neuroscience, electrophysiology, EEG signal processing, human-computer interaction and virtual reality. For example, the consortium has proposed novel techniques for processing and identifying cerebral data (eg classification of EEG signals based on fuzzy sets theory), as well as new paradigms for BCI based on neurophysiological experiments (eg the use of auditory signals for BCI). The connection between BCI and virtual reality technology has also been investigated.

In parallel, the OpenViBE consortium has developed free and open-source software devoted to the design, testing and use of brain-computer interfaces. OpenViBE processes brain signals: it can be used to acquire, filter, process, classify and visualize brain signals in real time. It is also notable for its high modularity. The platform comprises a set of software modules written in C++ that can be integrated easily and efficiently to design BCI applications. OpenViBE proposes a user-friendly graphical language to allow non-programmers to design a BCI without writing a single line of code (see Figure 1). As such, OpenViBE addresses the needs of all users, regardless of whether they are programmers or not. OpenViBE is portable, independent of hardware or other software, can run under Windows and Linux and is entirely based on free and open-source software. Various 2D and 3D visualization tools allow brain activity to be displayed in real time. Thanks to its generic acquisition server, the platform is compatible with many EEG machines. OpenViBE also includes pre-

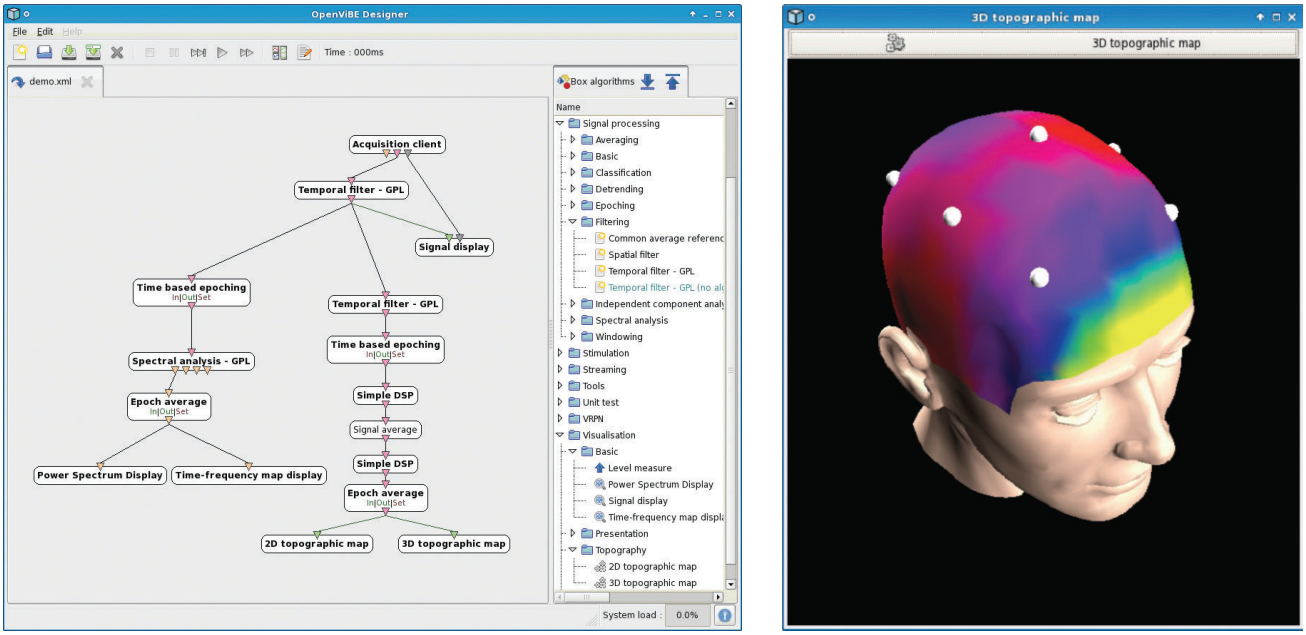

Figure 1: OpenViBE software: (left) the OpenViBE designer helps to program a BCI scenario with a graphical user interface and a graphical language; (right) 3D real-time topography of brain activity with OpenViBE visualization facilities.

configured scenarios that can be used for different applications including neurofeedback, and BCI.

The OpenViBE software is freely available from the INRIA forge under the terms of the LGPL licence. It has already been downloaded by numerous users, and an initial two-day training session was organized in Rennes, France, in January 2009.

Several applications and demonstrators have been built based on OpenViBE, and illustrate the numerous possibilities offered. For instance, a mental speller enables words to be written 'by thought', using a famous brain signal called 'P300'. A video game inspired by a famous sequence from the movie 'Star Wars' was also developed, in which users lift a virtual spaceship in the air by way of motor imagery. After an initial baseline-measuring phase, users can perform real or imagined foot movements to lift the spaceship as if they were controlling the 'force' with their minds (see Figure 2).

The OpenViBE project continues with national funding for both advanced research on BCI and future developments of the open-source software. One follow-up project is OpenViBE2, which is funded by the French National Agency of Research and will focus on video game applications. The project will assess future impacts of BCI on video games by making prototypes and testing them in a fully 'working environment'. The OpenViBE2 project will involve ten partners (including game editor UBISOFT) and will run for three years, commencing in the fall of 2009.

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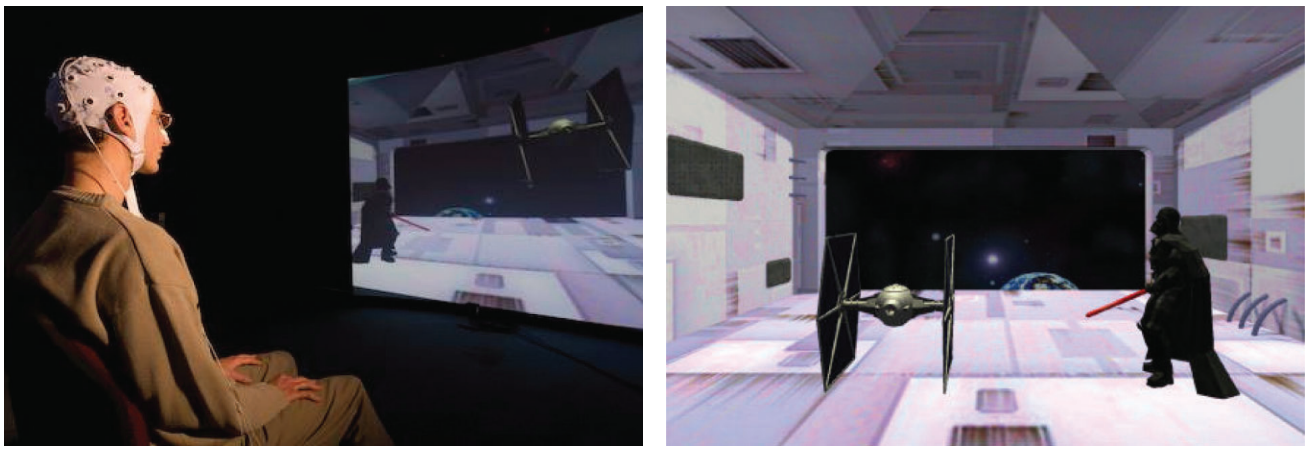

Figure 2: OpenViBE applications: virtual-reality application called 'Use-the-force', in which a participant equipped with an EEG cap is trained to control his mental activity. Imaginary foot movements control the take-off of a virtual 'tie-fighter', the famous spaceship from 'Star Wars'.

