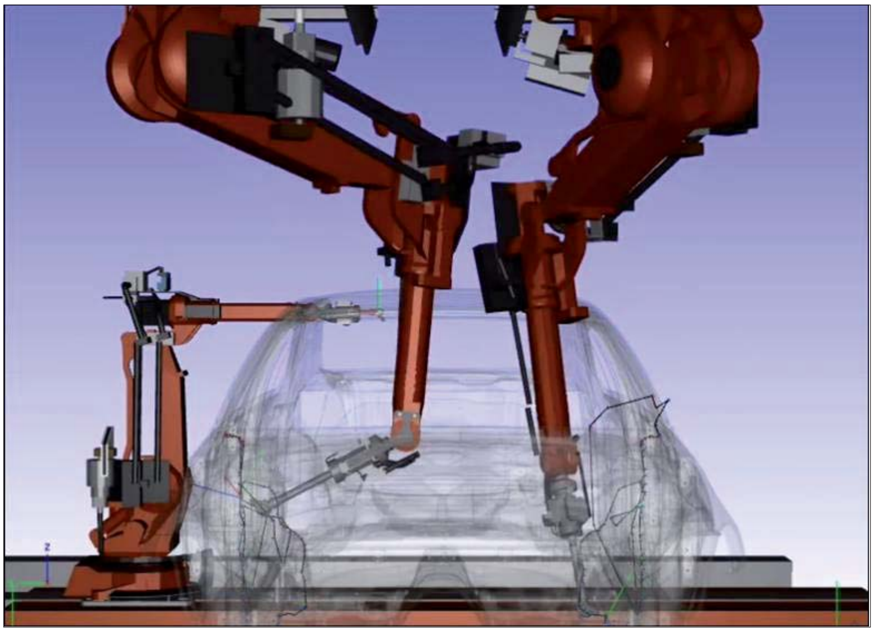
Fraunhofer
CHALMERS
Research Centre
Industrial Mathematics

Annual Report 2006



FCC

Fraunhofer-Chalmers Research Centre for Industrial Mathematics

This and other FCC reports are distributed by

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Cover

The front cover shows robots waiting for each other in order to avoid collisions and minimize cycle time, cf page 34 (courtesy of Volvo Car Corporation).

Illustrations

To illustrate our research on pages 12 - 45 we use Swedish inventions, cf the inner back cover.

Annual Report 2006

Fraunhofer-Chalmers Research Centre for Industrial Mathematics, FCC

Editors: Annika Eriksson, Uno Nävert
Layout: Annika Eriksson
Print: stromia.se
Published in May 2007

Contents

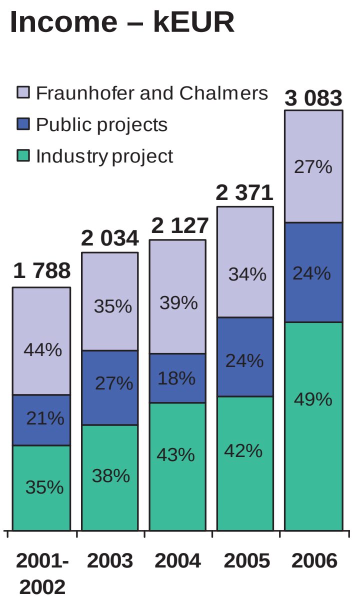
Preface

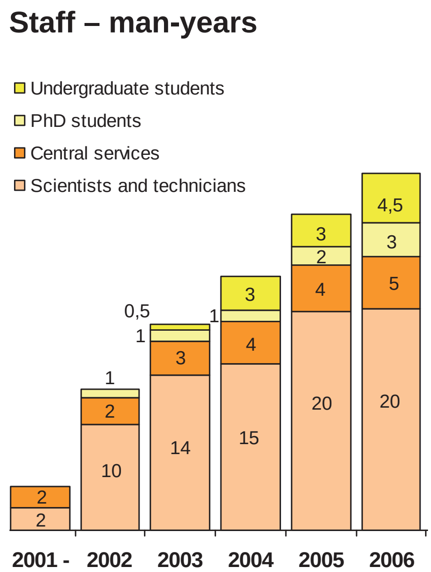
FCC operates in Chalmers Science Park.

After the successful build-up of FCC in 2001-2005 the Centre has entered a strategic expansion phase 2006-2010. Several important goals were achieved already in 2006. In particular, the income level passed three million euros while keeping the unbroken sequence of positive nets, this year being five percent on turnover.

Together with our partners Chalmers and the Fraunhofer industrial mathematics institute ITWM we cover a wide range of applications. In 2006, the project flow to ITWM increased to just below half a million euros. The start of the Gothenburg Mathematical Modelling Centre (GMMC) run by Mathematical Sciences 2006-2010 and the go-ahead decision for a Vinnex Centre run by the Wingquist Laboratory 2007-2016 are two prestigious Swedish strategic initiatives at Chalmers where FCC participates.

The diagrams below show the development of the centre in terms of income and staff.





The profile of the Centre is controlled by its income structure. The result of 2006 is well in line with the Fraunhofer financial model, i e, the project volumes from industry (49%), public financiers (24%), and Fraunhofer and Chalmers (27%) are well in balance.

www.fcc.chalmers.se

The department Geometry and Motion Planning, working in close co-operation with the Chalmers Wingquist Laboratory, has established an income level well above one million euros. The activities 2006 include the start of a second Vinnova MERA project, rapidly growing income from path-planning software licences, and substantial joint development with the ITWM department Dynamics and Durability.

The department Computational Engineering and Optimisation has expanded its work on electromagnetics simulation with leading Swedish industrial partners and by signing a long-term agreement with the recently started company Efield. The department has also launched strategic projects with the ITWM department Transport Processes and with the Optimisation department.

The department Risk Management has initiated a joint work with Chalmers and Fraunhofer ITWM on load analysis for automotive applications with six European truck manufacturers from Germany, Italy, The Netherlands, and Sweden. In finance and insurance, we have built software platforms for Asset Liability Management and Collateral Debt Obligations together with ITWM.

The Bio department has successfully continued its transformation towards a higher proportion of industrial income. In 2006, the income from other sources significantly exceeded the long-time grant from the Swedish Foundation for Strategic Research SSF.

I thank my co-workers at FCC for your excellent work and my colleagues at Chalmers and Fraunhofer ITWM for our fruitful collaboration. From 2001 we have started more than 200 projects, 170 of which have been completed and 40 of which are running, with companies and organizations of different size and from different branches.

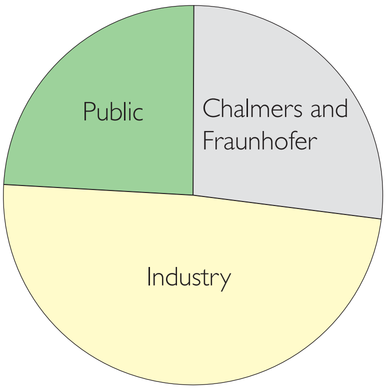
Göteborg in May 2007

Uno Nävert
Director

Uno Nävert, Director of FCC.

Profile

Mathematics has become a key technology for industrial innovation since mathematics is behind all work in the virtual world.



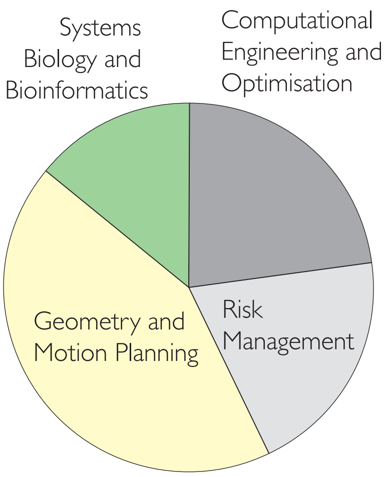
Project mix by income.

The Fraunhofer-Gesellschaft and Chalmers have founded FCC to undertake and promote scientific research in the field of applied mathematics to the benefits of Swedish and European industry, commerce, and public institutions. To do so the Centre undertakes scientific research and marketing financed by the founders and by public institutes, and works on projects defined by companies on a commercial basis.

FCC is an example of a bottom-up strategy to build the European research space. First we define a small network of closely (daily) co-operating research institutes. To solve concrete problems from companies from all over Europe, we then create optimal teams built out of this network. We do this in the field of mathematics, which is a key technology for industrial innovation, lying behind all work in the virtual world, e g, simulation for prediction, control, optimisation, and risk assessment.

By the end of 2006 the staff was twentyeight full-time equivalents, including four scientific advisers from Chalmers, each one working 10 percent to 20 percent of full time at FCC.

FCC undertakes scientific research financed by its founders and by public institutes.



Departments by income.

Scientific competence

The Centre undertakes scientific research projects and marketing of scientific results financed by its founders and by public institutes. Respecting the confidentiality of data from customers, the Centre encourages the publication of results. FCC supports efforts to use its research for educational purposes at all levels at Chalmers as well as at other educational institutions in Sweden and Europe. FCC sponsors PhD work, if the subjects are of basic interest for the research in the Centre. FCC keeps contact with the worldwide community of applied mathematicians by active participation in conferences and by inviting guest scientists.

In 2006 the Centre has received public grants from SSF (Swedish Foundation for Strategic Research), Vinnova (Swedish Agency for Innovation Systems), and EU (Network of Excellence Biosim).

Entrepreneurial competence

The Centre served thirty industrial clients in 2006. One of the largest customer is the Swedish Society for Applied Mathematics, STM, a consortium of companies with business in Sweden. A list of the members of STM, and of industrial (and public) clients since start, is shown on page 7.

Experiences from Fraunhofer show that small and medium size companies constitute an important market for an industrial mathematics institute. The number of SME projects at FCC is however still only marginal.

In 2006 the Centre has served international industrial clients from France, Germany, Italy, and the Netherlands.

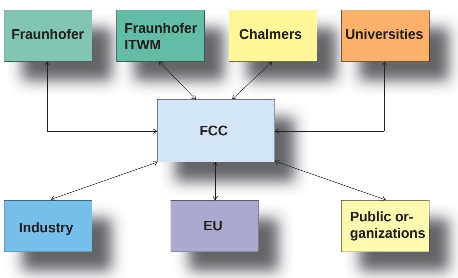
FCC works on projects defined by companies on a commercial basis.

Professional networking

The Centre has a very close relation to its founders Chalmers and Fraunhofer ITWM, cf pages 8 - 11, exchanging staff members, co-operating in projects, by joint participation in European projects, by connecting Swedish clients with ITWM and vice versa, and by stimulating the co-operation between Swedish industry and other Fraunhofer institutes.

In order to fulfil its tasks optimally, the Centre co-operates with competent scientific groups at universities and elsewhere, and promotes research and education in industrial mathematics at institutions outside the Centre, cf pages 12-13, 20-21, 28-29, and 38-39.

FCC in close co-operation with Chalmers and Fraunhofer shall be a leading international partner in industrial mathematics.



Financial mix

The financial model distinguishes between three income sources: project financing from the founders, industrial project income, and public project income. These three should be in reasonable balance.

Since start, the industrial and public project volume has increased more than expected in the original business plan. As a result of this, the relative project financing from the founders has decreased from 44 percent in 2001 to 27 percent in 2006, cf page 2.

FCC earns approximately 25% from its founders, 50% industrial income, and 25% public income.

Acknowledgements

The Centre is a Swedish foundation established by Chalmers and the Fraunhofer-Gesellschaft. The decision has been based on a business plan prepared by the Swedish Institute for Applied Mathematics (ITM) and Fraunhofer-Institut für Techno- und Wirtschaftsmathematik (ITWM).

The Swedish Society for Applied Mathematics (STM) and the former Swedish National Board for Technical and Industrial Development (NUTEK) have supported FCC taking over ITM operations.

The Swedish Foundation for Strategic Research (SSF) has played an essential role by giving support of one million euros for a public project where two future scientific leaders have been recruited to establish a research team in Bioinformatics and Systems Biology at the Centre.

In 2005 Fraunhofer and Chalmers decided to continue their commitments for the next five years 2006 - 2010.

Clients and Partners

Since its start in 2001, FCC has successfully co-operated with enterprises of different sizes and from many branches. In the following, those clients and project partners are listed who have accepted to be cited.

- ABB
- ABB Robotics
- ABB Power Technologies
- Adam Opel GmbH (D)
- Aerotech Telub
- Albany International
- AP2 Second Swedish National Pension Fund
- AstraZeneca R&D Alderley Park
- AstraZeneca R&D Mölndal
- AstraZeneca R&D Södertälje
- Atlas Copco Rock Drills
- Bergaskolan
- Bombardier Transportation
- BTG Pulp and Paper Sensors
- Consorzio Politechnico Innovazione (I)
- DAF Trucks (NL)
- Daimler-Chrysler (D)
- Efield AB
- Elforsk
- Elmo Leather
- Ericsson
- Faurecia Exhaust Systems
- FOI
- Fortum Power and Heat OY
- Front Capital Systems
- IIR Sweden
- InNetics
- Innovativ Vision
- Iveco (I)
- IVF Industriforskning
- Jernkontoret
- KP Pension and Insurance
- MAN (D)
- Micropos Medical
- NMCT
- Novo Nordisk (DK)
- Optimization Partner Stockholm
- PLANit Sweden
- Poseidon Diving Systems
- PSA Peugeot Citroën (F)
- Saab
- Saab Automobile
- Saab Communication
- Saab Ericsson Space
- Saab Microwave Systems
- Safe Technology
- Saint-Gobain Sekurit Scandinavia
- Sandvik Steel
- SCA
- Scania
- Simula Research Laboratory AS (N)
- SKF (Sweden and NL)
- STM Forskningsservice
- SP Sveriges Tekniska Forskningsinstitut
- Spotfire
- StoraEnso Corporate Research
- Sveriges Försäkringsförbund
- Sydkraft
- TetraPak
- Uddcomb
- Universitetssjukhuset MAS
- Volvo Aero Corporation
- Volvo Car Corporation
- Volvo Powertrain
- Volvo Trucks
- Volvo 3P

- Chalmers / Matematik, Matematisk statistik, Wingquist Laboratory
- Chalmers Industriteknik
- EU Biosim / DTU (DK)
- EU Visicade / Fraunhofer IGD (D)
- Fraunhofer ITWM (D)
- Göteborgs Universitet / Mikrobiologi, Molekylärbiologi
- ITM
- Kungliga Tekniska Högskolan/PSCI
- Linköpings Universitet / Beräkningsbiologi, Cellbiologi, Reglerteknik
- Lunds Universitet / Matematisk statistik
- University of California, Berkeley / Mathematics
- University of Rostock / Systems Biology and Bioinformatics

STM

The Swedish Society for Applied Mathematics, STM, has financed projects at FCC with 180 kEUR in 2006.

Members and shares 2006:

Engineering and transport	
Volvo	5
SKF	5
ABB	3
Saab	3
SP Technical Research Institute of Sweden	1
Pharmaceuticals	
AstraZeneca R&D Mölndal	5
Telecommunications	
Ericsson Microwave Systems	1
TeliaSonera Sverige	1
Energy	
Vattenfall	5
Insurance and finance	
Swedish Insurance Federation	5
Wood, pulp, paper	
StoraEnso Corporate Research	1
	35

www.itm.se

Fraunhofer-Gesellschaft

Professor Helmut Neunzert, ITWM,
Vice Chairman of FCC.

The Fraunhofer-Gesellschaft is the largest organization for applied research in Europe.

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration. The Fraunhofer-Gesellschaft maintains roughly 80 research units, including 56 Fraunhofer Institutes, at over 40 different locations throughout Germany. A staff of some 12500, predominantly qualified scientists and engineers, works with an annual research budget of over one billion euros. Of this sum, more than 900 million euros is generated through contract research. Roughly two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. The remaining one third is contributed by the German federal and Länder governments, partly as a means of enabling the institutes to pursue more fundamental research in areas that are likely to become relevant to industry and society in five or ten years' time.

The Fraunhofer-Gesellschaft is also active on an international level: Affiliated research centers and representative offices in Europe, the USA and Asia provide contact with the regions of greatest importance to present and future scientific progress and economic development.

The Institut für Techno- und Wirtschaftsmathematik, ITWM, in Kaiserslautern became a Fraunhofer institute on January 1, 2001. ITWM has continued its exceptional development and has now (2006) a budget of 10.5 million euros and a staff of 150 persons including 91 scientists, 42 PhD students, and 17 employees of the central services. The Institute further engages 111 reseach assistents, 36 trainees, and 8 apprentices. Its Director is Professor Dieter Prätzel-Wolters.

The ITWM is organized into eight units, which reflect key competence fields: Departments in Transport Processes, Flow in Complex Structures, Models and Algorithms in Image Processing, Adaptive Systems, Optimisation, Financial Mathematics, Dynamics and Durability, and the Competence Centre High Performance Computing and Visualization.

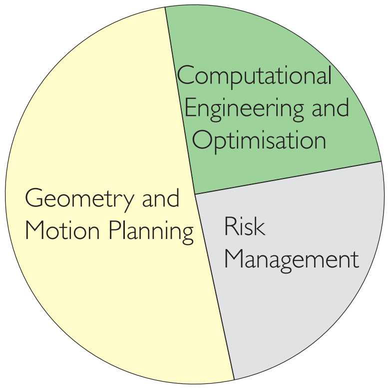
Professor Helmut Neunzert is responsible for international affairs at ITWM. FCC originates from his vision of a European institution operating in the Fraunhofer spirit.

www.fraunhofer.de
www.itwm.fraunhofer.de

Co-operation

FCC and ITWM are, more and more, growing together. Many projects are transferred in both directions - the flow is, in 2006, quite in balance, as it is altogether almost a million euros, which passes the border. But, of course, projects are not only given to the partner, but quite some projects were dealt with together, cf below.

The advantage of operating as one unit is clear: with a total of more than one hundred scientists FCC and ITWM offer a real power in industrial mathematics; it certainly belongs to the largest and most competent institutions for industrial mathematics in Europe.



ITWM income from FCC projects in 2006, in total 496 kEUR.

Computational Engineering and Optimisation

FCC and ITWM run joint projects on fibre flow modelling, fibre flow measurements, optimisation of products and configuration, and simulation based optimisation, cf pages 17 and 19. We have also started a joint strategic project on CFD methods for the food industry, cf page 16.

Geometry and Motion Planning

ITWM has developed improved methods for the simulation and vizualisation of robot cable motion and transient cable dynamics, cf page 32. FCC and ITWM run a joint industrial project on surface inspection, where we develop an automatic grading system for leather manufacturing, cf page 37.

Risk Management

FCC and ITWM run several joint projects in finance and insurance mathematics, where we develop asset liability management and option pricing tools, cf page 27.

Systems Biology

FCC and ITWM work together in a project on transport in Glial cells, cf page 42.

Chalmers

Professor Peter Jagers, Chalmers, Chairman of FCC.

The Chalmers University of Technology (Chalmers tekniska högskola) was founded in 1829. It is a non-profit, non-governmental university. With its more than 8700 students for engineering and architecture degrees, and more than 1000 PhD students it is one of Sweden's two leading technology universities.

Most of Chalmers' resources come from contracts with the state of Sweden (69%), but Chalmers also has strong support from non-governmental research organizations (19%) and industry (12%). The annual (2006) turnover is 240 million euros. Two thirds of the budget are alotted to research and to graduate studies. With its staff of 2167 full time equivalents, including 167 full professors, the University has strong and well-known departments in most fields of science and engineering.

Chalmers has made special efforts to integrate mathematics into a broader scientific and technological perspective. Strong activities in stochastics and numerical and modelling mathematics have emerged. Thus, besides activities in the various mathematical fields, Chalmers Applied Mathematics comprises three more specialized centres.

Professor Peter Jagers was the President of the Chalmers Faculty Senate 1993 - 2002. He brought up the idea of engaging Chalmers in a joint venture, when the Fraunhofer-Gesellschaft started to look for Swedish partners. He also represented Chalmers in the subsequent negotiations.

Co-operation

A key element in the operation of FCC is its close co-operation with Chalmers.

This co-operation is mainly organized through scientific advisers. Each adviser typically spends between 10 and 20 percent of full time at the Centre. In 2006 there were four advisers representing optimisation, stochastics (fatigue life), bio imaging, and mechanical engineering (product and production).

Below we describe three particularly successful areas within the co-operation.

www.chalmers.se
www.math.chalmers.se

Geometry and Motion Planning

Chalmers started the Wingquist Laboratory in October 2001 as part of Mechanical and Vehicular Engineering to increase the collaboration with Swedish industry and to concentrate research in strategic areas. The laboratory conducts interdisciplinary research within the field of virtual verification of product and production concepts.

FCC and Wingquist have a very close co-operation in geometry and motion planning focusing on product and production system modelling, robust design and variation simulation, and flexible production and automation systems, cf pages 28 - 35.

VINNOVA has decided on a ten year grant to Chalmers of 700 kEUR per year 2007 - 2016 for the Wingquist Laboratory Excellence Centre for Efficient Production Realization. Its director is Professor Rikard Söderberg.

Statistical Fatigue of Materials

Chalmers and FCC have together built up a strong operation in fatigue life and load analysis, with industrial income 2001 - 2005 from Swedish (585 kEUR), French (150 kEUR), and Italian (15 kEUR) companies. The industrial income 2006 was 275 kEUR.

The strategy has been to consider the fatigue group as one unit jointly supported by Chalmers and FCC. In that way, problems from industry are imported into the academic work and research results are exported to industry. This two-way communication has proved fruitful for the students at Chalmers, including students from industry hosted at Chalmers and FCC, as well as for the industrial partners, cf pages 22 -25.

"The establishment of FCC has made it possible for the fatigue group to host competence for solving particular industrial problems as well as for doing purely academic work."

Professor Jacques de Maré
Chalmers Mathematical Sciences,
Scientific adviser FCC

Gothenburg Mathematical Modelling Centre GMMC

In December 2005 the Swedish Foundation for Strategic Research (SSF) decided to finance seventeen strategic centres including the Gothenburg Mathematical Modelling Centre (GMMC).

The research programme includes (1) Optimisation and modelling, (2) Biomathematics, and (3) Risk, reliability, quality. In 2006 the focus of FCC has been on combustion engine and positioning system optimisation, particle traction and gel structure modelling, and reliability and quality through variation mode and effect analysis, cf page 19, 24, 44-45.

SSF has decided on a five year grant to Chalmers of 500 kEUR per year 2006 - 2010 for the Gothenburg Mathematical Modelling Centre GMMC. The director of GMMC is Professor Holger Rootzén.

Computational Engineering and Optimisation

Modern product design and process operations are heavily based on computational mathematics through work in the virtual world. Traditional hands-on engineering are replaced by systematic approaches based on computer simulations, which provide insight in the design phase reducing the need for expensive measurements. The department of computational engineering and optimisation does mathematical modelling of physical phenomena that can be described by partial differential equations (PDEs). Novel methods and engineering tools are developed which enable efficient solution of complex system of PDEs, making real industrial problems tractable to scientific analysis and simulation-based optimisation.

The work is organized in three areas:

- Electromagnetics
- Fluid Dynamics
- Optimisation

In electromagnetics we are an implementation partner of the company Efield that commercializes the software that was developed in the national research and code development project GEMS. The software constitutes an excellent platform for research as well as for performing consultancy projects. We have good connections with Swedish telecommunication industry and projects are performed together with the Swedish Society for Applied Mathematics, STM. The research in fluid dynamics is focused on fibre flows and fluid-structure interaction. Multi-physics applications are a core competence of the department, in particular applications that require coupling of fluid dynamics and electromagnetic solvers. The activities in optimisation are concentrated on simulation based optimisation with respect to multiple criteria and optimisation of resources in logistics and transportation.

The department collaborates with researchers at Chalmers in particular through the Gothenburg Mathematical Modelling Centre (GMMC) which is funded by the Swedish Foundation for Strategic Research (SSF). The projects are performed in co-operation with industry and are focused on simulation-based optimal design and multi criteria optimisation.

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The ship propeller. *John Ericsson's most important inventions were of ship propellers. Ericsson became widely famous when he built the "Monitor", an armoured battleship that in 1862 triumphed over the Confederate States' "Merrimac" in an American Civil War sea battle.*

The Computational Engineering and Optimisation Research Group

- Fredrik Edelvik, PhD, Associate Professor, Computational Electromagnetics
- Erik Höök, MSc Engineering, Computational Fluid Dynamics
- Stefan Jakobsson, PhD, Computational Electromagnetics and Optimisation
- Robert Rundqvist, PhD, Computational Fluid Dynamics
- Ann-Brith Strömberg, PhD, Optimisation
- Anders Ålund, Lic, Numerical Analysis and High Performance Computing
- Peter Lindroth, MSc Engineering, Volvo, PhD student
- Einar Guðfinnsson, Master student
- Nikulas Sigfússon , Master student
- Michael Patriksson, Professor in Applied Mathematics at Chalmers, Scientific Adviser at FCC

Fredrik Edelvik

Erik Höök

Stefan Jakobsson

Robert Rundqvist

Ann-Brith Strömberg

Anders Ålund

Peter Lindroth

Einar Guðfinnsson

Nikulas Sigfússon

Michael Patriksson

Electromagnetics

The rapid increases in computer power and the development of efficient numerical methods have facilitated computer simulation of complex electromagnetic propagation and interaction phenomena. This is an emerging technology in application areas such as wireless technology, antenna analysis, electromagnetic compatibility, micro electronics, radar signature and medicine.

The activities in electromagnetic simulations at FCC are based on the software suite developed in the national research and software development project GEMS (General ElectroMagnetic Solvers), PSCI project 24082-62591. FCC's participation as sub-contractor in GEMS has brought the center to the forefront in electromagnetic simulations. During 2006 the company Efield AB was founded to commercialize the software. FCC is an implementation partner of Efield AB and contracted to perform further development and software maintenance. FCC markets efield® to new customers as well as performing consultancy projects using the software.

In 2006 the FCC group in computational electromagnetics has been increased with a specialist in the area of integral equation methods, in particular fast multipole methods, thus complementing the expertise of the group in time domain finite difference and finite element methods, high performance computing, multiscale modeling and electromagnetic compatibility.

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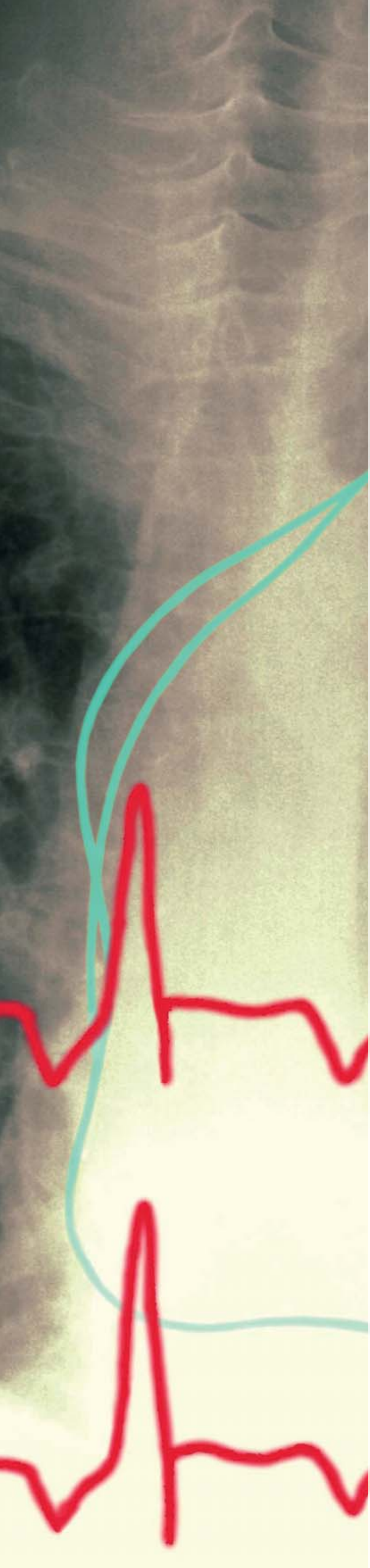
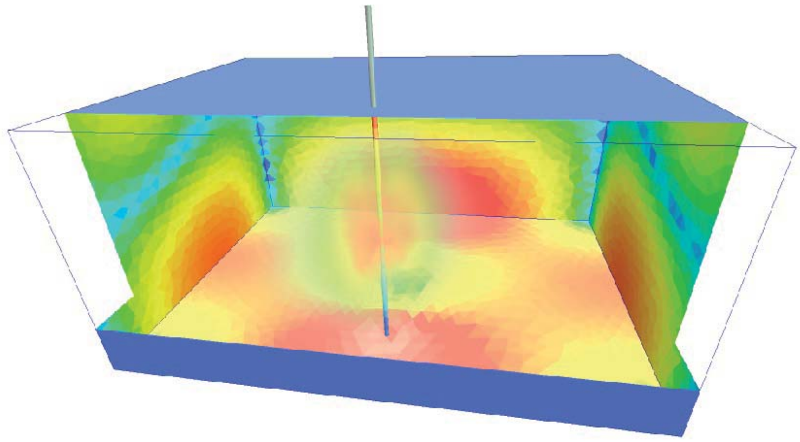


The pacemaker. *In 1958, Rune Elmqvist developed a small battery-powered pacemaker which can be surgically implanted under the skin of a cardiovascular patient. It emits electrical impulses that cause the heart muscle to resume normal, regular contractions. The same year, Åke Senning performed the first pacemaker operation at the Karolinska Hospital in Stockholm.*

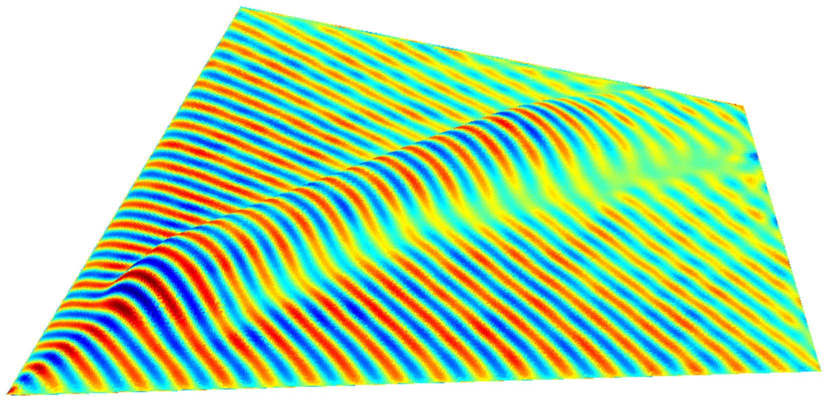
The efield® software

The efield® software is a result from a successful collaboration between Swedish academia and industry. FCC has played an important part in the development of the software and is currently performing further development as well as software maintenance contracted by Efield AB. Major activities during 2006 have been the development of a Windows version of the software and preparation for the first release. The software constitutes an excellent platform for research in computational electromagnetics and this is performed in a base program funded by the industrial consortium STM and FCC.

The software is used for antenna design, electromagnetic compatibility, radar signature and microwave applications. The solvers are based on formulations in both time domain and frequency domain. A key feature is the use of hybrid methods. In frequency domain a Method of Moments, MoM, boundary integral solver is coupled to a physical optics solver. In time domain an unstructured finite element method is coupled to a finite difference method. The underlying idea of the hybrid methods is to take advantage of the strengths of the individual methods without suffering from their weaknesses and thereby substantially increase the spectrum of solvable problems.



A shielded enclosure with a wire. The currents are displayed on the wire and the surface currents are shown on the walls of the enclosure. The electric field is rendered volumetrically close to the wire. A time domain finite element method has been used.



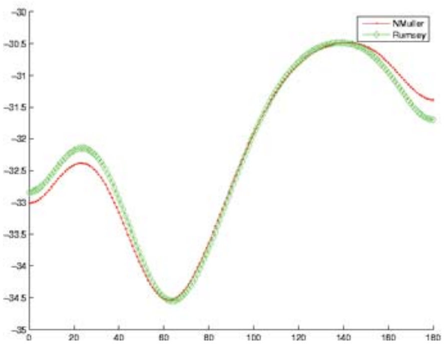
Surface currents on the FOI UAV Eikon after a radar pulse has hit the aircraft head-on. A multilevel fast multipole method (MLFMM) has been used.

Integral formulations for dielectric materials

In the frequency domain solver, the integral formulation for dielectrics is very ill-conditioned. This is a problem in particular when iterative methods are used since the iterative process converges slowly if it converges at all. This is of crucial importance since this fact limits the use of the fast multipole method to problems with only perfect electric conductors. The industrial consortium STM and FCC have together financed a joint research effort, where alternative integral formulations that improves the convergence rate several orders of magnitude are investigated.

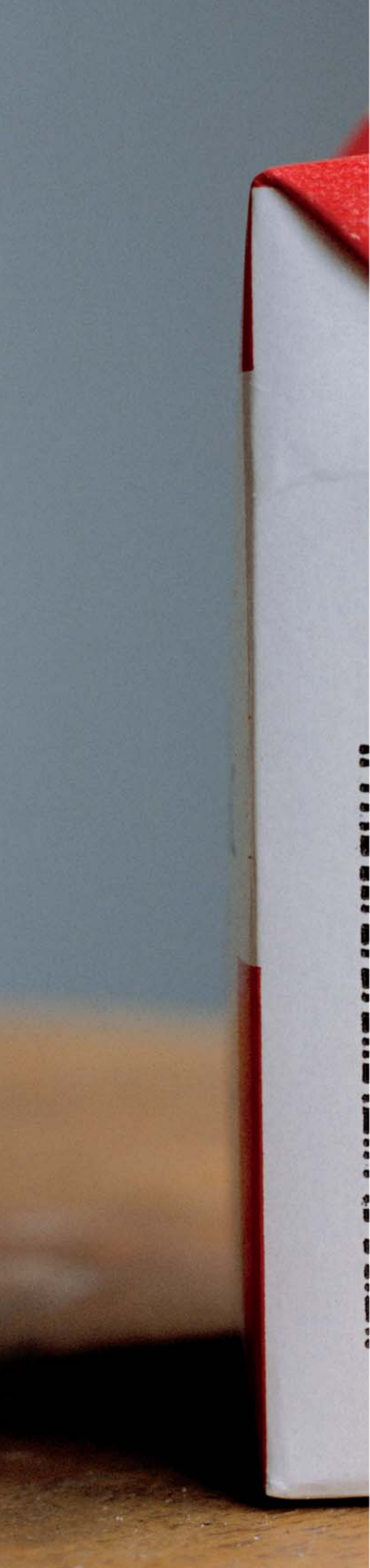
Below the bistatic radar cross section for a dielectric object with two different formulations: the Rumsey reaction principle, which is currently used in the solver, and the Müller formulation, is presented. On this particular example, the condition number was reduced a factor of 400 for the Müller formulation compared to the Rumsey reaction formulation. At the moment we are also investigating other possible formulations.