Adaptive Committees of Feature-Specific Classifiers for Image Classification

by Fabrizio Falchi, Tiziano Fagni, and Fabrizio Sebastiani

Researchers from ISTI-CNR, Pisa, are working on the effective and efficient classification of images through a combination of adaptive image classifier committees and metric data structures explicitly devised for nearest neighbour searches.

An automated classification system is normally specified by defining two essential components. The first is a scheme for internally representing the data items to be classified; this representation scheme, which is usually vectorial in nature, must be such that a suitable notion of similarity (or closeness) between the representations of two data items can be defined. Here, 'suitable' means that similar representations must be attributed to data items that are perceived to be similar. If this is the case, a classifier may identify, within the space of all representations of data items, a limited region of space where lie the objects belonging to a given class; here, the assumption of course is that data items that belong to the same class are 'similar'. The second component is a learning device that takes as input the representations of training data items and generates a classifier from them.

In this work, we address single-label image classification, ie the problem of setting up an automated system that classifies an image into exactly one from a predefined set of classes. Image classification has a long history, with most existing systems conforming to the pattern described above.

We take a detour from this tradition by designing an image classification system that uses not one but five different representations for the same data item. These representations are based on five different descriptors or 'features' from the MPEG-7 standard, each analysing an image from a different point of view. As a learning device we use a 'committee': an appropriately combined set of five feature-specific classifiers, each based on the representation of the image specific to a single MPEG-7 feature. The committees that we use are adaptive; to classify each image, they dynamically decide which of the five classifiers should be entrusted with the classification decision, or determine whose decisions should be trusted more. We study experimentally four different techniques for combining the decisions of the five individual classifiers, namely dynamic classifier selection and weighted majority voting, each of which is realized in standard and in confidence-rated forms.

As a technique for generating the individual members of the classifier committee, we use distance-weighted k nearest neighbours, a well-known example-based learning technique. Technically, this method does not require a vectorial representation of data items to be defined, since it simply requires that the distance between any two data items is defined. This allows us to abstract away from the details of the representation specified by the MPEG-7 standard, and simply specify our methods in terms of distance functions between data items. This is not problematic, since distance functions both for the individual MPEG-7 features and for the image as a whole have already been studied and defined in the literature.

Since distance computation is so fundamental to our methods, we have also studied how to compute distances between data items efficiently, and have implemented a system that makes use of metric data structures explicitly devised for nearest neighbour searching.

We have run experiments on these techniques using a dataset consisting of photographs of stone slabs classified into different types of stone. All four committee-based methods largely outperform, in terms of accuracy, a baseline consisting of the same distance-weighted k nearest neighbours fed with a 'global' distance measure obtained by linearly combining the five feature-specific distance measures. Among the four committee-based methods, the confidence-rated methods are not uniformly superior to those that do not use confidence values, while dynamic classifier selection methods are found to be definitely superior to weighted majority voting methods.

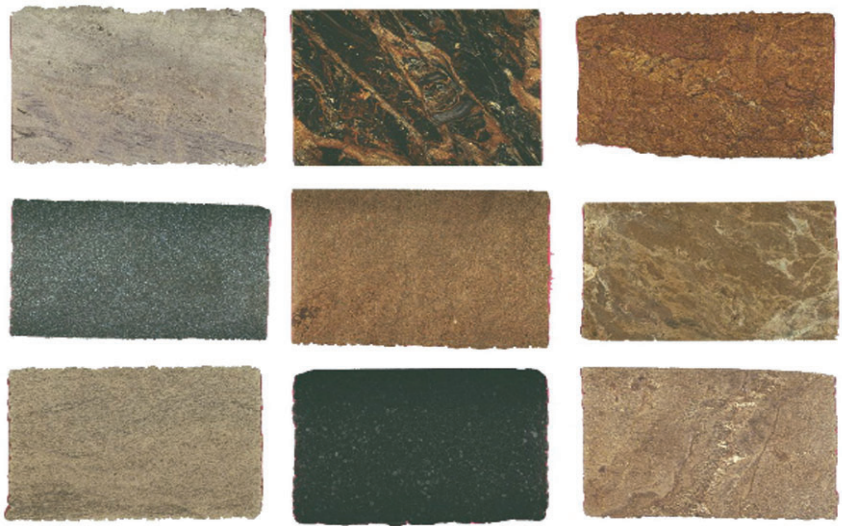

Figure 1: Photographs of stone slabs classified into different types of stone, used to experiment automated classification.

Link:
http://www.isti.cnr.it/People/F.Sebastiani/Publications/IMTA09.pdf

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3D MEDIA: A Unique Audio and Video R&D Project Spanning Wallonia

by Jacques G. Verly, Jerome Meessen and Benoit Michel

3D MEDIA is part of a new portfolio of R&D projects that will run for five years, financed by the European Regional Development Fund (ERDF). 3D MEDIA covers most scientific and technological aspects concerning the management and processing of audio and video contents. It involves the three largest Universities in Wallonia, the Faculté Polytechnique de Mons (FPMs), the Université Catholique de Louvain (UCL), and the Université de Liège (ULg); it is managed by the Multitel Research Center.

3D MEDIA has already given some spectacular results, such as NeuroTV's capability of projecting in 3D stereo a synthetic avatar ('Toon') animated backstage by an artist (see figure).

While not directly financed by the project, industry is a key player of the project. First, the consortium reaches out to the audio and video industry to identify scientific and technical problems that industry does not have the time, the manpower, or the skills to solve. These problems are turned into well-defined challenges; the universities work on them for, say, 18 months, and the results are then transferred back to industry with appropriate licensing agreements. The overall view is a series of challenges staggered in an innovation pipeline. Second, the three Universities, which are fully financed, are also free to explore more challenging and risky avenues and, where warranted, to transfer this technology to industry. Given that Multitel is only partially financed, it generally needs to find contracts with industry, which also helps in finding technical challenges for the consortium to work on. Once an idustrial partner has identified a potential partnership within the project, it can go to the regional government and ask for its own funding.

The consortium partners – Multitel, FPMs, UCL, and ULg – have complementary expertise. Early on in the 3DMEDIA project, they all listed their existing capabilities and looked for ways to combine them to come up with innovative capabilities. One approach was to identify each partner's strengths, and to look for ways in which they could be combined in visual demonstrations, which also proved to be very useful in establishing a dialog with industry.

Figure 1: During the preview of the 3D Stereo MEDIA event on 17 March 2009 in Liège, Belgium, NeuroTV showed, as a world first, the live animated character Toon in full 3D stereoscopy. Above are examples of the slightly different left-eye (left) and right-eye (right) views of a 3D projection. An overlay of both (bottom) shows the difference. (courtesy of NeuroTV, member of the 3D MEDIA project).

The different research themes of the 3D MEDIA project can be found at different points along the traditional chain of acquisition, processing, and exploitation/immersion. The project considers advanced acquisition means, such as pairs of stereoscopic cameras, multiple-camera and omni-directional-camera systems, and 3D cameras that can acquire range information directly. The use of several cameras may call for the registration of views, the reconstruction of a 3D scene, and the automatic determination of the position of the cameras. Applications often call for tracking objects and persons, for recognizing them, and for interpreting their motion. Transmission and security calls for compression and for techniques such as watermarking. Mixing real and synthetic data is becoming increasingly important. 'Match-moving' is one technique that allows this to be done automatically. Indexation, annotation, and summarizing of video are important for archiving large amounts of video data. Data mining allows one to quickly retrieve information from large databases of images. Image understanding also plays a role in man-machine interfaces, such as in recognizing gestures and facial expressions. The result of acquisition and processing must ultimately be experienced by the user. Here, we mainly talk about 3D stereo visualization and the creation of immersive acoustical and visual environments.

The application domains of 3D MEDIA are varied, such as 3D cinema, entertainment, sports, and videosurveillance. One concrete example in sports is the

automatic tracking of players from multiple cameras for resolving occlusions (TRICTRAC project), which then leads to the automatic analysis of games and, eg, to the possibility of raising an alarm in case of off-side.

As the name indicates, it was judged important by the partners of the consortium that the project have a significant 3D flavour. This is in line with the sudden acceleration of interest worldwide for everything 3D. One of the major factors behind this impetus is the arrival of digital cinema in theatres, and the fact that the jump from 2D to 3D in digital cinema is relatively straightforward, at least in terms of visualization.

To meet this exploding interest in 3D, the first author has led the organization of a new event called 3D Stereo MEDIA, which will take place in Liège, Belgium, on 1-3 December 2009, and for which a very successful preview was held on 17 March 2009. A unique feature of this event is the bringing together of artists and engineers who share a passion for 3D acquisition, processing, and stereo visualization. Importantly, the event will feature 3D projection capabilities, not only for movies but, more unusually, for scientific and technical presentations. It is during the March preview of 3D Stereo MEDIA that the Toon avatar was shown for the first time ever in 3D stereo (see figure).

Links:
http://mediatic.multitel.be/platforms/3dmedia.html
http://www.montefiore.ulg.ac.be/
http://intelsig.montefiore.ulg.ac.be/~verly/
http://www.neurotv.com
http://www.3dmedia2009.com

See also the announcement for the International 3D Stereo Film & Technology Festival on page 49 in this issue.

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Model-Based Early Warning and Decision Support to Improve Infrastructure Surveillance

by Francesco Flammini, Andrea Gaglione and Concetta Pragliola

Critical Infrastructure Protection (CIP) against both natural and intentional threats has become a major issue in modern society. CIP involves a set of multidisciplinary activities and requires the adoption of appropriate protection mechanisms operated by centralized monitoring systems. Such systems are still highly dependent on human operators for supervision and intervention. One of the challenging goals of the research community in this field is the automatic and early detection of threats, including strategic terror attack scenarios. DETECT (Decision Triggering Event Composer & Tracker) is a new framework able to recognize complex events. This is achieved by a model-based correlation of basic events detected by possibly heterogeneous sensorial subsystems.

The best way to face threats is to stop them before they cause catastrophic consequences. Unfortunately, if the sequence of events is heterogeneous, geographically distributed or rapidly evolving, visual surveillance of video streams and sensor alarms provided by current security systems does not provide operators with satisfactory situational awareness. Operators are therefore less likely to recognize sequences of events that are indicative of a possible threat, due to their limited alert threshold and knowledge base. Furthermore, operators cannot guide and coordinate alarm responses or emergency interventions if they are not precisely aware of what is happening or has happened. The adoption of early warning and decision support systems is a way of coping with these issues.

To this end, we have designed the DETECT framework. The basic assumption behind the framework is that threats can be detected by predicting the set of basic events (ie the patterns) that constitute their 'signature'. For instance, Figure 1b shows the multi-layered asset protection provided by modern security systems. In each layer a set of sensors (eg video, motion, temperature, vibration, sound, smoke) are installed. Threat scenarios must be precisely identified during vulnerability assessment and risk analysis.

DETECT operates by performing a model-based logical, spatial and temporal correlation of basic events detected by different sensor subsystems, in order to recognize sequences of events which indicate likely threats. DETECT is based on a real-time detection engine which implements the concepts of data fusion and cognitive reasoning by means of soft computing approaches. The framework can be interfaced or integrated with existing SMS (Security Management Software). It can serve as an early warning tool or even to automatically trigger adequate countermeasures for emergency/crisis management. As such, it may allow for a quick, focused and automatic response to emergencies, though manual confirmation of detected alarms remains an option.

In fact, human management of critical situations, possibly involving many simultaneous events, is a very delicate task that is both prone to error and subject to forced inhibition. Used as a warning system, DETECT can alert operators to the likelihood and nature of a threat; used as an autonomous reasoning engine, it can activate responsive actions, including audio and visual alarms, unblocking of turnstiles, air-conditioning flow inversion, activation of sprinklers, and emergency calls to first responders. Furthermore, the correlation among basic events detected by diverse redundant sensors can be employed to lower the false alarm rate of the security system, thus improving its overall reliability.

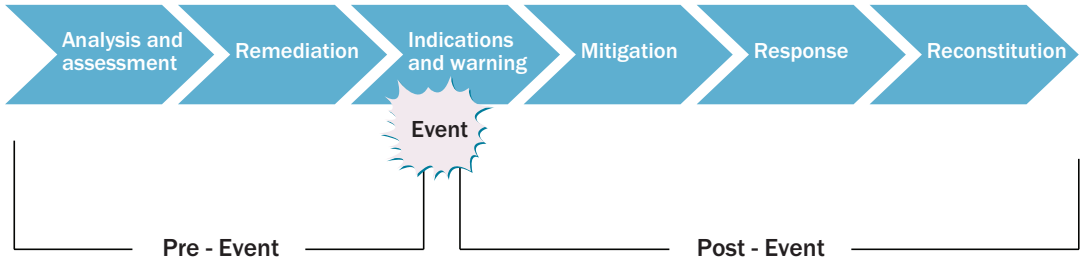


Figure 1a: CIP protection life-cycle.