The integral equation formulations must also be able to handle several domains of dielectrics mixed with PEC and port boundary conditions, and also acceleration with the fast multipole method. Future work includes to investigate basis functions for the surface currents with two degrees of freedom for each edge compared to the standard basis functions which have only one.



Comparison of bistatic radar cross section for a geometry filled with dielectric material computed with the Rumsey reaction principle and the Müller formulation, respectively.

Fluid Dynamics



Computational fluid dynamics has applications ranging from straightforward solution of standard systems of equations using commercial flow packages to advanced modelling of multiphase flow systems involving chemical reactions and compressible flows. In industrial systems, like paper making, energy production, or other manufacturing facilitites, understanding the physics of fluid dynamics holds one key to drastically improve the process with respect to production speed, environmental impact, or production cost.

Different problems require different solver capabilities. At one end of the scale, in meteorology, large-scale structures are modelled, the geometry of the system is simple, and the fields are generally computed on a two-dimensional grid. The complexity lies solely in the large amount of data to be handled and the strong non-linearity of the system. At the other end lies combustion engineering, where the flow is fundamentally three dimensional and the geometry is complex and involves moving boundaries. The picture is further complicated by the presence of fuel sprays, flame fronts and compressibility effects.

FCC solves problems within the field of fluid dynamics using the best tool at hand rather than advocating a specific method. In some cases, this tool is a commercial flow solver, e g, a general PDE-solving package like COMSOL, or a specialized solver like FLUENT. In other cases the solution can only be obtained by programming everything from scratch. The most common strategy is however a mixture of the above approaches.

In 2006, FCC has been focusing on different aspects of multiphysics coupling related to CFD problems. Much of the work has been related to lagrangean tracing of particles in a combination of flow and electrostatic fields. Two examples from these activities are described in more detail in the following sections. Together with ITWM we have also started a study on CFD applications for food industry.

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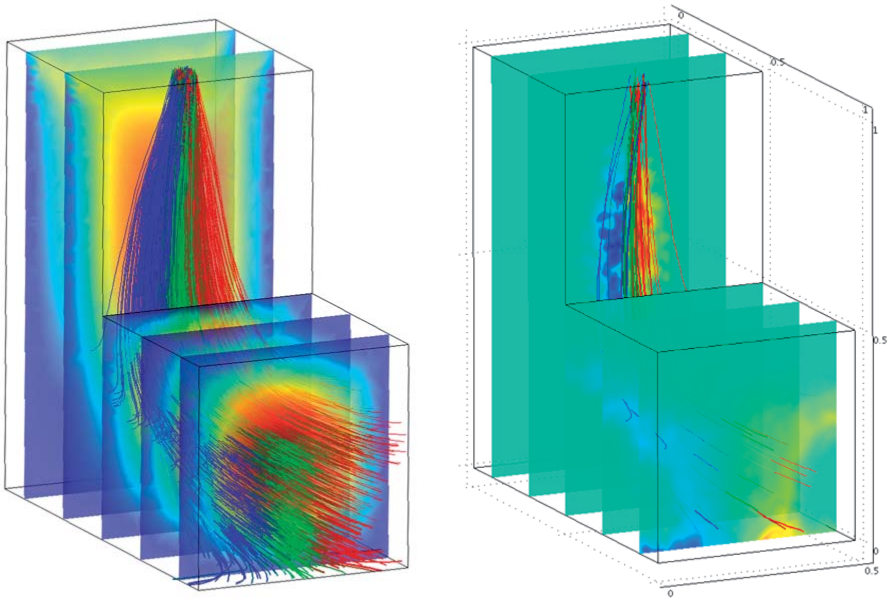
The tetra pak *is an invention for storing, packaging and distributing liquid foodstuffs, for example milk and juice. Erik Wallenberg was the main inventor, while businessman Ruben Rausing developed and produced it. Since the company Tetra Pak delivered its first liquid food packaging in 1952, it has developed various new types of packaging, of which the best known and most widely used is Tetra Brik.*

Particle tracing in multiphysics environments

In this project, which is performed in collaboration with the department of Geometry and Motion Planning, a general particle tracking algorithm was developed with the purpose of tracing particles in a general electromagnetic flow and gravity field provided by an external solver. The particle tracer is called as a function with the fields as arguments, and in return the tracer delivers eulerian density fields integrated from the lagrangean simulations as well as the desired amount of individual particle paths.

The particle tracer works with adaptive timestepping and Verlet integration of the forces affecting the simulated particles. The local fields are interpolated on structured or unstructred grids. Below is shown an example of particles in a fluid flow in a sharp turn of a square duct. The particles, which in this case follow a log-normal random size distribution and a uniform charge distribution, are inserted into the flow in a small region upstream of the turn. There is no gravity in this case, but there is a uniform electrostatic field applied in the cross-stream direction.

From the simulation it is evident how the flow separates particles of different mass and how the electrostatic field separates particles of different charge.

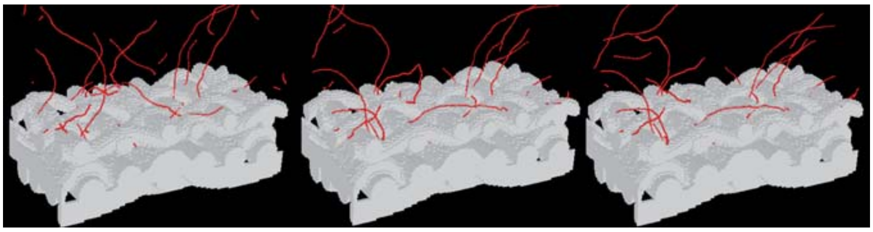


To the left slices of fluid velocity are shown, with red being high and blue being low velocity. Fluid and particles enter at the the top of the geometry and exit at the side facing the viewer. The colour of the particle lines shown signifies charge, with red meaning negative charge and blue positive charge. The thickness of the line represents the diameter of the particles. To the right slices of a space charge field computed from the particle traces are shown. Here too, red is negative charge and blue is positive charge. The Reynolds number of the simulations was in this example case kept well within the laminar region.

Paper forming simulations

During 2006 particle tracing has also been taking another direction than tracking of spherical particles in multiphysics environments. In a project aimed at paper industry, simulation techniques for tracking long and flexible fibres in a fluid flow were developed by FCC together with ITWM. The fibre tracker works with the ITWM software FilterDict, which is used for fluid dynamics calculations and for post processing.

The fibres are simulated as a string of spherical particles connected with springs. To get fibres rigid enough at a reasonable computational cost, the fibre main axes are reconstructed during each timestep, providing a local coordinate system in which relative positions of neighbouring particles can be evaluated. This means that moderately flexible fibres can be modelled without explicitly solving the angular momentum and orientation problem for the fibres and without encountering the problem of the degenerating twisting angle that appears when the bending angle approaches zero. In an investigation of the influence of the geometry of paper forming fabrics on the quality of the formed paper, two different fabrics were compared under different operating conditions. It was found that the laydown pattern of fibres in the simulation using the more advanced weaving pattern was notably more even than in the simulations of the more simple fabric, implying that laydown quality – and thereby some aspects of paper quality – as a property depending on the forming fabric is detectable in this kind of simulation. This work was presented at the NAFEMS Nordic seminar on Integration of Numerical Simulations into the Product Development Process in Gothenburg.



Sequence of simulation images representing fibres settling on a forming fabric. A small segment of a forming fabric is subjected to a batch of settling fibres. When all fibres are caught or have passed through the fabric the resulting fiber network can be evaluated, and a new batch of fibres can be released. If required, the caught fibres can also be made part of the fabric geometry, enabling simulations of the initial network forming process of a paper material.

Optimisation

The core competences of the optimisation group are simulation based optimisation with respect to multiple criteria and optimisation of resources in logistics and transportation. Our applications appear in the economical, engineering, and medical sciences. Many of these ask for tradeoffs between different criteria such as costs and different quality indicators.

- **Optimisation of products and processes with respect to multiple criteria**

In the last decades the engineering sciences have seen a massive break-through of computer assisted methods. This enables the use of simulations for virtual testing of products and processes prior to expensive physical testing and validation which, in turn, opens the door for applying modern optimisation techniques in the design process. Mathematical optimisation methods, tailored for specific application areas and customer demands on precision and robustness, provide efficient search strategies, which improve this process. To facilitate such an automated design process, we develop a powerful platform that integrates the simulation models and algorithms in an optimisation framework.

- **Maintenance planning**

Maintenance and replacement activities often have a large impact on a stable production by creating larger availability, higher production speed, and better quality results. In many industries the costs for spare parts are very high and also the maintenance activity itself may generate high costs in terms of, e g, lost production. Optimisation of maintenance plans and schedules helps to preserve a stable production and low maintenance costs.

Maintenance planning usually combines statistics and optimisation techniques. The optimisation and fatigue groups at FCC and Chalmers mathematics study efficient methods for the maintenance of aircraft engines in a joint research project.

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Cream separator. *In 1872 Gustaf de Laval invented what would be one of his most important inventions, the cream separator. The first model was patented in 1878. In 1883 a company called AB Separator (later Alfa Laval) was established to manufacture and export the separator.*

Decision support based on simulation and multi-criteria optimisation

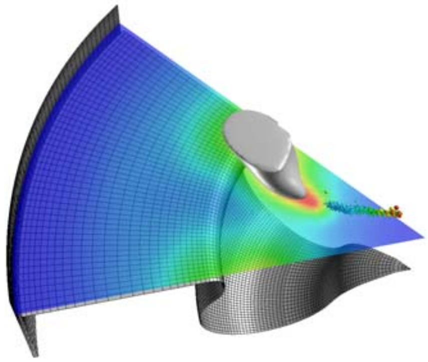
This three year project is part of a base program with the industrial constortium STM, cf page 7. The goal is to develop and market a prototype decision support tool that integrates multiple criteria optimisation and simulation and that visualises solutions in an interactive decision support tool. In 2006 several case studies have been investigated and a first version of the prototype optimisation tool, consisting of a number of modules for mathematical modeling, simulation computations, optimisation algorithms, and visualization, has been developed. The modules communicate via data files controlled by the user. The optimisation algorithms can be adapted to one or multiple objectives and to various mathematical properties of the design models. Simulation computations can be made in different simulation environments. Visualisation can be made in the optimisation objective space as well as in the space of the simulation model.

Combustion engine optimisation

It is nowadays possible to simulate the physical and chemical processes inside combustion engines by appropriate software and high performance computers. These simulations can predict, for example, fuel consumption and emissions of soot and nitrogen oxides. By varying the design parameters of the engine, different configurations of these can be simulated and their performances compared. We use global and local optimisation algorithms in combination with simulations to find Pareto optimal design parameters with respect to several goal functions.

Evidently, it is favorable for combustion engines to have low fuel consumption as well as low emissions of soot and nitrogen oxides. The goal function, defined by the designer, combines these different goals. Since the engine must work well in certain ranges of load and speed conditions, it is necessary to take several such conditions into account in the optimisation. Moreover, since an engine simulation may consume several days of computer time, it is clear that very efficient optimisation algorithms are required.

The project is a co-operation between GMMC, cf page 12, Volvo Car Corporation and Volvo Powertrain with the overall goal to develop a software demonstrator for combustion engine optimisation based on computational fluid dynamics.

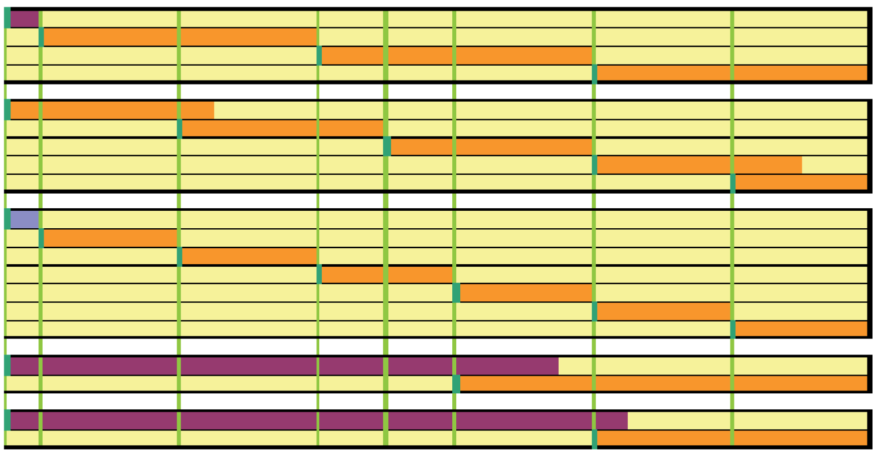


The figure shows a sector calculation of the cylinder of a combustion engine. The droplets consist of fuel and their colors indicate their temperature. The grey object is an isosurface for the concentration of soot and the plane with a coloured contour plot illustrates the fuel concentration (illustration from Volvo Car Corporation)

Decision support for cost efficient maintenance of aircraft engines

The spare parts of an aircraft engine are often very expensive and the maintenance activity itself generates large costs for, e.g., transport, administration, inspection, spare engines, and operation stops. Therefore, at every maintenance occasion one should consider the possibility to replace parts that has not yet reached their maximal allowed age. A store with used spare parts should also be utilised.

Finding schedules for the replacement of parts that minimises the total expected maintenance cost is a very complex optimisation problem, which has been modeled by Tekn Lic Niclas Andréasson. The optimisation group has created a decision support tool that computes and presents solutions to this model in the form of maintenance schedules.



An optimal maintenance schedule for five parts in an engine module. Time goes from left to right. The vertical green lines denote maintenance occasions and the orange, lilac, and blue horizontal fields correspond to lifetimes of new, current, and used components, respectively.

Risk Management

This department covers uncertainty and risk in a broad sense. The basic tool is mathematical statistics including stochastic process theory. We concentrate on two application areas:

- Fatigue Life and Load Analysis
- Finance and Insurance

Many failures of engineering structures are caused by fatigue of metals. It is therefore important to be able to predict the time until fatigue failures. The fatigue phenomenon is extremely complex, and hence reliable predictions demand detailed knowledge to an extent that is rarely possible to achieve. There are two main approaches to fatigue design in practise: The first one is about components that are subjected to at most a few millions of damaging stress fluctuations, then one design for fatigue life, using empirical relationships between stress and life. The second approach is about components that need to withstand more stress fluctuations, then one design for infinite life, using the estimated fatigue limit. We have used both approaches in several industrial projects, including an initial study of load analysis in automotive applications with six European truck manufacturers.

Finance and insurance mathematics is one of the most growing fields in applied mathematics. The underlying mathematical tools were developed in the last decades. So the time until the application was very short although the theory contains some sophisticated results. Our focus has been on developing a state-of-the-art modelling platform for asset liability management.

Risk management is one of three focus areas of the Gothenburg Mathematical Modelling Centre, GMMC, which started its operations in 2006.

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The safety match. *Gustaf Erik Pasch laid the groundwork for the Swedish match industry. In 1844 Pasch received a patent for the safety match. He replaced the hazardous yellow phosphorus found in the matches of that period with red phosphorus and put it on the striking surface instead of the match head.*

The Risk Management Research Group

- Pär Johannesson, PhD, Fatigue Life and Load Analysis
- Joachim Johansson, PhD, Finance and Insurance
- Carl Lindberg, PhD, Finance and Insurance
- Sara Lorén, PhD, Fatigue Life and Load Analysis
- Thomas Svensson, PhD, Fatigue Life and Load Analysis
- Magnus Karlsson, MSc Engineering, Volvo, PhD student
- Martin Eckerljung, Master student
- Thomas Nordlund, Master student
- Ralf Korn, Professor, University of Kaiserslautern / Fraunhofer-ITWM, Scientific Adviser at FCC
- Jacques de Maré, Professor in Mathematical Statistics at Chalmers, Scientific Adviser at FCC


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Joachim Johansson


Carl Lindberg


Sara Lorén


Thomas Svensson


Magnus Karlsson


Martin Eckerljung


Thomas Nordlund


Ralf Korn


Jacques de Maré

Fatigue Life

The fatigue group strategy is to develop new methods for fatigue assessment in industrial practice together with the department of Mathematical Statistics at Chalmers. Our methods are based on two main fundaments, namely scientific knowledge and statistical skills, and knowledge about industrial practice and needs.

The first fundament is realized by a close connection to Mathematical Statistics at Chalmers, working in public research projects, involvement in PhD and master thesis projects, and working for the extension of industrial project results to scientific publications.

The second fundament is primarily maintained by our main activity: solving problems for industrial partners. By participation in networks like the Swedish Fatigue Network (UTMIS) new problems are identified and new industrial contacts are established.

- **Scientific projects**

During 2006 the group has participated in one part of the newly established Gothenburg Mathematical Modelling Centre, GMMC. The actual part is a co-operation between FCC and two departments from Chalmers, Mathematical Statistics and Quality Science and aims at merging different reliability tools into a common frame, useful for industrial practice. The work is done in co-operation with partners from the industrial sectors of automotive industry, air engine industry and electrical power management.

- **Industrial projects**

A pilot project has been done in a co-operation of European truck manufactuers. Six different companies have been involved and common interests within load analysis been identified. FCC has together with collegues at ITWM and Chalmers made two investigations: one finding the current practice and needs at the european truck companies regarding load analysis, and one finding the state-of-the-art of the subject in scientific literature and in commercial software.

Other industrial projects have been performed in the fields of load analysis, measurement quality, spectrum fatigue, and fatigue limit modelling.

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The ball bearing. *Sven Wingquist is regarded by many as the father of the modern ball bearing - an invention of revolutionary importance to mechanical design. In 1907 he invented the spherical ball bearing. He also founded AB Svenska Kullagerfabriken (SKF), which remains the world´s leading producer of industrial bearings. It is interesting to note that Volvo, Sweden´s largest automobile manufacturer, was founded in 1915 as an early spin-off of SKF.*

Guide to Load Analysis for Automotive Applications

In fatigue design of mechanical components and systems there are two main variables, namely, the load the component is exposed to, and the strength of the component. The ultimate goal for the manufacturer is to make a design that exactly meets the needs of the customers, neither too strong nor too weak. The requirements need to be converted into for example a certain small risk of failure, a proper safety factor, or an economical expected life. In order to make a robust design it is as important to have good knowledge about the properties of the customer loads, as it is to have good knowledge about the mechanical behaviour of the material and structure in question. The development of information technology and its integration in vehicles has given new possibilities for measurements in service. Further, the design process is also changing where the development is moved into the computer. Both these tasks require a refined view on load analysis and lead to a renewed interest in load analysis.

This collaboration project is run at FCC in collaboration with Fraunhofer-ITWM, and mathematical statistics at Chalmers. The industrial partners in the project are DaimlerChrysler, DAF, Iveco, MAN, Scania, and Volvo.

The goal of this study is the development of a guide to load analysis. We want to present and to further the understanding of the mathematical and statistical tools in load analysis. During the year of 2006 an initial one-year project was carried out, with the aim to prepare the ground for a Guide to Load Analysis. The project included two main activities; 1) visits to each of the six participating companies, investigating the requirements among manufacturers, especially investigating their current practice and future needs within the area of load analysis, and 2) a survey on the state-of-the-art in the area of load analysis for durability in automotive applications.

It was found that:

- there are several existing methods in load analysis that are not widely known within the industrial engineering community,
- there are numerous areas of possible research within the subject of load analysis,
- there is a need to unify the terminology and to explain mathematical and statistical methods.

Especially the following points are covered in the state-of-the-art and should be included in a Guide to Load Analysis:

- Basics about load data analysis
- Methods for multi-input loads
- Models for random loads
- Principles of building a design load spectrum
- Methods for load editing
- Generation of time signals
- Evaluation of customer loads
- Issues concerning test tracks
- Advantages and disadvantages of the state-of-the-art methods
- The area of application for the state-of-the-art methods
- Variability in loads and uncertainty of the methods

The durability specifications of trucks depend on the transport mission. The timber truck in the picture needs to be designed to sustain very high loads.

The design specifications within the automotive industry are to a large extent based on testing and measuring loads on test tracks (courtesy of Volvo).

Life Prediction for Service Loads

A project for a new reliability method for Volvo Aero started in 2005 and was closed at the end of 2006. Based on a few worked out examples from the company we have written a handbook of instructions for a reliability approach based on available information. The method has also been introduced at an internal course at the company and will be included in their practice.

For the air engine applications at Volvo Aero fatigue life predictions are based on specified thermal and external loads, material data, nominal structural geometry, mathematical models describing thermal and mechanical deformation, and models for damage accumulation.

Lack of information about input variables and unknown model errors make life predictions uncertain and there is a need for estimating these uncertainties in order to establish proper safety factors for reliability in service.

In cooperation with Volvo Aero, FCC has designed a special reliability method for cases when there is weak knowledge about the statistical distributions of the input variables and the model uncertainties. The method is only based on estimated variances without reference to distribution types, which can be seen as an adjustment to the amount of prior knowledge that is at hand in practice.

By a proper transformation and use of the Central Limit Theorem the confidence of the final life prediction is judged based on a normal distribution assumption.

For the sake of rational updating, the sources of variation in life assessments are divided into two types:

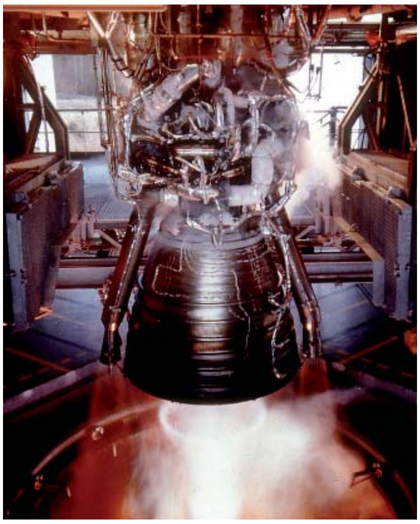
1) material properties, structural geometry, environment and external forces are not known in detail in the prediction stage which gives rise to scatter in fatigue life caused by differences between individual components and usages.

2) the physical models for damage mechanisms are not true, but more or less rough approximations of reality which gives uncertain predictions. Furthermore, model parameters must be estimated from a limited number of tests giving rise to statistical uncertainties.

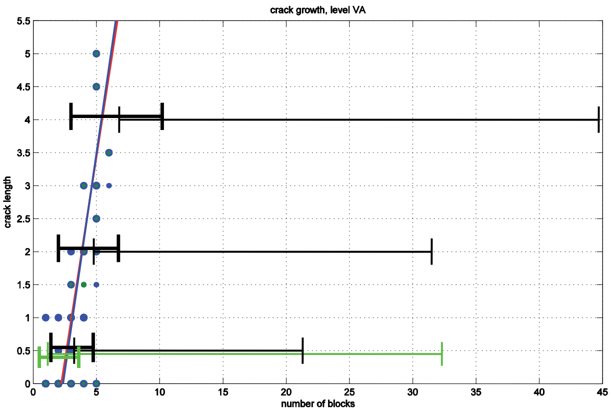
It is straightforward to use statistical tools for analysing the scatter caused by the first type of sources. Uncertainties caused by the second type of sources are more difficult to take into account. However, looking at the overall prediction situation these model errors can be modelled as random variables.

A simplified reliability model for strain-life fatigue is established by a Taylor expansion of the logarithm of the life around the nominal values of the error variables. Such a simplification makes it easy to apply the Gauss approximation formula which simply summarizes variances originated from both scatter and uncertainty.

The method has been used on several Volvo Aero applications and proved useful. In particular it has been helpful 1) to find the weakest links in the reliability assessment, 2) to establish relevant safety factors, and 3) to update the reliability assessment based on partial new knowledge.



Volvo Aero Corporation is responsible for the development and production of the Nozzle Extension for Vulcain 2, which is the main engine of the Arianne 5 rocket.



Crack growth curve for validation tests including prediction intervals before and after updating. The thicker lines show intervals after updating

Courses for practising engineers

An important part of the fatigue group activities is to give courses for industry. Several different courses have been developed during the last years.

- *Measurement uncertainty.* This three days course has been given at Volvo Trucks, and is based on the newly developed lecture notes "Nio tumregler och två kungsvägar för att behärska mätosäkerhet" by Thomas Svensson.
- *Course in spectrum fatigue.* This three days course has been given two times in co-operation with SP Technical Research Institute of Sweden in Borås.
- *Statistics for loads, fatigue, and reliability.* This course is given as four half-days, where each half-day is based on an industrial problem given by the industry. The course has now been given four times following the lecture notes "Problemdriven Statistikkurs - Belastning, utmattning och tillförlitlighet" by Pär Johannesson and Jacques de Maré.

Supervising PhD students

- As a part of our co-operation with PSA Peugeot Citroën in France, Pär Johannesson and Jacques de Maré has supervised Gwenaëlle Genet in her PhD work. She defended her thesis "A statistical approach to multi-input equivalent fatigue loads for the durability of automotive structures" on October 27, 2006.

  The work treats structures in service that are often exposed to complex variable amplitude loads. The cars have to sustain speeding on highways, climbing in the mountains tugging caravans, pot holes on country side roads, and queuing in dense city traffic. The panel of customers with different behaviours is very large.

  In order to characterize the severity of customers, or to define specifications for designing metallic structures, simple forces are more useful. These simple forces have to be representative to the complex forces, i.e. they have to induce the same damage as the complex forces on the structures in service.

  The equivalent fatigue approach is a method for transforming measured variable amplitude loads into simpler loads, equivalent in terms of damage. The equivalent fatigue approach has been developed for structures exposed to one single load. The aim of this work was to extend the one-input equivalent fatigue method, to multi-input loads. Her research subject is closely connected to the automotive industry needs and is focussed on statistical approaches to multi-axial fatigue.

  She also received a prize, the prize Jacques Pomey, for her work. The prize is given to the best work presented by a young scientist (less than 32 years old) on the congress given by the French Association for metals and materials "Société Française de Métallurgie et de Matériaux, SF2M".

Gwenaëlle Genet

- The automotive industry problem of customer correlation is represented in our work by the PhD project "Parameterization of customer environment" for Volvo Trucks, where Magnus Karlsson is supervised by Thomas Svensson, Jacques de Maré and Pär Johannesson. The project is dedicated to the problem of load analysis of truck customers and includes modelling of vehicle cornering, fatigue assessment of components sensitive to lateral loads, random process modelling and statistical design of field data measurements.
- In a joint project for Volvo Aero two PhD students work on optimisation of maintenance schemes for aero engines. One part of the project is devoted to statistical aspects on optimal maintenance and the PhD student Johan Svensson is supervised by Jacques de Maré, Thomas Svensson and Pär Johannesson.

Finance and Insurance

The financial and insurance sectors today are two of the largest industries in the world. In 2005, the global options and futures markets alone saw a turnover in excess of 1400 trillion USD, according to the Bank for International Settlements.

Both finance and insurance offer a wide range of mathematical challenges. Insurance faces issues such as estimation of mortality and risk, fair pricing of insurance contracts, pension plans and so on. Finance, especially the options and futures markets, needs to model interest rates, stocks, bonds, real estate – to name but a few – in order to derive fair prices for its wide selection of products.

As the finance and insurance markets become increasingly inter-twined, as can be seen for instance by the emergence of the Catastrophe (CAT) bonds market and in the interest in Asset Liability Management (ALM) modelling, it will be important to find a common mathematical ground for the two disciplines. This is important also for avoiding arbitrage opportunities between the two sectors – a problem acknowledged in the ongoing Basel II and Solvency II initiatives.

FCC and our associates, having a strong understanding of the underlying mathematics complemented by practical modelling experience, offer expertise for financial and insurance institutes in Sweden and across Europe. Together with our partners Chalmers and Fraunhofer-ITWM we have developed theory and software for ALM, robust portfolio optimisation, and credit derivative pricing.

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Dynamite. *Alfred Nobel was 29 years old when he patented a detonating cap for nitroglycerine and nitric acid. But nitroglycerine was still likely to explode on the slightest impact. In 1866 Nobel discovered that nitroglycerine flowing out of a broken bottle was absorbed by kieselguhr - a porous diatomite - which protected the container from blows. The mixture was very stable and easy to handle but retained its explosive characteristics. This marked the birth of dynamite.*

SimIns - an ALM/DFA platform

FCC, in co-operation with the Swedish Insurance Federation through STM, cf page 7, has developed a state-of-the-art modelling platform for Asset Liability Management (ALM)/Dynamic Financial Analysis (DFA). The platform aims at simplifying the modelling construction process and providing a basis for company specific risk models. Another important goal is to further the interest of actuarial mathematics and econometric modeling in general.

The aim of ALM-studies is in fact manyfold. It is of interest to analyze the current market conditions and see how changes, so called stress-tests, will impact existing long-term strategies. Further, combining the simulations with an optimisation algorithm may lead to important insights regarding changes in investment policies and new benchmark portfolios. It is also possible to evaluate how new and proposed rules and regulations may influence one specific company or, on a macroscopic level, the economy of an entire industrial sector.

Traditionally, companies, pension-funds and other investors do not perform these simulations themselves, but rely on the results of external consultants. A consequence of this is that the simulation model, from the customer's point of view, is perceived as a black box. Further, these external models are usually not able to cater to the specific needs by the different companies.

FCC and our partner ITWM have performed ALM-projects with The Second Swedish National Pension Fund, AP2, and with KP Pension and Insurance. The main aim has been to develop models which include all relevant properties of the Swedish pension system and the fund's specific portfolios.

In this kind of projects, the first step is an investigation of models for different asset classes. It is important to focus on the ability to identify parameters, seeing as the number of parameters is usually rather high. In the above-mentioned projects, several macroeconomic parameters in seven different economies were simulated. Another topic is the presence of models in the "real-world" for bank accounts as well as corresponding models in the "risk-neutral world" for bonds, i.e. it is important to choose the market price of risk.

The SimIns platform, complete with optimisation and portfolio strategy plug-ins and a set of example models, are planned to be distributed amongst the Federation members in 2007.

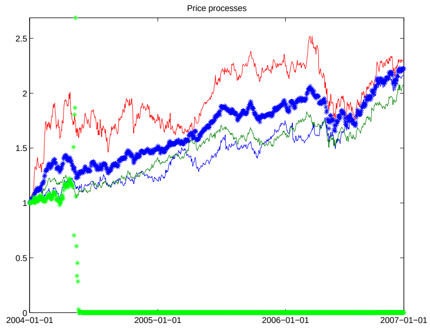
Robust portfolio optimisation

The fundamental question of portfolio optimisation is quite natural: How do we trade in the stock market in the best possible way? However, this is not easy to answer. It is widely known that when classical optimal portfolio strategies are applied with parameters estimated from data, the associated portfolio weights become remarkably unstable and volatile. The predominant explanation for this is the difficulty to estimate expected returns with sufficient accuracy.

Recently, a new approach has been developed at Chalmers which gives stable and robust estimates of expected returns. These expected returns are particularly well suited for use in portfolio optimisation.

We parameterize an n stock Black-Scholes model as an n factor Arbitrage Pricing Theory model where each factor has the same expected return. Hence the non-unique volatility matrix determines both the covariance matrix and the expected returns. This approach gives stable and robust estimates of expected returns. The investor can impose his or her views on the market, either for individual stocks or for groups of assets, by selecting a volatility matrix which suggests expected returns of the stocks that he or she believes are reasonable.

The example below shows the outcome for a portfolio of three stocks. The optimal strategy is applied out-of-sample, and the model parameters are estimated from a window of 18 months of data, which is updated each month.



Price development for three individual stocks and wealth process based on ranks for Markowitz´ optimal strategy (thick green line; unstable) and the robust strategy (thick blue line).

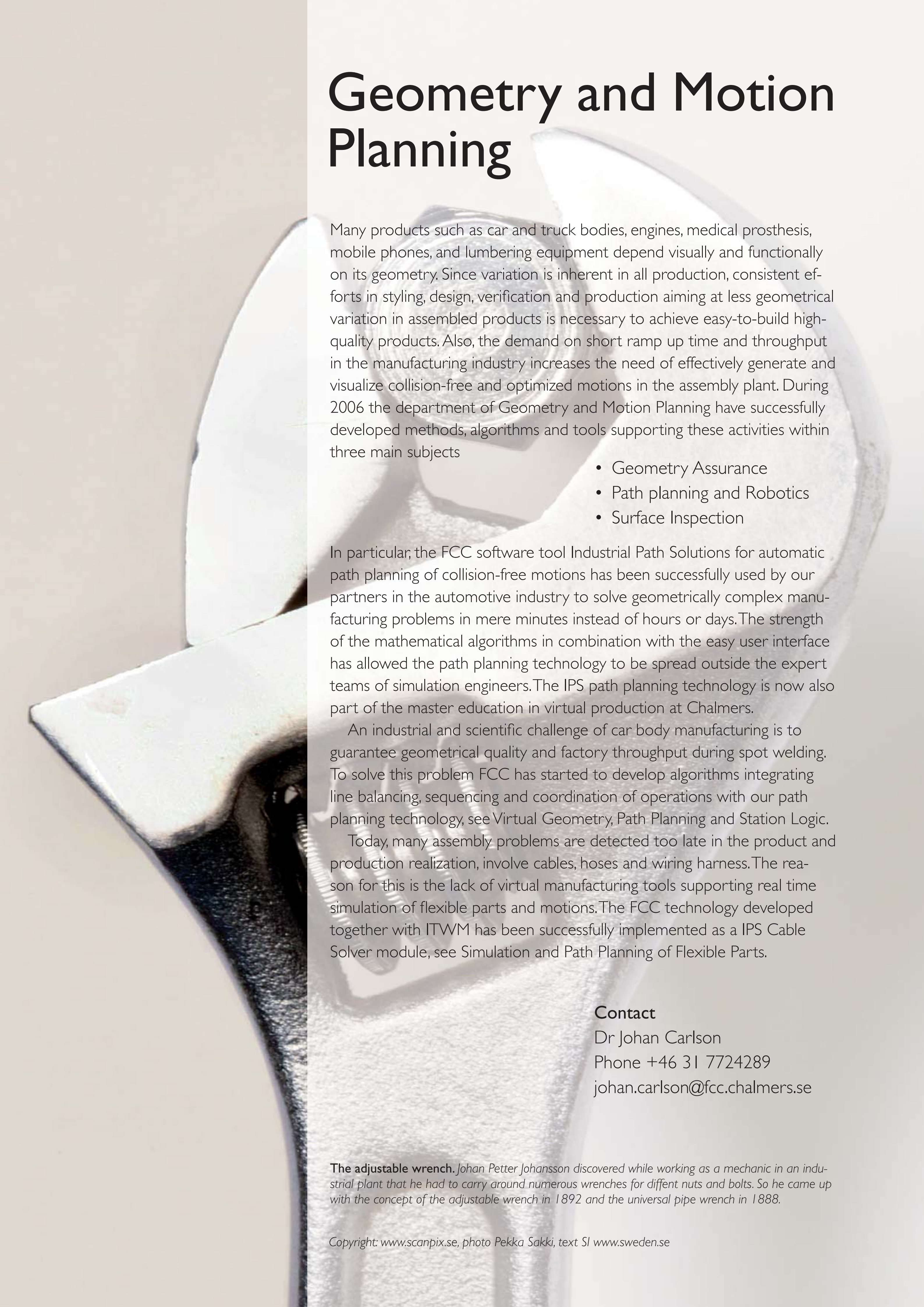
FCC is working together with The Second Swedish National Pension Fund, AP2, and Chalmers to develop the new methodology for robust portfolio optimisation described above. The preliminary results are very promising for circumventing the well-known stability problems associated with many of the standard mean-variance portfolio strategies.