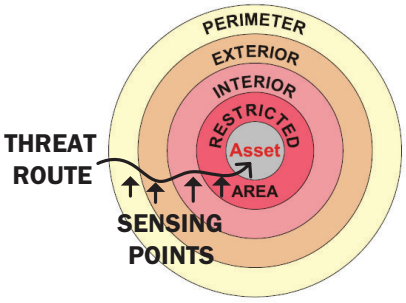


Figure 1b: multi-layer sensing in modern security systems.

Threats are described in DETECT using a specific Event Description Language (EDL) and stored in a Scenario Repository. Starting from this repository, one or more detection models are automatically generated using a suitable formalism (eg event graphs, Bayesian networks, neural networks etc). In the operational phase, a model manager macro-module performs queries on the Event History database for the real-time feeding of the detection model according to predetermined policies. When a composite event is recognized, the output of DETECT consists of the identifier(s) of the detected/suspected scenario(s); an alarm level, associated to the scenario evolution (used as a progress indicator); and a probability of attack (used as a threshold in heuristic detection). A high-level architecture of the framework is depicted in Figure 2.

Together with a sensor network integration framework, DETECT can perform fusion and reasoning of data generated by smart wireless sensors. To this aim, DETECT is being integrated with SeNsIM (Sensor Networks Integration and Management), as illustrated in Figure 4. SeNsIM is a framework used to integrate heterogeneous and distributed sensor systems (including ad-hoc networks), by offering the user a common view of all data sources.

We are currently working on the implementation of a detection model based on Bayesian networks. The next operational step will be to interface the overall system with a real security management system for field trials. The integration will be performed using Web services and/or the OPC (OLE for Process Communication) standard protocol.

DETECT is a collaborative project carried out by the Innovation Unit of Ansaldo STS Italy and the Department of Computer and Systems Engineering (Dipartimento di Informatica e Sistemistica, DIS) at the University of Naples 'Federico II'.

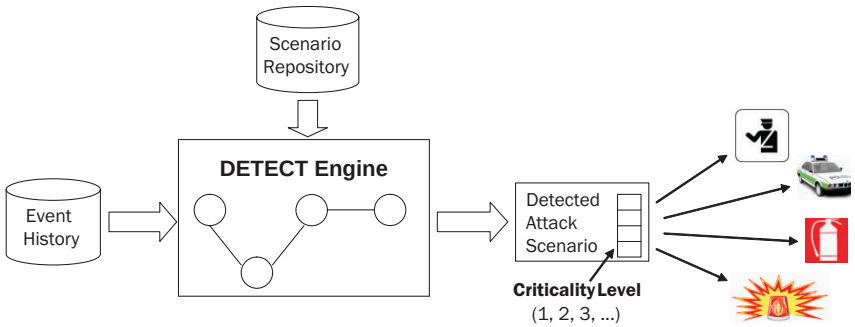
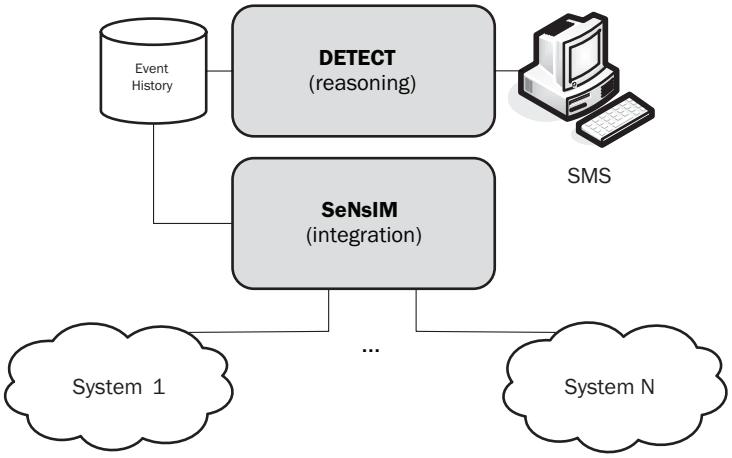


Figure 2a: The DETECT framework (top) and its integration with external systems (Figure 2 b below).



Link:
DETECT and SeNsIM project pages in the Seclab research group Web site:
http://www.seclab.unina.it/

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Evolutionary Testing for Complex Systems

by Tanja E. J. Vos

Complex systems exhibit emergent behaviour, which makes them hard to predict. This presents particularly challenging problems during testing. However, this is a challenge that simply cannot be avoided: testing is a vital part of the quality assurance process. With important partners from Spain (ITI), UK (Kings College), France (INRIA), Germany (Fraunhofer, Daimler, BMS), Bulgaria (RILA) and Greece (European Dynamics), the EvoTest project, funded under the 6th Framework programme (IST-33742), is attacking the problem of testing complex systems using evolutionary algorithms.

The EvoTest project addresses a fundamental problem faced by the European software industry: quality assurance of complex software systems. There is strong empirical evidence that deficient testing of both functional and non-functional properties is one of the major sources of software and system errors. Even though many test automation tools are currently available to aid test planning and control as well as test case execution and monitoring, all these tools share a similar passive philosophy towards test case design, selection of test data and test evaluation. They leave these crucial, time-consuming and demanding activities to the human tester. This is not without reason; test case design and test evaluation are difficult to automate with the techniques available in current industrial practice. The domain of possible inputs (potential test cases), even for a trivial program, is typically too large to be exhaustively explored. One of the major challenges associated with test case design is the selection of test cases that are effective at finding flaws without requiring an excessive number of tests to be carried out. This is the problem that EvoTest has taken on.

The strategy is to combine various visions of the IST programme: a multi-disciplinary approach to evolving, adaptive and automated testing as a solution to some of the challenges of mastering complexity in software development. During its running period, 2006-2009, the project has successfully developed, applied and evaluated Evolutionary Testing techniques. Evolutionary Testing is an exciting, novel, nature-inspired solution, which transforms testing into an optimization problem. This allows the problem to be attacked using search techniques inspired by Darwinian evolution. To increase the test efficiency for complex systems EvoTest has developed an Automated Evolutionary Testing Framework. This framework is able to automatically search for high-quality test cases with a high probability of error detection. Automation is widely regarded as the key to efficient testing.

The impossibility of anticipating or testing all possible uses and behaviours of a (complex) system suggests a prominent role for Evolutionary Testing, because it relies on very few assumptions about the underlying problem it is attempting to solve. In addition, optimization and search techniques are adaptive and, therefore, able to modify their behaviour when faced with unforeseen situations. These two properties make evolutionary testing approaches ideal for handling complex systems.