CDO pricer

Since the introduction of credit derivatives in the middle of the nineties, these comparably young derivatives have also been one of the most strongly expanding markets of financial products. This is not only reflected by an exponentially growing trading volume and an increasing interest by numerous hedge funds, but also by an increasing standardization of simple derivatives and a simultaneously strongly growing demand for exotic and structured products.

The problem in trading credit derivatives is that there is no standard model, implying the lack of a standard model in pricing of simple and structured products.

Together with our partner Fraunhofer-ITWM, we have analyzed, implemented and further developed appropriate models for credit derivatives, in particular collateral debt obligations, CDO.



Geometry and Motion Planning

Many products such as car and truck bodies, engines, medical prosthesis, mobile phones, and lumbering equipment depend visually and functionally on its geometry. Since variation is inherent in all production, consistent efforts in styling, design, verification and production aiming at less geometrical variation in assembled products is necessary to achieve easy-to-build high-quality products. Also, the demand on short ramp up time and throughput in the manufacturing industry increases the need of effectively generate and visualize collision-free and optimized motions in the assembly plant. During 2006 the department of Geometry and Motion Planning have successfully developed methods, algorithms and tools supporting these activities within three main subjects

- Geometry Assurance
- Path planning and Robotics
- Surface Inspection

In particular, the FCC software tool Industrial Path Solutions for automatic path planning of collision-free motions has been successfully used by our partners in the automotive industry to solve geometrically complex manufacturing problems in mere minutes instead of hours or days. The strength of the mathematical algorithms in combination with the easy user interface has allowed the path planning technology to be spread outside the expert teams of simulation engineers. The IPS path planning technology is now also part of the master education in virtual production at Chalmers.

An industrial and scientific challenge of car body manufacturing is to guarantee geometrical quality and factory throughput during spot welding. To solve this problem FCC has started to develop algorithms integrating line balancing, sequencing and coordination of operations with our path planning technology, see Virtual Geometry, Path Planning and Station Logic.

Today, many assembly problems are detected too late in the product and production realization, involve cables, hoses and wiring harness. The reason for this is the lack of virtual manufacturing tools supporting real time simulation of flexible parts and motions. The FCC technology developed together with ITWM has been successfully implemented as a IPS Cable Solver module, see Simulation and Path Planning of Flexible Parts.

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The adjustable wrench. *Johan Petter Johansson discovered while working as a mechanic in an industrial plant that he had to carry around numerous wrenches for diffent nuts and bolts. So he came up with the concept of the adjustable wrench in 1892 and the universal pipe wrench in 1888.*

Acknowledgement

During 2006, the successful collaboration with Winqquist Laboratory at Chalmers has been further strengthen by Vinnova's appointment of Wingquist Laboratory with FCC as partner as a Vinn Excellence Centre. Also the collaboration with the Industrial Research and Development Corporation (IVF), and the ITWM departments Dynamics and Durability and Image Processing, has grown by working together on common projects.

In 2006, the Geometry and Motion Planning group has received substantial funding from Vinnova and the Swedish Foundation for Strategic Research.

The Geometry and Motion Planning Research Group

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- Claes Roth, Master Student
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Geometry Assurance

Geometry-related quality problems are often discovered during the assembly process when parts are about to be assembled and do not fit as expected. Often the reason is geometrically sensitive product and production concepts that have not been verified enough due to lack of powerful analysis tools. A design or production change at this stage is very costly and does almost always result in delays in market introductions with lost revenue as a consequence. Therefore, FCC in corporation with the Wingquist Laboratory at Chalmers and the Swedish Institute of Production Engineering (IVF) operates to support a systematic reduction of variability in processes and products in the following key areas:

- Robust design and variation simulation
- Inspection planning preparation and optimisation
- Statistical process control and root cause analysis

The three-point seat belt. *Nils Bohlin constructed the three-point seat belt which was introduced into Volvo cars as standard equipment as early as 1959. The three-point seat belt saves a life every six minutes and is regarded as one of the most important innovations ever for traffic safety worldwide.*

Robust Design & Variation Simulation

The key idea behind Robust Design is to make the product as insensitive to variation or disturbance as possible, to make it withstand potential uncertainties in the manufacturing process or changes in the operating environment. We use statistical Monte Carlo simulation, sensitivity analysis and contribution analysis from our partner RD&T Technology to make the product insensitive to manufacturing and assembly tool variation. This reduces the need for costly physical prototypes and test series, see figure 1.

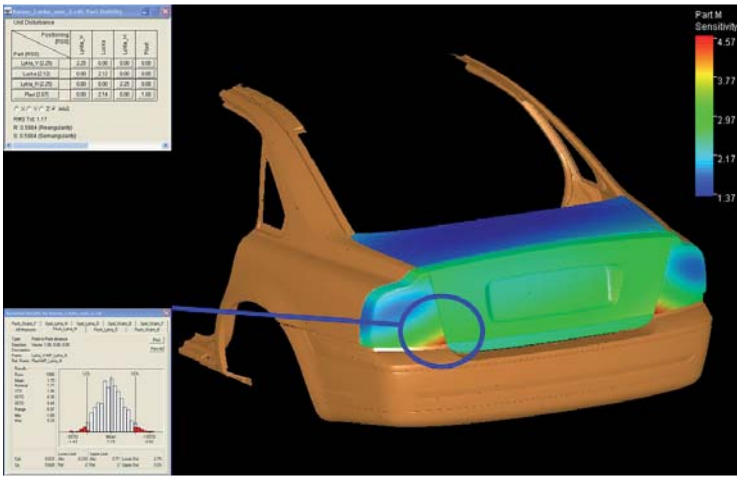

Figure 1. Colour Coding, based on sensitivity analysis, of the Volvo S80 Car Body. Areas sensitive to dimensional variation are indicated with red colour (courtesy of Volvo Car Corporation).

Inspection Planning and Analysis

Inspection planning refers to the activity to gather information about variation in individual parts, processes, assemblies and assembly equipment, in order to control the manufacturing process and to be able to give feed-back to a number of activities in the geometry assurance process. Today inspection planning is almost always solely based on experience and can be improved significantly by using mathematical and statistical analysis. We develop methods and support tools for intelligent inspection preparation. The motive is to gather as much information about the product and the process as possible with minimum number of inspection points, see figure 2.

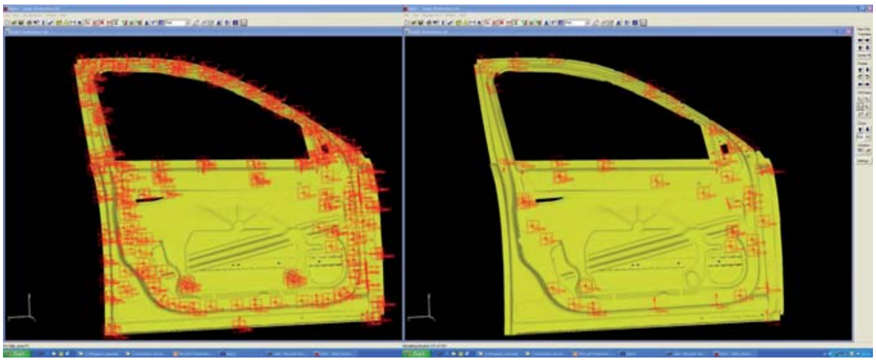

Figure 2. Inspection point reduction in action on car body door (courtesy of Saab Automobile).

Statistical Process Control and Root Cause Analysis

Today routine measurements in the industry are often made on-line during the production process. Statistical process control (SPC) is a set of quality tools aimed at reducing variability utilizing these measurements. For manufacturing processes of simple parts, patterns on a control chart may provide enough diagnostic information to an experienced operator to pin point the root cause. However, experience shows that many SPC attempts fail to produce meaningful results because the lack of diagnostic support for the effort. Therefore, we develop statistical methods to make root cause analyses on the product to find and correct problems in the manufacturing and assembly process. The motive is fast identification and correction of problems and increased knowledge about product/process correlation, see figure 3.

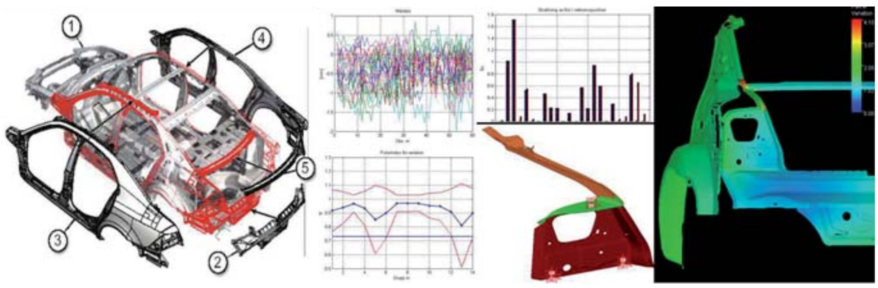

Figure 3. A multi-fixture assembly where a number of parts are assembled. From left to right: Assembly, production data, multivariate statistical process control, root cause analysis, assembly fixture fault, simulated effect of correction (courtesy of Saab Automobile).

Path Planning

Automatic Path Planning for Rigid Bodies and Industrial Robots

Despite that modern industries use virtual prototypes to replace physical prototypes, visualize assembly processes and program industrial robots off-line, the full potential of the virtual factory is not reached. Programming of motions and paths for robots and equipment is still done manually, since the existing support for automatic path planning is very limited. Another limitation is the geometrical accuracy between the virtual model and the physical reality. Therefore, geometrical tolerances need to be considered during path planning. This is a first step, going from nominal to production adapted virtual models and hence connecting the production loop including styling, design and manufacturability.

Virtual verification of that products can be assembled and later on disassembled for service purposes is an important part of geometry simulation in the manufacturing industry. Methods and software for automatically generating collision free assembly paths are therefore of great interest. Also, off-line programming of robots and coordinate measurement machines used in the factory lead to hard problems for the simulation engineer when trying to manually find collision free paths between points, with that of minimizing cycle time and joint wear. Therefore, FCC operates to support the following path planning applications:

- Assembly visualization / verification/design
- Assembling with robot
- Welding and sealing
- Coordinate measurement machine
- Load balancing, sequencing and coordination of robot operations

The zipper *was admittedly invented by an American, but in 1900 Sweden's Gideon Sundbäck was the first to introduce a well-functioning design.*

Assembly Visualization/ Verification/Design

This project with our partner Volvo Car Corporation has resulted in simulation software for automatic path planning, viewed in figure 1. The software is based on a virtual 3D model describing the kinematics and the geometry in the assembly cell, interacting with a collision tester.

For small sub-assemblies as well as final assemblies, simulations give valuable support when evaluating new concepts and comparing alternative solutions. Also different assembly sequences can be compared and verified. As a result, product functionality and manufacturability can be improved.

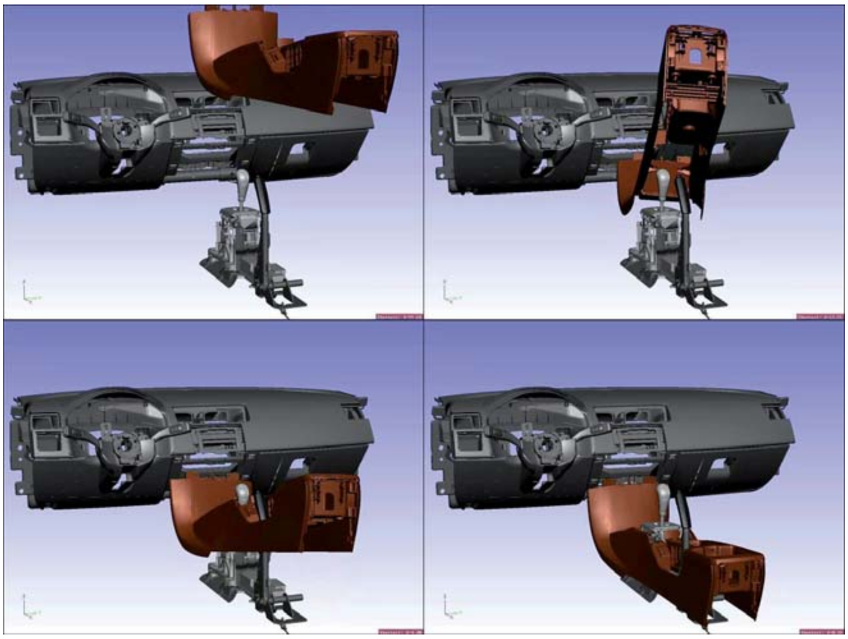

Figure 1. Is it possible to assembly the tunnel bracket? The FCC path planner finds a solution in less than 2 minutes. Even an experienced simulation engineer will struggle for days with this assembly verification (courtesy of Volvo Car Corporation).

Assembling with Robot

In addition to collision avoidance and kinematic constraints, automatic robot programming involves minimization of cycle time, robot wear and joint forces. Efficient path planning and reachability analysis is also beneficial when comparing station layouts choosing robots and designing tools, grippers, and fixtures, see figure 2.

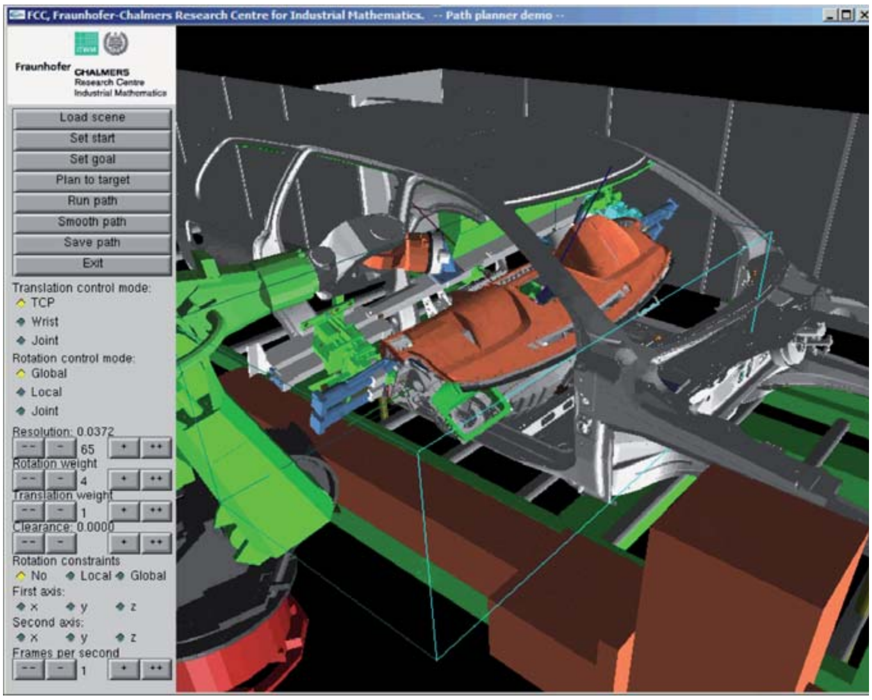

Figure 2. In this station, the driving unit is assembled into the car body. Due to the narrow door opening, the clearance is very small and programming without support from a path planner is difficult. This demo application developed by FCC finds a solution in 3 minutes (courtesy of Volvo Car Corporation).

Path Planning and Sealing of Car Body Seams

This project with our partner Volvo Car Corporation has resulted in simulation software for automatic path planning of Robotized sealing applications. In the sealing station, robots spray the sticky sealing mass along, for instance, spot welded seams. By covering the seams, dirt and water cannot come into the chinks and cause corrosion. The sealing also has a sound insulating effect. In the first step, the algorithm finds several different collision-free motions applying the sealing mass along each seam. In the second step, collision-free motions are generated in such way that an optimal sequence connecting one solution for each seam is obtained, see figure 3.