Black-box evolutionary testing at Daimler.

EvoTest has reached the following objectives:

- An extensible and open Automated Evolutionary Testing Framework has been developed. The framework provides general components and interfaces to facilitate the automatic generation, execution, monitoring and evaluation of black-box and white-box testing of C programs.
- The performance and the quality of the Evolutionary White-box Testing has been increased by combining evolutionary testing with other software engineering techniques, such as slicing and program transformation. These advanced techniques have been tailored both to reduce the size of the search space and to transform the search space.
- The EvoTest tools and techniques have been evaluated using real-world case studies from the automotive and telecommunications industries. Case studies have been performed for black-box and white-box testing activities.

EvoTest results have made it abundantly clear that evolutionary testing holds great promise as a solution to many challenges faced by the software industry. Future work on Evolutionary Testing should concentrate on theoretical foundations, search technique improvements, new testing objectives, tool environment/testing infrastructure, and new application areas.

The EvoTest project has brought together European entities that are world leaders in this emerging field. ITI (Spain) is project coordinator and research partner providing expertise in software testing and evolutionary computation. Moreover, ITI acts as software developer, implementing various components of the Framework. INRIA (France) serves as research partner providing expertise in evolutionary computation. Fraunhofer FIRST

(Germany) is a research partner providing expertise in software development, technology, validation and verification. Kings College (United Kingdom) is a research partner providing expertise in software engineering techniques like slicing and program transformations. Daimler (Germany) is a case study provider of a complex automotive application. Moreover, they serve as research partner contributing expertise on evolutionary testing. Berner & Mattner (Germany) is a case study provider of testing infrastructure. Rila (Bulgaria) is a case study provider of a complex accessibility solution, and acts as a software developer. European Dynamics (Greece) is a technology provider and software developer.

Link:
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The WPU Project: Web Portal Usability

by Janne Jul Jensen, Mikael B. Skov and Jan Stage

The Web Portal Usability (WPU) project is working on usability engineering methods, which are important in the development of Web portals. These methods are tested with companies that design modern Web portals.

Usability evaluation and user interaction design are two key activities in the development of an interactive system. They are mutually dependent, but in practice there is often little or no fruitful interplay between them. Considerable efforts have been devoted to improving the interplay between usability evaluation and software development, with two approaches being typical. The first focuses on better methods, and the second on better feedback.

Compared to these approaches, Web site development is particularly challenging. Web sites involve vast amounts of information, services and purchasing possibilities, and the users are a tremendously heterogeneous group who employ Web sites for a multitude of purposes. Because of this, Web site developers must accommodate the massive variety in user preferences and capabilities.

Yet many contemporary Web sites suffer from problems with low usability. The challenges of developing user-friendly Web portals originate from two major sources. First, the projects that develop Web portals usually have a very short duration. Second, the users of most Web portals are exceedingly diverse.

Usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 1998). The purpose of conducting usability evaluations is to facilitate a feedback loop: the results of a usability evaluation are fed back into the software development activities that create and shape the product in order to enhance usability.

State-of-the-art usability engineering methods have had so far a very limited influence on Web portal development, because they provide very few solutions to the main challenges. Extensive research has documented the fact that users encounter serious problems when they use Web services, wasting large amounts of time and often giving up before they achieve what they set out to do.

The WPU project is based on the following hypotheses:

1. The usability of Web portals can be improved considerably by applying selected usability engineering methods that are tailored to this domain.

2. It is possible to develop usability engineering methods that are directly relevant to Web portal development, and to reduce the demands for resources and expertise to a level where these methods can be integrated with Web portal projects.

The aim of the WPU project is to confirm these hypotheses by developing and testing usability engineering methods. The project will produce the following results:

- a set of new methods for usability engineering in Web portal development
- a set of guidelines for selection and application of the methods
- a training programme for Web portal developers
- research training for two PhD students and a post-doctoral researcher.

The WPU Project will involve a combination of state-of-the-art survey, method creation, method training and experimental assessment. The state-of-the-art survey will collect experiences with usability issues in Web portal development that are documented in the literature. The method creation will build the catalogue of methods that will be a key result of the project. This will include the experiences and the list of fragments of usability engineering methods compiled in the state-of-the-art survey. Method training will involve the design of training programmes for the methods created in the project, and the use of these programmes in a participating company. The experimental assessment will collect experience with the new methods. The quality of the methods will be assessed through a series of experiments, conducted by a participating software company and in a laboratory setting.

The project is supported in part by the Danish Research Councils under grant number 2106-08-0011. It also receives support from Aalborg University and the two participating companies.

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ADOSE: New In-Vehicle Sensor Technology for Vehicle Safety in Road Traffic

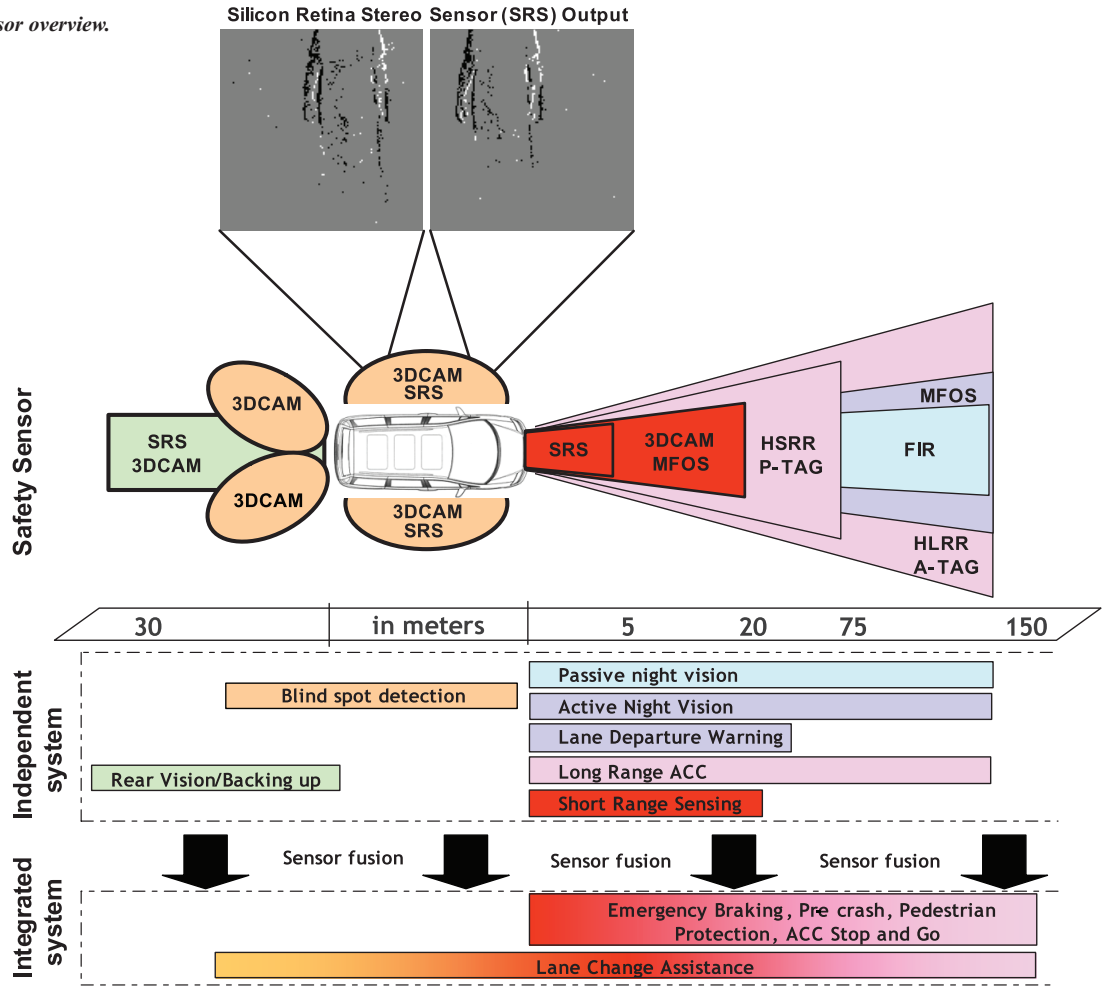
by Jürgen Kogler, Christoph Sulzbachner, Erwin Schoitsch and Wilfried Kubinger