Figure 3. Automatic path planning and optimisation of a sealing station (courtesy of Volvo Car Corporation).

Coordination/Interlocking of Multi-Robot Manufacturing Cells

In many manufacturing operations, e.g. spot welding of car bodies, several robots needs to share the same workspace. To coordinate and avoid collisions the robots are synchronized by defining interlocking points along the robot paths. At an interlocking point it is checked whether the program can continue without the risk of collision or not. If the risk of collision is present the program halts until this is no longer the case. Programming of interlocking points is today done on-line, as current simulation software lacks support for automatic generation and validation. This project with our partner Volvo Car Corporation has resulted in interactive software providing methods and algorithms for minimizing interlocking related time-loss through an efficient use of interference zones, see figure 4.

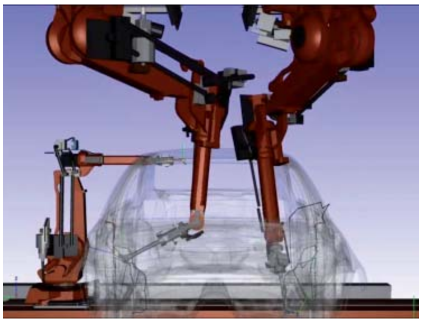

Figure 4. Where and when shall the robots wait for each other in order to avoid collisions and minimize cycle time (courtesy of Volvo Car Corporation)?

Virtual Geometry, Path Planning and Station Logic

The goal of this project is to create a cost-effective and quality-assured assembly process for complex products. Today, geometry assurance, robot path planning and line balancing are carried out partly manually and isolated with limited transparency. Therefore, this project integrates variation simulation, path-planning, sequencing and line balancing with station logic to generate an integrated and cost-effective manufacturing process where product quality and cycle time can be evaluated and optimized for different product and production systems. A PhD student within Volvo Cars industrial PhD program is specially working with integration and interfaces between the three areas. The projects will in particular show how welding point locations and sequence affects auto-body quality and cycle time.

This project is part of the Vinnova MERA program and is a collaboration project between Volvo Cars Corporation, AB Volvo, Saab Automobile AB, Scania AB, Semcon AB, Caran AB, Fraunhofer-Chalmers Centre, Wingquist Laboratory at Chalmers, see figure 5.

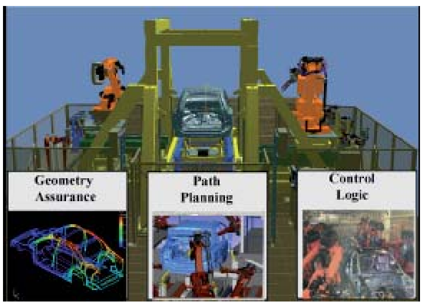

Figure 5. New virtual methods and tools for geometry assurance, path planning and station logic allow for a more efficient production and preparation (courtesy of Volvo Car Corporation).

Fast and Memory Efficient Sweep Volume of Moving Parts

The swept volume is the space generated when a part is moved along a path. Such volumes have many applications in virtual prototyping, e.g. booking the volumes needed for different parts during an assembly operation or to find interference zones for multi-robot coordination. The sweep volume can be very complex since both the part geometry and motion can be complex. Due to this complexity the computing time and the memory needed for generating and representing the volumes has been too large to be used in practice. In this project, FCC has developed and implemented a solution that meets the high demands of manufacturing engineering when it comes to computing time and complexity of geometry models, see figure 6.

Figure 6. An assembly path and corresponding swept volume (courtesy of Volvo Car Corporation).

Non-Nominal Path Planning

One important aspect in the assembly process design is to assure that there exists a collision-free assembly path for each part. To manually verify assembly feasibility in a digital mock-up tool can be hard and time consuming. Therefore, the recent development of efficient and effective automatic path planning algorithm and tools are highly motivated. However, in real production, all equipment, parts and subassemblies are inflicted by geometrical variation, often resulting in conflicts and on-line adjustments of off-line generated assembly paths. Therefore, we have developed a new algorithm and working procedure enabling and supporting a more cost effective non-nominal path planning process for assembly operations. The basic idea is to combine state-of-the-art technology within robust design and variation simulation with automatic path planning. By integrating variation and tolerance simulation results into the path planning algorithm we can allow the assembly path going closer to areas of low variation, while avoiding areas of high variation, see figure 7.

Simulation and Path Planning of Flexible Parts

The project goal is a more efficient and quality assured production preparation of flexible parts. Examples of flexible parts in automotive industry are air pipes, fuel pipes, electrical wires, and tubes on production equipment like robots, see figure 8 - 10.

The project has generated a software demonstrator in which cables and wires of various material parameters can be simulated in real time. Forces and moments can be analyzed, cable length can be optimised, clips can be attached, and motions can be evaluated. The project results include (i) Simulation results have proven to be accurate, (ii) The software is already used in car projects, (iii) GM has decided to support the technology developed in this project as a global standard for simulation of flexible cables, and (iv) Approximately 40 engineers at Saab/GM and Volvo Cars are trained in the software demonstrator developed in the project.

The project is part of the Vinnova MERA program and is a collaboration project between Saab Automobile AB, Volvo Cars Corporation, and Fraunhofer-Chalmers Centre.

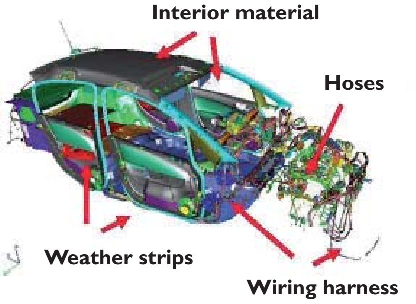

Figure 8. Examples of Compliant/flexible parts (courtesy of Saab GME).

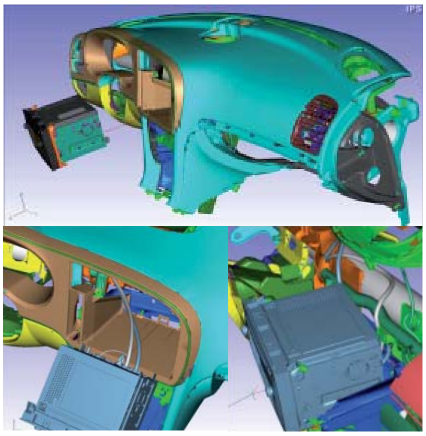

Figure 9. Optimization of length, clip positions and effect of over length of the Radio Assembly cables (courtesy of Saab GME).

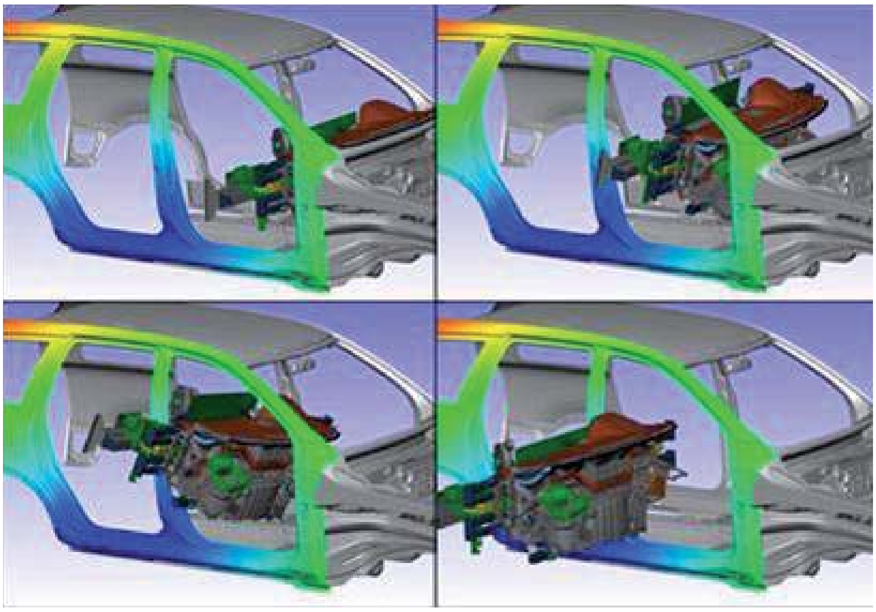

Figure 7. A driving unit assembly path taking results from variation simulation of the car body into account. Areas of high geometrical variation are avoided (courtesy of Volvo Car Corporation).

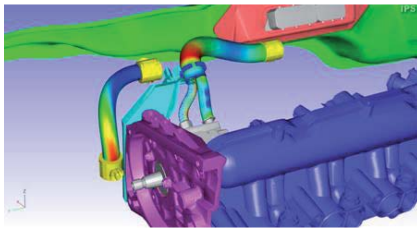

Figure 10. Force analysis of engine hose (courtesy of Saab GME).

Surface Inspection

Esthetic design has become an important factor in many branches of the production industry. The interaction between the geometrical shape and the surface quality of a product has a substantial impact on the impression conveyed by a product. Despite ever improving production processes and quality enhancing measures, all industrial production is subject to errors and defects. Since the quality requirements from the customers' part are constantly increasing, improved quality control in general is of vital importance, and in particular surface quality control.

Up to recently, the quality control of produced objects´ surfaces has been done by human inspection. Even though the quality controllers usually are very experienced, variations in the inspection results occur, both between individuals, but also due to mood, fatigue etc.

An alternative is to set up an automatic surface inspection utilizing a camera system and image processing algorithms (see figure 1 and 2) to automatically detect and rate defects. A number of high-resolution cameras covering the entire object to be inspected continuously acquire images which are sent to an equal number of processing units, where modern image processing algorithms are evaluating the image data. Candidate defects are generated by some fast algorithms looking for irregularities, and these candidates are subject to a more detailed analysis verifying the existence of a defect and categorizing its type.

An automatic system has many advantages, including

- Objectivity. The inspection result for a certain object will always be the same, which is not the case for manual inspection.
- Speed. Automatic systems are usually faster than humans to find and classify defects. Furthermore, while humans have a limit, the speed of an automatic system may be improved by increasing the hardware capacity.
- On-line. An automatic system can usually be installed directly in the production line, without interrupting the production. Manual inspection must usually take place off-line, which in reality means that only a few selected samples may be inspected.
- Statistics. An automatic system supports systematic gathering of detailed statistical data over the occurrences of various defects.

The Celsius thermometer. *Anders Celsius (1701-44), astronomer and mathematician, is best known today for the centigrade thermometer that bears his name and is now used in much of the world. But Celsius initially designated the boiling point of water as zero degrees and the melting point of ice at 100°. Later, Linnaeus is said to have turned this scale upside down. Celsius carried out a number of highly important astronomical measurements as well.*

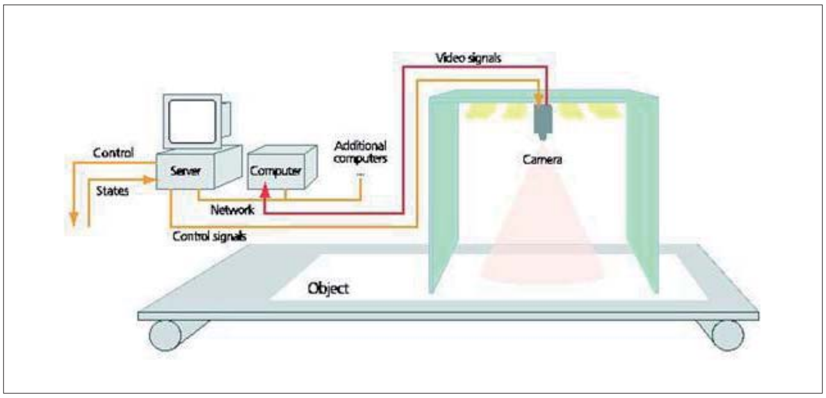

Figure 1. Schematic description of an automatic visual inspection system.

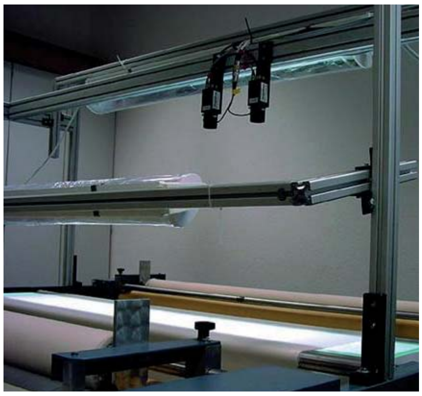

Figure 2. An automatic inspection system for fabrics.

Inspection and grading of leather hides

Currently, FCC and ITWM are jointly involved in a project for developing an automatic inspection and grading system for a major Swedish leather hide manufacturer.

The task of the system is to sort hides after the tanning process into a number of quality classes, depending on the number of defects and their location on the hide. The quality class controls the degree of further processing (painting) which determines the value of the hide. If the quality is overestimated, defects may be visible after finished processing, leading to further processing and additional costs. Underestimating the quality leads to excessive painting and loss of product value. An automatic system reducing the errors and variation in the early grading may thus be very cost-efficient.

The problem of automatically classifying a hide according to quality may be divided into two steps:

- Automatic detection of all relevant defects such as scratches, insect bites, warts, and shingles eczemas, while avoiding spurious detections caused by natural irregularities of the hide (e.g. veins). Examples of defects and natural structures are shown in figure 3.
- The result of the detection algorithm is a list of defects describing their type, intensity/severity, and position on the hide. All of this is taken into account by a grading algorithm to select a quality class.

During 2006, an off-line prototype system has been evaluated at Elmo showing promising results. In December it was moved to the production line to be tested and further developed under realistic production conditions during 2007.

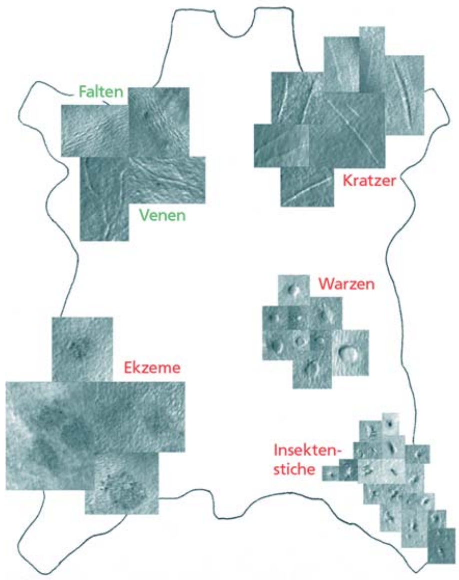

Figure 3. Schematic image of various defect types.

Systems Biology (including Bio Imaging)

The application of tools and techniques, borrowed from engineering disciplines such as systems and control theory, signal processing, and computer science, for studying biological and biochemical systems has received an increasing attention over the last couple of years. This is due to a number of factors such as recent advancements in measurement technology, a need for pharmaceutical companies to find alternative strategies to beat current shortcomings in early drug development and increase competitiveness, and the improved understanding of living systems due to the sequencing of genomes and characterization of the function and role of corresponding proteins. FCC provides an integrated approach to the study of biochemical and physiological processes, from the characterization of single parts to the analysis of dynamic phenomena on a systems level. The work at the department includes both biological/biomedical modeling applications as well as development of computational tools and algorithms. Currently we are involved in modeling projects where yeast (Saccharomyces cerevisiae) and oocytes (Xenopus laevis) are used as model organisms. Modeling of ion-channels and action potential propagation is also an area of research that we are involved in.

This year was the second year of operation for the EU funded network of excellence – BioSim, which aims at increasing the use of biosimulation in drug development. Here one sample contribution by FCC has been in the area of insulin signaling in fat cells through a PhD project, which was successfully completed during the year. At the beginning of the year we also organized a BioSim workshop on The Integration of Glucose Homeostasis Related Modeling Efforts with about 30 distinguished international researchers participating.

We are also happy to conclude that the interest from commercial clients in our applied research has resulted in a number of industrial projects during the year.

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The AGA beacon. *Gustaf Dalén, chief engineer of Svenska Gasackumulator (AGA) 1906, was responsible for a series of important inventions: agamassa, a substance that absorbs acetylene, reducing the risk of explosions; a switch for maritime beacons; the sun valve, which automatically turned on the beacon at nightfall and turned it off at dawn, and the Dalén mixer, an apparatus which blended acetylene gas with air. The AGA beacon meant major savings in personnel and materials and made shipping safer around the world during most of the 20th century.*

Acknowledgement

In 2006, the Systems Biology and Bioinformatics department has received substantial funding from the Swedish Foundation for Strategic Research. Furthermore, the group has also received funding for the BioSim project from the European Commission.

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Nils Lämås


Mikael Sunnåker


Bengt Söderberg


Peyman Zarrineh

Systems Biology

Combining model based signal processing, system identification, mechanistic models, and sensitivity analysis with novel measurement platforms provides a strong competitive edge for researchers in the pharmaceutical and biotech industry. Systems biology partly addresses these things and is an emerging scientific field that aims at elucidating the properties and function of biochemical and biological systems on a systems level, e g, how biomolecules interact and implement various functions which cannot be understood by studying the system components in isolation.