Reliable Advanced Driver Assistance Systems (ADAS) aid drivers in a variety of traffic and environment/weather conditions. Growing traffic volumes require sensors and systems that handle difficult urban and non-urban scenarios. For such systems, the EU FP7 project ADOSE is developing and evaluating new cost-efficient sensor technology that will provide vehicles with a 'virtual safety belt' by addressing complementary safety functions.

The EU-funded project ADOSE (reliable Application-specific Detection of road users with vehicle On-board SEnsors), coordinated by Centro Ricerche Fiat (CRF), is evaluating new sensors and sensor systems. Such sensors are necessary for ADAS like lane departure warning, collision warning or high-beam assist. Figure 1 illustrates the various sensors from different project members. Additionally, the operating distance of each sensor and examples of its use are depicted.

Cost-effective solutions for ADAS are still missing, which is preventing both extensive market penetration and an increase in the number of sensors and supported safety functions. Studies were performed in 2005 to evaluate customers' desire and willingness to pay for active and passive safety systems in passenger cars (Frost & Sullivan, European Markets for Advanced Driver Assistance Systems, B844-18, (2006)). In general, the price that consumers are willing to pay for their ideal package of safety fea-

Figure 1: Sensor overview.



tures is significantly lower than what they perceive its market price to be. Researchers and manufacturers therefore need to find ways to reduce the prices of safety options to increase customer acceptance. For this reason, it is critical to develop and implement high-performance sensors that considerably reduce the costs of ADAS for safety in passenger cars. As an example, the penetration of ADAS dependent on classical vision sensors in the highly cost-driven automotive market is still limited by the cost of the electronics required to process images in real time.

The five sensor technologies to be developed further are (partners in brackets):

- far infrared (FIR) add-on sensor with good thermal and spatial resolution at lower cost, to be combined with a high-resolution imager for enhanced night-vision applications (more reliable obstacle detection and classification) [Bosch]
- low-cost multi-functional CMOS vision sensor, detecting critical environmental parameters (fog, rain etc) and providing information on the driving scenario (oncoming vehicles, vulnerable road users (VRUs) in night conditions) [CRF, STMicroelectronics, Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM)]
- high spatial resolution and low-cost 3D range camera based on 3D packaging, optical CMOS and laser radar technology for short-range safety requirements (eg for pre-crash) [Interuniversity MicroElectronics Centre (IMEC)]
- harmonic radar combined with passive nonlinear reflective and active tags enabling easy detection and identification of traffic obstacles and vulnerable road users, even in dark or adverse weather conditions [Valtion Teknillinen Tutkimuskeskus (VTT), Triad, Uppsala University]
- high temporal resolution and low-cost bio-inspired silicon retina stereo sensor (SRS), addressing time-critical decision applications [Austrian Institute of Technology (AIT)].

The approach of the Austrian Institute of Technology (AIT) to reducing the costs of ADAS is to use an SRS. An SRS is a vision-based sensor that delivers information about the illumination changes ('events') in the visual field. Figure 1 illustrates an example of the SRS output, which rather than reflecting static images, records events when either the object or the vehicle (or both) are moving. Derived from the human vision system, the bio-inspired silicon retina sensor is a new type of imager. It detects intensity changes in an observed scene, with each pixel delivering its address and event data separately and independently. This type of sensor is intended to overcome certain obstacles in classical vision systems: high temporal resolution allows quick reactions to fast motion in the visual field, on-sensor pre-processing significantly reduces both memory requirements and processing power, and wide dynamic range helps in the difficult lighting situations encountered in real-world traffic.

The SRS is specifically tailored to serve as a pre-crash warning and preparation sensor for side impacts. Pre-crash applications must reliably react in real time to prepare the vehicle (eg activate the pretensioner, preparation of a side airbag) for the imminent impact (which, in case of side impact, cannot be avoided by a reasonable reaction of the impacted vehicle). For the pre-crash sensor, it is necessary to take distance measurements of objects approaching the sensor. Two silicon retinas have therefore been coupled to a stereo vision unit, allowing depth information to be extracted from moving objects in the viewed scenery. Before the depth information is available, it is necessary to match the corresponding SRS data in the acquired left and right images. The so-called 'stereo-matching' step is an essential part of each stereo vision system. A new kind of stereo vision algorithm has been developed within the ADOSE project especially for the silicon retina sensors, along with advanced sensors with higher resolution than ever before.

Links:
http://www.adose-eu.org
http://www.arcs.ac.at
http://www.smart-systems.at

Please contact:
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SAFECOMP 2009 28th International Conference on Computer Safety, Reliability and Security

Hamburg, Germany,
15-18 September 2009

SAFECOMP focuses on state-of-the-art and innovative approaches to risk assessment and management from the safety, security and reliability viewpoints. The scope includes IT systems and infrastructures considered critical within their present or emerging contexts. All aspects of dependability and survivability of critical computer-based systems and infrastructures are included. In particular, SAFECOMP emphasises multidisciplinary approaches to deal with the nature of complex critical IT systems and applications.

SAFECOMP offers a platform for knowledge and technology transfer between academia, industry, research institutions and licensing bodies.

Topics to be presented include application and industrial sectors,such as aerospace and avionics, automotive, industrial process control, networking & telecommunication, railways, robotics, medical systems, off-shore technology, ship building, internatioinal safety and security guidelines and standards, power systems; as well as research areas such as safety & security risk assessment, design for dependability, diversity, fault tolerance, verification & validation, testing, education & training, human-factors, dependability analysis and modelling.

The ERCIM Working Group on Dependable Embedded Systems will hold a joint workshop at SAFECOMP 2009 in cooperation with EWICS - the European Workshop on Industrial Computer Systems Reliability, Safety and Security and the DECOS (Dependable Embedded Components and Systems) interest group.

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

CALL FOR PARTICIPATION

FMICS 2009 - 14th Intl. ERCIM Workshop on Formal Methods for Industrial Critical Systems

Eindhoven, The Netherlands, 2-3 November 2009

The aim of the 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 are intended to bring together scientists and practitioners who are active in the area of formal methods and interested in exchanging their experiences in the industrial usage of these methods. These workshops also strive to promote research and development for the improvement of formal methods and tools for industrial applications.

Invited Speakers

This year, FMICS will feature four outstanding invited speakers - two outstanding scientists and two prominent industrialists working in top companies with an emphasis on formal methods for critical systems :

- Dino Distefano, Queen Mary, Univ. London, UK
- Diego Latella, ISTI-CNR, Italy
- Thierry Lecomte, ClearSy, France
- Ken McMillan, Cadence, USA

Accepted Papers

- J. B. Almeida, M. Barbosa, J. Sousa Pinto and B. Vieira: 'Correctness with respect to reference implementations'
- D. Delmas, E. Goubault, S. Putot, J. Souyris, K. Tekkal and F. Védrine:'Towards an industrial use of FLUCTUAT on safety-critical avionics software'
- J de Dios and R. Pena: 'A Certified Implementation on top of the Java Virtual Machine'
- S. Evangelista and L. M. Kristensen: 'Dynamic State Space Partitioning for External and Distributed Model Checking'
- A. Goodloe and C. Munoz: 'Compositional Verification of a Communication Protocol for a Remotely Operated Vehicle'
- J. Mariño, Á. Herranz, M. Carro and J. J. Moreno-Navarro: 'Formal modeling of concurrent systems with shared resources'
- P. Parizek and T. Kalibera: 'Platform-Specific Restrictions on Concurrency in Model Checking of Java Programs'
- M. Raffelsieper, M. Reza Mousavi, J.-W. Roorda, C. Strolenberg and H. Zantema: 'Formal Analysis of Non-Determinism in Verilog Cell Library Simulation Models'
- E. Schierboom, A. Tamalet, H. Tews, M. van Eekelen and S. Smetsers: 'Preemption Abstraction: a Lightweight Approach to Modelling Concurrency'
- K. J. Turner and K. Leai Larry Tan: 'A Rigorous Methodology for Composing Services'.

Accepted Posters

- A. Ferrari, A. Fantechi, S. Bacherini and N. Zingoni: 'Formal Development for Railway Signaling Using Commercial Tools'
- N. Izerrouken, M. Pantel, X. Thirioux and O. Ssi yan kai: 'Integrated Formal Approach for Qualified Critical Embedded Code Generator'
- L. Ladenberger, J. Bendisposto and M. Leuschel: 'Visualizing Event-B models with BMotionStudio'
- A. Mathijssen, Y. S. Usenko and D. Bosnacki: 'Behavioural Analysis of an I2C Linux Driver
- W. Mostowski, E. Poll, J. Schmaltz, J. Tretmans and R. Wichers Schreur:'Model-Based Testing of Electronic Passports'
- L. Panizo, M. M. Gallardo, P. Merino and A. Linares: 'Developing a decision support tool for Dam management with SPIN'

FMICS 2009 is part of the first Formal Methods Week (FMweek), which will bring together a choice of events in the area. For the latest information on FMweek, see http://www.win.tue.nl/fmweek.

Organisation

- PC co-Chairs:María Alpuente (T. U. Valencia, Spain) and Byron Cook (Microsoft, UK)
- Workshop Chair: Christophe Joubert (T. U. Valencia, Spain).

More information:
http://users.dsic.upv.es/workshops/fmics2009/

Competition on Plagiarism Detection - 3rd Intl. PAN Workshop on Uncovering Plagiarism, Authorship and Social Software Misuse

Donostia-San Sebastián, Spain, 10 September 2009

The detection of plagiarism by hand is a laborious retrieval task, a task which can be aided or made automatic. The PAN competition on plagiarism detection shall foster the development of new solutions in this respect. The competition has two main tracks:

- External Plagiarism Analysis - the task is to find all passages within the suspicious documents which have been plagiarised from one or more of the source documents.
- Intrinsic Plagiarism Analysis - the task is to detect paragraphs, in a set of suspicious documents, which have not been written by its main author.

The competition, which is sponsored by Yahoo! Research, raised interest among scientists, companies, private groups (more than 20 teams from all over the world have registered) as well as in the media.

More information:
http://www.webis.de/pan-09/competition.php

CALL FOR PARTICIPATION

3D Stereo MEDIA – International 3D Stereo Film & Technology Festival

Liège, Belgium, 1-3 December 2009

Imaging is undergoing a true revolution: 3D stereo imaging. While the tip of the iceberg of this revolution is 3D cinema - with the number of 3D-equipped movie theaters and 3D movies quickly increasing – 3D stereo visualization will increasingly be found elsewhere, eg in the home (TV, games, cell phones, etc.), in science and engineering, and in communication and advertising.

The event will feature both a technology festival and a film festival. The technology festival will consist of a main track of presentations and panels (sometimes with two parallel sessions) and of a technical exhibition. Ben Stassen, a pioneer in 3D movie making, and author of "Fly me to the moon," will be the President of Honor of the festival. He will give a preview of his new movie "Around the world in 50 years." The film festival will be open to the general public. Since 3D stereo imaging is of interest to people with a wide variety of backgrounds (artists, scientists/engineers, communication/advertising experts, business people, etc), the conference programme will be designed in such a way that the main track will be appealing to all. The goal is to foster the get-together and interaction of, say, artists and engineers.

The high-level themes of the technology festival are the fundamentals of 3D (stereoscopy, holography, 3D displays), 3D in cinemas and homes ('3D at home'), 3D visualization in science and engineering, 3D visualization in advertising and communication, advanced topics in 3D acquisition, processing, communication, and visualization (including integral imaging, free-viewpoint TV, and multiview imaging), and the applications of 3D visualization in science and engineering (design and conception; architecture and urban planning; cartography, geomatics, and remote sensing; security and defense; space exploration and astronomy; radar, IR, UV, and passive MMW imaging; simulators for vehicles, defense, and training; guidance, control, and navigation; microscopy, etc.). Medical imaging and life sciences will be covered in a separate event to be held in the spring of 2010.