The activities in systems biology at FCC are focused around the application and development of computational methods and mathematical models of biological systems on sub-cellular, cellular, tissue, organ, and whole body level, utilizing systems level measurements. The computational tools and algorithms developed at the department can be divided in three main areas: System identification – to build mathematical model of dynamic systems based on measured data; Model reduction – to reduce the size and scope of models to arrive at models whose parameters can be estimated and validated using available measurement data; Software tools – to support the model building process and computational analysis of the obtained models. The research is carried out in close co-operation with both academic and industrial partners. The in-house competences are in the area of control and dynamic systems and the group has several years of experience of both software development and application of methods from systems and control theory to projects in both the engineering and pharmaceutical industry.

Our vision is to develop means to enable researchers to delineate and understand the underlying mechanisms of a disease or phenomenon at the mechanistic level, i e, in terms of biochemical reaction or interaction networks. We focus on mechanistic models to map out and better understand a specific biological phenomenon or pathological condition.

The systems biology group at FCC also has very close collaboration with the Swedish company InNetics, who are the developers of the systems biology software PathwayLab.

The kerosene (Primus) stove *was developed by Frans Wilhelm Lindqvist. It was patented in the late 1880s. In partnership with a factory owner, he began to manufacture the new stove. About 50 million Primus stoves were made.*

Systematic Modeling Framework

We are developing a systematic modeling framework for biochemical and biological systems. The focus is on dynamic models based on ordinary differential equations. The main steps of the proposed modeling framework are: a) definition of a model network structure, b) determination of mathematical rate expressions, c) parameter determination (experiment design, identifiability analysis, parameter estimation, model reduction), and d) model validation. The framework includes the fact that the modeling process will, in general, not be sequential but that the different steps need to be repeated in a problem dependent cyclic manner. The goal of the presented modeling framework is on one hand to give a guideline when approaching new challenging applied projects, but equally important it serves to highlight parts of the modeling process for which important system theoretic results and/or computational tools are strongly needed. A minor result of the framework is the insight that computational tools used for different steps need to focus on the needs of the users that are supposed to use them. This might seem a trivial result; however, within systems biology presently available computational tools are often very difficult to use by the targeted user group and/or impose limitations that are not acceptable.

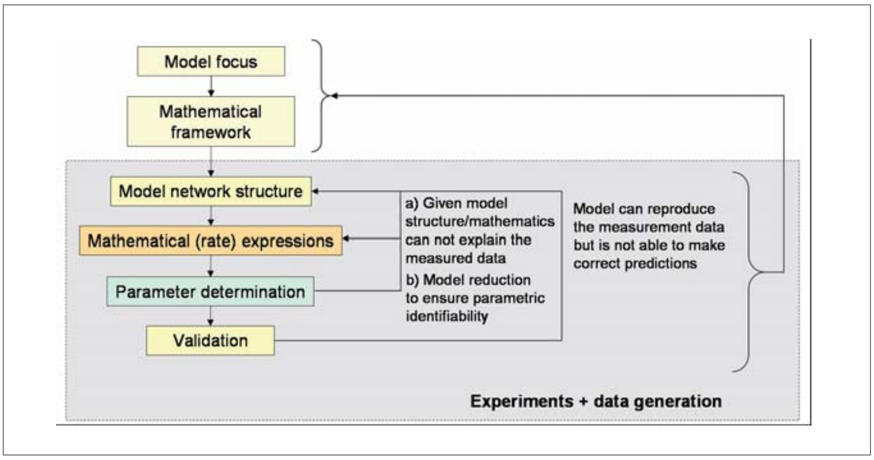


Figure 1. The six main steps of the systemtic modeling framwork

Parameter Estimation

In this project we have considered systems of ordinary differential equations with parameters to be determined from time-series data, i.e., a mixed continuous-discrete problem. Today the dominating approach to this problem in the systems biology community is to measure the goodness of fit between the data and a simulated response from the system using a sum-of-squares criterion. Minimization of such a criterion is then carried out using a range of alternative methods from gradient based local minimization methods to global optimization algorithms such as simulated annealing and genetic algorithms. We have demonstrated the importance of working with alternative formulations of the measure of the goodness of fit or objective function to obtain less challenging minimization problems. The methods can be considered to belong to the class of so called prediction error minimization methods, which can be put in a maximum likelihood framework using stochastic differential equations observed at discrete points in time.

The rationale behind using prediction error minimization is that the performance of a model should be judged based on how good it is on prediction. The basic idea is to construct a predictor and compare its predictions with available data using some suitable measure. Note that the approach of comparing simulated response with measurement data is just a special case of this approach where the predictor equals a simulation model of the system. In general the predictor is also allowed to take old measurement data into account, which substantially reduce the prediction error.

Model Reduction

In this project we have made an inventory of currently existing methods for model reduction and extended the set of techniques with a number of methods particularly suited for biochemical applications. Model reduction methods can in general be divided into the following main categories; lumping, sensitivity analysis, and time scale analysis. We have presented a systematic step by step method that can be used to reduce nonlinear biochemical models. Much focus has been put on numerical methods to identify which states that can be considered as fast, slow, or correlated. The theory has been applied to a model for glucose transport through a cellular membrane where we in a systematic way obtained the same reaction rate equations as the original authors. An algorithm for automatic model reduction according to the developed theory has been implemented in Matlab.

We have also considered the special case of linear reaction systems and a method has been developed for how such models can be reduced. Since we are mostly interested in the values of individual states in the original model, so called fraction parameters are computed. These parameters enable a mapping of the states in the reduced model to those in the original model, which is import to be able to regain the biological insight provided by the original complex model. The resulting method has been implemented in Matlab and successfully been applied to a 26 states model for photosynthesis, which is reduced to six states, still capturing the main features of the original model, see figure 2. Finally, this model reduction method was applied in a nonlinear case with satisfactory performance.

Systems Biology Toolbox

The Systems Biology Toolbox for Matlab has been further extended as part of the BioSim project and projects financed by SSF. This toolbox offers systems biologists an open and extensible environment, in which to explore ideas, prototype and share new algorithms, and build applications for the analysis and simulation of biological and biochemical systems. Additionally it is well suited for in-classroom use for educational purposes. The toolbox supports the Systems Biology Markup Language (SBML) by providing an interface for import and export of SBML models. In this way the toolbox connects nicely to other SBML enabled modeling packages, such as CellDesigner, JDesigner, or PathwayLab. The Systems Biology Toolbox for Matlab is open source and freely available from http://www.sbtoolbox.org. The website also contains a tutorial, extensive documentation, and examples. The toolbox has been developed partly as a contribution to the BioSim project. During its short time of existence it has become very popular and has been widely spread both within and outside the BioSim network (over 2000 downloads).

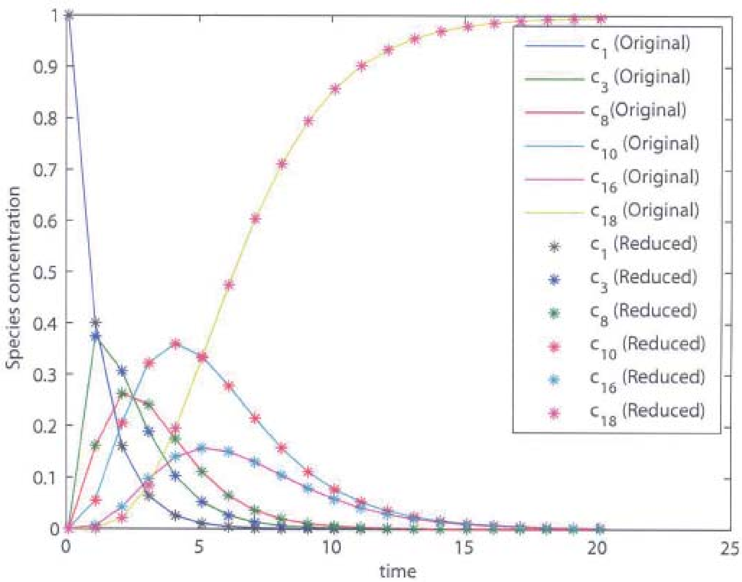


Figure 2. A comparison of the transient behavior of a few key variables computed by the original (-) and reduced (+) model.

Modeling the Interplay between Neuron and Glial Cells

Glial cells serve a variety of functions in nervous systems. In this project we consider a special kind of glial cell, known as astrocytes, which can be seen as mediators between neurons and blood vessels. Astrocytes respond to neurotransmitters, released by neurons, via receptors, but also take up some of the transmitters to help terminate the synaptic process. Among these, glutamate uptake by astrocytes is pivotal to avoid transmitter-mediated excitotoxicity. A new model has recently been proposed by our collaborators in which glutamate uptake via the excitatory amino acid transporter (EAAT/GLAST) is functionally coupled to other astrocyte transporters, in particular the sodium-bicarbonate cotransporter (NBC) and the monocarboxylate transporter (MCT), as well as other astrocyte functions, such as calcium signaling, a high potassium conductance and CO2 consumption. The central issue of this hypothesis is that the shuttling of sodium ions and acid/base equivalents, which drive the metabolite transport across the astrocyte membrane, cooperate with each other, and hence save energy. As a result, glutamate removal from synaptic domains and lactate secretion serving as energy supply for neurons would be facilitated and could operate with greater capacity.

Even though the principle of the interplay between neuron and astrocytes seems to be relatively well understood, the above described model is still a hypothesis. The importance of many involved elements, such as the different transporters, the glutamate triggered calcium signaling, the effect of extra and intracellular carbonic anhydrase, remain relatively unknown. The full model network structure corresponding to the current biological understanding is shown in figure 3. However, a realistic mathematical model cannot directly address the whole system and often so called model systems are used where certain aspects are investigated.

In this work we have built a mathematical model of a biological model system of a subsystem of the neuron glial system. The model system consists of a certain type of frog eggs so called Xenopus laevis oocytes, which can be genetically engineered to express membrane transport proteins that can be found in astrocytes. In this way a part of the mechanisms proposed for the neuron astrocyte interplay can be investigated in isolation with experimental techniques such as patch clamping (fixing membrane potential and measuring ion-currents) can be used to generate time-series data to be used for system identification and parameter estimation. This project is carried out in close co-operation with Fraunhofer-ITWM and Professor Dr Joachim Deitmer and Dr Holger Becker at the Division of General Zoology at Kaiserslautern University.

Thiamine Regulation in Yeast

In an ongoing project we are building a dynamic model for the regulation of thiamine metabolism in yeast. As a first step towards this model we have setup a preliminary structure of the overall system and subdivided it into four different modules that will be considered one by one, see figure 4. These modules are 1) thiamine transport, 2) de-novo synthesis, 3) gene regulation, and 4) carbon source sensing/metabolism. Initially we have focused mainly on the transport module and have obtained preliminary results, consisting of the overall model network structure and experimental results that will allow the determination of reasonable rate laws and kinetic parameters for the transport module. This project is one of the test cases for the systematic modeling framework described above.

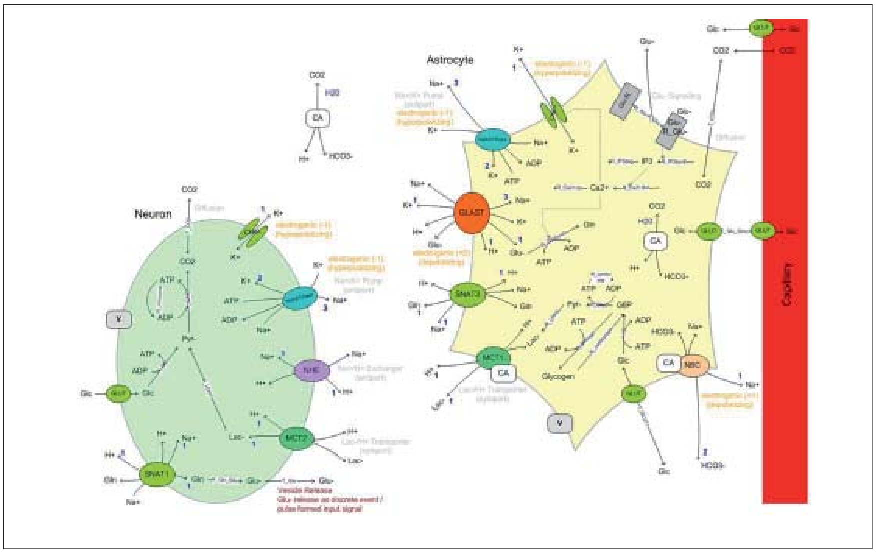


Figure 3. The model network structure of the Neuron Glial system.

Implementation and Validation of a Model for Ventricular Action Potential

In this project the so called Hund-Rudy model of ventricular myocyte action potential (Hund and Rudy: Rate Dependence and Regulation of Action Potential and Calcium Transient in a Canine Cardiac Ventricular Cell Model, Circulation, 110:3168-3174, 2004) was implemented and validated using the Systems Biology Toolbox for Matlab (SBtoolbox). This model is known to be very useful since it articulates the relationship between ion-channel blockade and action potential prolongation in the routine safety screenings which are required for regulatory purposes. Implementing the model in SBtoolbox format makes it possible to apply a whole range of tools for further computational analysis such as sensitivity analysis, parameter estimation, and model reduction or modification. Furthermore, the model can easily be exported to other formats such as the Systems Biology Markup Language (SBML), which facilitates exchange with other programs for computational analysis. We have also extended the Hund-Rudy model to be able to remove the currently inherent problem of long term drift in some ion-concentrations, which is a necessary for carrying out any type of steady state analysis (e.g., action potential duration and morphology studies at different pacing rate). A number of parameters have also been added to the model to allow quick specification of experimental conditions such as clamping to certain membrane potentials for specific time intervals; pacing amplitude, rate, and pulse duration; and inhibition of different enzymes. Finally, the model has been validated against results generated by the original Hund-Rudy model code, by pairwise comparison of state and current trajectories. Similarly, the automatically generated SBML code has been validated by the same pair-wise state and current trajectory comparison with the SBtoolbox code. The project has also demonstrated the power of using an integrated computational platform for systems biology such as SBtoolbox for rapid model development and computational analysis. The project was partly financed by AstraZeneca via the industrial consortium STM.

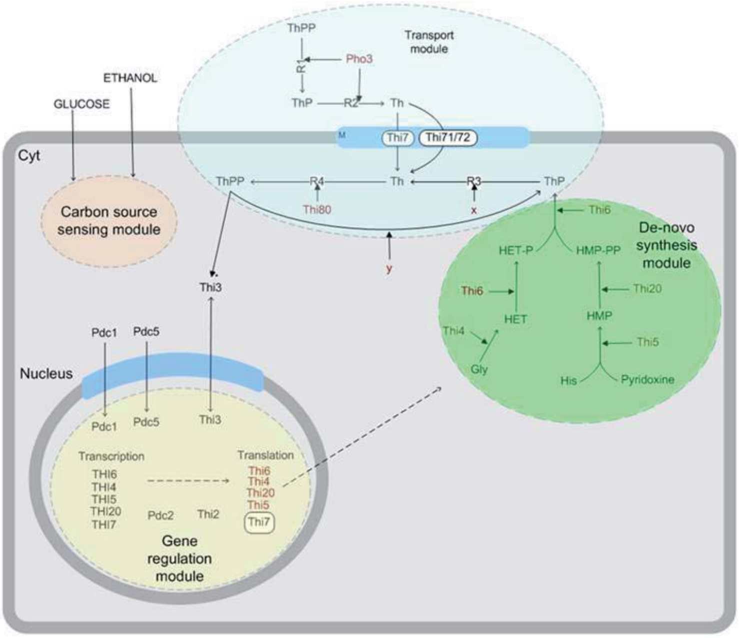


Figure 4. The model network structure of thiamine regulation in yeast.

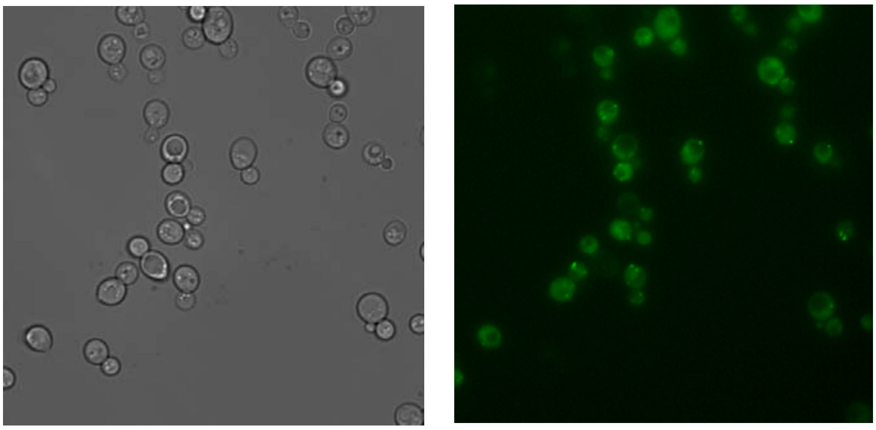
Quantitative cell studies

Quantitative microscopy has in the last couple of years aroused substantial interest for life sciences applications. In eukaryotic cells, quantitative measurements of protein expression, protein localization and protein-protein interactions are key components for a proper understanding of protein functionality. FCC collaborates with the Center for Biophysical Imaging at Chalmers, for developing algorithms and computer software for quantitative in vivo imaging. For the image analysis algorithms used, the emphasis lies on robust methodologies which enables long time-lapse studies of protein localization, migration, and inheritance over several cell cycles, as well as high through-put screening of protein functionality of a large number of gene-disrupted cells.