Throughout the main track of presentations, several commented clips of 3D movies will be shown. Needless to say that our conference rooms will be equipped with 3D stereo visualization equipment, both for movie projection and for technical presentations. The event will also feature training sessions in 3D stereo movie making, some with hands-on workshops (limited to small groups). These sessions will be organized by the stereographers Kommer Kleijn and Peter Wilson, and will take place immediately before and after the main event. Companies interested in sponsoring the event and in renting a booth in the exhibition area should contact the organizers.

More information: http://www.3dmedia2009.com

Two Networking Workshops in Zurich in November

On November 9-10, 2009 in Zurich, Switzerland, two workshops will be held:
the 4th Workshop on "The Future Internet" and the 2nd Workshop on "Economic Traffic Management"

The two main goals of the 4th GI/ITG Kommunikation und Verteilte Systeme [Communication and Distributed Systems] (KuVS) Workshop on Future Internet and the 2nd Workshop on Economic Traffic Management (supported by the FP6 EMANICS Network of Excellence and the FP7 STREP SmoothIT) are to give scientists, researchers, and operators the opportunity to present and discuss their ideas in these areas as well as strengthening the cooperation in the field of an economic-technology interplay.

The set of topics of these two combined workshops are focused on but not limited to:

- Cloud and Grid computing infrastructures
- SLA and service management
- Energy efficiency and green ICT
- Service-oriented networks and infrastructures
- Content-based routing
- Routing mediation (pub/sub)
- Economic traffic management mechanisms
- Separating of identity and address (locator/ID split)
- Infrastructure/ Platform as a Service
- Cross-layer design, cross-layer optimization
- Predictable QoS and Quality-of-Experience
- Next generation transport, e.g., carrier grade Ethernet
- Network management and control plane
- Sensors networks and applications
- Distributed control and management approaches
- Network virtualization and segmentation
- Future network and services business models
- Regulatory effects on networks and infrastructure
- Future mobile network and
- Clean-slate architectures.

These two workshops will take place at the University of Zurich (UZH), CSG@IFI, in Zurich, Switzerland. They are organized jointly by the Communication Systems Group CSG of UZH and SAP Research, Zurich, Switzerland.

More information: http://www.csg.uzh.ch/events/fi-etm

Future Internet Conference supported by ERCIM

ERCIM was a sponsor of the Future of Internet Conference, a Czech EU Presidency conference on the perspectives emerging from R&D in Europe, held in Prague on 11-13 May 2009. The latest issue of ERCIM News featuring a special theme on 'Future Internet Technology' was distributed to the more than 500 participants. Together with the sponsorship, it contributed to the success of the conference.

More information: http://www.fi-prague.eu/

Stefano Baccianella Winner of the 2009 “Franco Denoth Award“

Stefano Baccinella, of ISTI-CNR, Pisa, Italy, is the winner of the 2009 “Franco Denoth Award“. The award, now at its first edition, is granted by the "Fondazione Franco ed Enrico Denoth" in memory of Franco Denoth, computer science pioneer and, among others, former member of the ERCIM Board of Directors (see ERCIM News 72 for a tribute to Franco on the occasion of his death). The 2009 “Franco Denoth Award“ is granted to the best MSc thesis obtained in 2008 from the University of Pisa, dealing with issues related to the development of the Internet. Stefano obtained his MSc degree in Computer Science with a thesis entitled “Multi-Facet Rating of Online Hotel Reviews: Issues, Methods and Experiments”, carried out under the supervision of Andrea Esuli and Fabrizio Sebastiani, both of ISTI-CNR (see ERCIM News 77, pp. 60-61 for a brief description of Baccianella's thesis work). Stefano’s thesis is now a book, published by VDM Verlag, Saarbrücken, Germany. Stefano is currently pursuing a PhD in Information Engineering at the University of Pisa.

Gabriella Petri Denoth presenting the award to Stefano Baccianella.

EEES: Elite Education in Embedded Software

In April 2009, the Danish Ministry of Science gave the official approval of the elite master education in embedded software at Aalborg University. In total only 20 educations were approved in Denmark, and at Aalborg University in addition to embedded systems three other educations were approved, including wireless communication, biotechnology, and tourism. The elite education in embedded software aims at recruiting top bachelor candidates with the ambition of carrying out their master education in close collaboration with the research at CISS, Center for Embedded Software Systems. The educational program in embedded software includes also the aspects of hardware architecture and control theory. With the approval of the the education comes a grant to cover the extra curriculum activities, including participation in PhD schools, conferences and workshops as well as investment in special purpose equipment and software. The intension is to recruit approximately ten qualified Danish and international students.
http://eliteeducation.aau.dk/
http://www.eliteuddannelser.aau.dk/uddannelsesliste/3803886

Graduated Elite students of 2008.

SpaRCIM Appoints New ERCIM Representatives

During 2008, new representatives for SpaRCIM (Spanish Research Consortium for Informatics and Mathematics) in ERCIM have been appointed. Founding president of SpaRCIM, Juan José Moreno-Navarro, was nominated General Director for Technology Transfer at the Ministry of Science and Innovation (Ministerio de Ciencia e Innovación). Manuel Hermenegildo, IMDEA Software and Technical University of Madrid, was elected as the new SpaRCIM director and representative on the ERCIM Board of Directors. In January 2008, the ERCIM Executive Committee representative, Ernesto Pimentel, was replaced by Pedro Merino, University of Malaga. In December 2008, Christophe Joubert, Technical University of Valencia replaced Salvador Lucas as Spanish local editor on the ERCIM News editorial board. And SpaRCIM’s national contact for the ERCIM Fellowship Programme, Fernando Orejas, was substituted by Javier Larrosa, Technical University of Catalonia. SpaRCIM represents Spanish computer science in ERCIM. It is currently spread over five universities and one research institute from the Spanish Research Council (CSIC).

From right to left: Juan José Moreno-Navarro, Manuel Hermenegildo, Pedro Merino and Christophe Joubert during the ERCIM Days and 20th anniversary of ERCIM in Paris, 28 May 2009.

ERCIM
European Research Consortium for Informatics and Mathematics

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.

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
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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 Wiskunde & Informatica
Centrum Wiskunde & Informatica
Science Park 123,
NL-1098 XG Amsterdam, The Netherlands
http://www.cwi.nl/

danaim
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http://www.danaim.dk/

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http://www.fnr.lu/

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

Fraunhofer Gesellschaft
Fraunhofer ICT Group
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http://www.iuk.fraunhofer.de/

INRIA
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et en Automatique
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http://www.inria.fr/

IUA
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http://ercim.computing.dcu.ie/

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SARIT
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MTA SZTAKI
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http://www.sztaki.hu/

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