A software demonstrator in Matlab equipped with graphical user-interface (GUI) for automated recognition and tracking of yeast cells from transmission microscope images, combined with quantification and localization of GFP-tagged proteins using fluorescence microscopy, has been developed during the last year. A screen-shot of the main window of the software can be seen in the right-most panel of figure 1.

Particle Tracking

Control of the microscopic characteristics of colloidal systems, primarily the interaction and diffusion coefficients, is critical in a wide range of application areas, including food products and pharmaceuticals. These characteristics determine the macroscopic properties of the system, such as whether the particles will coagulate or remain freely diffusing. For example, in milk, interactions between the small (100 nm to 1000 nm in diameter) fat particles and proteins suspended in the fluid determine whether it coagulates into cheese or yoghurt. In pharmaceutical drugs, the active substances must remain stable in tablet or liquid form for several months between production and medication. When finally delivered to the body, these substances have to be released in a controlled fashion in order for them to be effective.



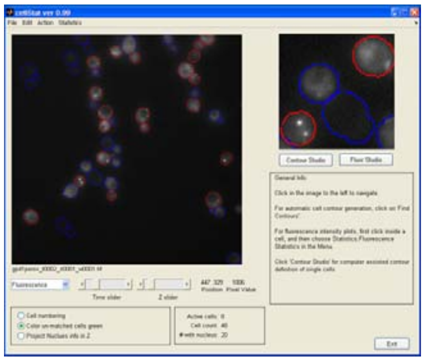


Figure 1. Bright-field image (upper left) and the corresponding fluorescence image (upper right) of a GFP-tagged fluorescent protein in a population of yeast cells. The main window (right) of the software developed at FCC for quantitative cell analysis. Here, cells which contain high local concentrations of the fluorescence protein are colored red.

The data modelled and analysed are sequences of microscope images obtained at AstraZeneca of diffusing polystyrene particles of diameter 500 nm. Suspensions of polystyrene spheres are a common test system for colloidals since by varying the solvent and salt concentration we can emulate features of a wide variety of more intricate colloidal systems. Figure 2 shows an image of a video sequence of diffusing particles. This system is used as a model for describing release of medical drugs in pharmacy, where the understanding of interaction and mobility of the active drug substances is of crucial importance. The positioning methods developed can be used for 3-D tracking from sequences of 2-D images of diffusing particles and the accuracy of the position estimates goes well beyond sub-pixel accuracy. The same principle for tracking can be used in virtually any application where the depicted objects are roughly rotationally symmetric.

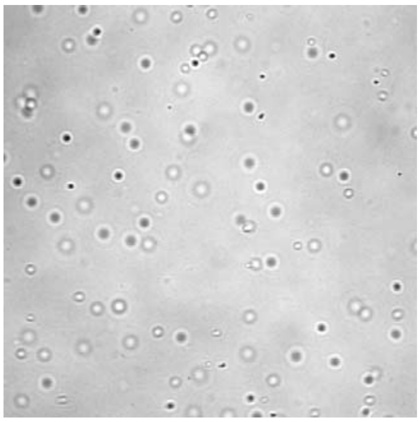


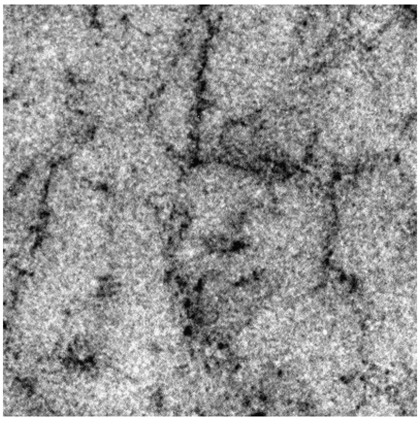
Figure 2. An image from a video sequence of diffusing polystyrene particles. The particles are all of the same size; their difference in appearance is due to an out-of-focus effect, which is used for depth estimation.

Gel structure modelling

A method for identifying the three-dimensional gel microstructure from statistical information in transmission electron micrographs has been developed by FCC in co-operation with SIK (the Swedish Institute for Food and Biotechnology), Department of Mathematical Statistics and Department Of Chemical and Biological Engineering, Chalmers. The micrographs, see the left part of figure 3 are projections of stained strands in gel slices.

The gel strand network is modelled as a random graph with nodes and edges, and parameters in the model are estimated by a Markov chain Monte Carlo method. The three-dimensional network may be simulated from the model and the right part of figure 3 shows a 3D rendering from such a simulation. It would be of considerable interest to actually try to reconstruct the underlying 3D network from the micrographs. Development of MCMC algorithms for such a reconstruction is a challenging research problem. However, it would decrease the effort of arriving at a 3D network from TEM experiment of a microstructure.

In connection with this, we also run a project on simulation of diffusing particles and molecules in complex 3-D geometries such as gel networks estimated from the TEM images. For this we have developed an adaptive time-stepping solver for stochastic differential equations (SDE). The surrounding geometry acts as obstructing medium for the diffusing molecule and the solver can take care of more general kinds of particle-structure interactions using interaction potentials, as well as reflection and adsorption. Here, it is of interest to be able to predict the diffusive behavior (e.g. mobility, stability) of the molecule-structure pair, where either one, or both, is designed for a specific purpose. The estimated diffusion coefficients are validated by comparing with diffusion coefficients measured via an experimental method called NMR diffusometry.



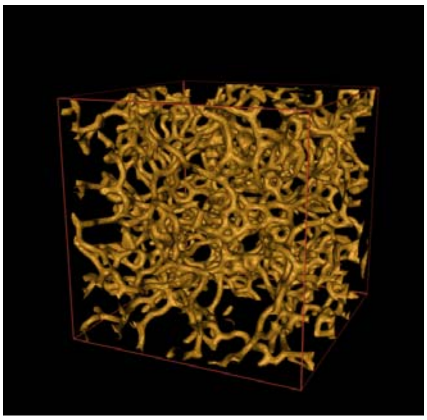


Figure 3. Left: part of a TEM micrograph from a stained Sepharose gel. Right: screen shot from a 3D rendering of the simulated gel network

Årsredovisning

för tiden 1 januari 2006 - 31 december 2006

Resultaträkning (kSEK)	060101-061231
Intäkter	
Nettoomsättning	27 745
Övriga intäkter	17
Summa intäkter	**27 762**
Kostnader	
Externa kostnader	-9 486
Personalkostnader	-16 389
Avskrivningar av materiella anläggningstillgångar	-465
Summa kostnader	**-26 340**
Rörelseresultat	**1 422**
Resultat från finansiella investeringar	
Ränteintäkter och liknande	48
Räntekostnader och liknande	-15
Resultat efter finansiella poster	**1 455**
Bokslutsdispositioner	-345
Årets skatt	-319
ÅRETS RESULTAT	791

Balansräkning (kSEK)	061231
Anläggningstillgångar	
Maskiner och inventarier	1 057
Summa anläggningstillgångar	**1 057**
Omsättningstillgångar	
Kundfordringar	9 374
Förutbetalda kostnader och upplupna intäkter	1066
Övriga kortfristiga fordringar	-
Kassa och bank	3 463
Summa omsättningstillgångar	**13 903**
SUMMA TILLGÅNGAR	14 960
Eget kapital	
Eget kapital vid årets ingång	1 814
Årets resultat	791
Summa eget kapital	**2 605**
Obeskattade reserver	763
Kortfristiga skulder	
Leverantörsskulder	4 148
Övriga kortfristiga skulder	2 341
Skatteskulder	256
Upplupna kostnader och förutbetalda intäkter	4 847
Summa kortfristiga skulder	**11 592**
SUMMA SKULDER OCH EGET KAPITAL	14 960

Styrelsen för Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik, FCC, får härmed avge följande redovisning över verksamheten under tiden 1 januari 2006 – 31 december 2006, stiftelsens femte verksamhetsår.

Stiftelsen bildades av Chalmers och Fraunhofersällskapet i juni 2001 och registrerades av Länsstyrelsen i Västra Götalands län i oktober 2001 som en svensk näringsdrivande stiftelse. Stiftelsen skall enligt strategiplan från oktober 2005 bygga upp en verksamhet som år 2010 omsätter tre och en halv miljon euro och omfattar 35 anställda. Chalmers och Fraunhofersällskapet kommer under denna period att stegvis öka sin finansiering från 400 000 euro 2006 till 500 000 euro 2010.

Årets omsättning har varit ca tjugoåtta miljoner kronor. Medeltalet anställda har ökat från tjugofyra personer (varav sex kvinnor) 2005 till tjugosex personer (varav fem kvinnor) 2006. Stiftelsen har tecknat ett femårigt hyresavtal till och med 31 mars 2011 omfattande 1 096 kvm i Chalmers Teknikpark med Fastighets KB Forskarbyn.

Styrelse och ledning den 20 mars 2007. Sittande: Lars-Göran Löwenadler (Volvo), Helmut Neunzert (vice ordförande, Fraunhofer ITWM), Peter Jagers (ordförande, Chalmers), Dieter Prätzel-Wolters (Fraunhofer ITWM), Gunnar Andersson (KP Pension & Försäkring). Stående: Uno Nävert (föreståndare, FCC), Tomas Lefvert (Vattenfall), Jöran Bergh (Chalmers), Johan Carlson (biträdande föreståndare, FCC).

FÖRVALTNINGSBERÄTTELSE

Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik skall utveckla och anpassa matematiska metoder för industrin. Stiftelsen bedriver konkurrensneutral forskning och marknadsföring med finansiering från grundarna och genomför projekt definierade av företag och offentliga finansiärer på kommersiell grund.

Rörelsens intäkter har uppgått till 27 762 kSEK. Av detta utgör 49% industriprojekt, 24% offentliga projekt och 27% finansiering från grundarna. Årets resultat efter skatt är 791 kSEK. Eget kapital uppgick den 31 december 2006 till 2 605 kSEK.

Stiftelsens styrelse har under verksamhetsåret sammanträtt fyra gånger. Ersättning har utgått till ordföranden med 3 525 kronor per möte och till övriga ledamöter med 2 350 kronor per möte man deltagit i.

Stiftelsens ställning och resultatet av dess verksamhet framgår av efterföljande resultat och balansräkningar, vilka utgör en integrerad del av årsredovisningen.

Result (kEUR)	060101-061231
Income	
Net sales	3 083
Others	2
Total income	**3 085**
Cost	
External cost	-1 054
Staff	-1 821
Depreciations	-52
Total cost	**-2 927**
Result of business	**158**
Result of financial investments	
Interest and similar income	5
Interest and similar cost	-2
Result including financial investments	**161**
Appropriations	-38
Tax	-35
TOTAL RESULT	88

Balance (kEUR)	061231
Fixed assets	
Machinery and equipment	117
Sum of fixed assets	**117**
Current assets	
Accounts receivables	1 042
Prepaid expenses and accrued income	118
Other current receivables	-
Cash and bank	385
Sum of current assets	**1 545**
TOTAL ASSETS	1 662
Equity capital and debts	
Equity capital at beginning of year	201
Result	88
Total equity capital	**289**
Untaxed reserves	85
Short-time debts	
Debts to suppliers	461
Other debts	260
Tax debts	28
Accrued expense	539
Sum of short-time debts	**1288**
SUM OF DEBTS AND EQUITY CAPITAL	1662

Göteborg den 20 mars 2007

Peter Jagers, ordförande
Jöran Bergh
Helmut Neunzert, vice ordförande
Dieter Prätzel-Wolters
Gunnar Andersson, adjungerad
Tomas Lefvert, adjungerad
Lars-Göran Löwenadler, adjungerad

Räkenskaperna har granskats av Deloitte.

Appendix

Presentations / Conferences

J S Carlson:
NIST workshop on Smart Assembly, Washington DC, USA, October, 2006.

G Cedersund, H Schmidt, and M Jirstrand:
Model Reduction for Various Levels of Model Development, 7th International Conference in Systems Biology 2006, Yokohama, Japan, October 2006.

G Cedersund, M Jirstrand, J Roll, and P Strålfors:
A Core-box Model for Insulin Receptor Signalling in Human Fat Cells, 2nd BioSim Conference, Mallorca, Spain, October 2006.

S Danø, G Cedersund, M Madsen, M Jirstrand, and D Fraenkel:
Estimation of Enzyme Kinetic Parameters in Vivo, 2nd BioSim Conference, Mallorca, Spain, October 2006.

F Edelvik:
Finite Element Methods for Electromagnetics, Docent seminar, Department of Information Technology, Uppsala University, March 2006.

S Jakobsson:
Beräkning av radarmålarea med randinte-gralmetoder. Chalmers Kontaktdag Högskola Industri, June 1, 2006.

M Jirstrand:
System Identification in Systems Biology, Invited lecture for the Open Day in Bioinformatics arranged by the National Research School in Genomics and Bioinformatics, University of Skövde, February 2006.

M Jirstrand:
System Identification in Systems Biology, Invited seminar at the Division of Scientific Computing, Department of Information Technology, Uppsala University, April 2006.

M Jirstrand:
System Identification in Systems Biology, Invited speaker, ITWM Colloquium "There is nothing more practical than a good theory", Kaiserslautern, Germany, September 2006.

M Jirstrand, H Schmidt, and G Cedersund:
Parameter Estimation Using Alternative Cost Functions, 7th International Conference in Systems Biology 2006, Yokohama, Japan, October 2006.

M Jirstrand:
PathwayLab - A Software for Modeling and Simulation of Biochemical Reaction Networks, 1st Annual YSBN Meeting, Vienna, Austria, November 2006.

K Logg, M Kvarnström, A Diez, K Bodvard, and M Käll:
Automatic image analysis of in-vivo protein localization in fluorescence microscopy: a quantitative study of GFP-tagged proteins in budding yeast. SPIE Photonics West Bios. January 2007.

M Kvarnström:
Algorithms for quantitative yeast cell analysis. 6th French-Danish Workshop on Spatial Statistics and Image Analysis in Biology, Skagen, Denmark, May 2006.

M Kvarnström:
Yeast cell recognition using a dynamic programming algorithm for convex contour extraction. Spatial and Spatio-temporal Modelling in Biology, Ecology and Geosciences, Smögen, August 2006.

M Patriksson:
A survey on the continuous nonlinear resource allocation problem, at the 21st EURO Conference, Reykjavik, Iceland, July 2-6, 2006.

M Patriksson:
Mathematical optimization models for maintenance management, at KTH School of Electrical Engineering, KTH, October 16-17, 2006.

H Schmidt and M Jirstrand:
Modeling of Biochemical Reaction Systems - Systems Theory and Computational Tools, co-lecturers in the course for Gene Expression and Cell Modelling, Int. Master's Program for Bioinformatics, Chalmers University of Technology, Gothenburg, March 2006.

H Schmidt:
A Systems Biology Toolbox for Matlab, guest lecture for Computational Biology PhD Course, Institute for Cancer Research and Treatment, Turin, Italy, April 2006.

H Schmidt:
A Systems Biology Toolbox for Matlab, Max-Planck-Institut für Dynamik komplexer technischer Systeme, Magdeburg, Germany, May 2006.

D Mojzita, A Nahmany,
H Schmidt, and S Hohmann:
Dynamic Modelling of Thiamine Regulation in Saccharomyces cerevisiae Based on High Performance Liquid Chromatography (HPLC) Measurements, International Specialised Symposium on Yeasts, Helsinki, Finland, June 2006.

H Schmidt:
A Systems Biology Toolbox for Matlab, Cell Signalling Systems Biology Conference, Rostock, Germany, September 2006.

H Schmidt:
A Systems Biology Toolbox for Matlab, Tutorial at the 7th International Conference on Systems Biology 2006, Yokohama, Japan, October 2006.

H Schmidt, M Jirstrand, and G Cedersund:
A Systematic Modeling Framework for Biochemical and Biological Systems, 7th International Conference in Systems Biology 2006, Yokohama, Japan, October 2006.

H Schmidt:
A Systematic Modeling Framework for Biochemical and Biological Systems, Invited lecture for a course in Systems Biology arranged by the National biomedical PhD education program, Karolinska Institute, Stockholm, November 2006.

A-B Strömberg:
Participation in the seminar Elunderhållsdagen at the fair Underhåll Svenska Mässan, Göteborg, March 16, 2006 .

A-B Strömberg:
Optimisation of preventive maintenance, poster at PLANs Forsknings- och tillämpningskonferens 2006, Trollhättan, August 23-24, 2006.

T Svensson:
Model complexity versus scatter in fatigue. UTMIS Spring meeting 2006.

T Svensson:
An uncertainty weighted safety factor for fatigue design, Presentation at the FESI and ESIS TC12 meeting "Using probability modelling in structural integrity assessments", London, England, June 9, 2006.

P Zarrineh, H Schmidt, and M Jirstrand:
Development of Parameter Estimation Methods for Biochemical Reaction Systems, 7th Swedish Bioinformatics Workshop, Stockholm, November 2006.

Publications

R Söderberg, L Lindkvist, J S Carlson:
Managing Physical Dependencies through Location System Design, Journal of Engineering Design, Vol 17, No 2, 2006

R Söderberg, L Lindkvist, J S Carlson:
Virtual Geometry Assurance For Effective Product Realisation, Proceeding of 1st Nordic Conference on Product Lifecycle Management - NordPLM' 06, Göteborg, January 25-26 2006.

G Cedersund:
Elimination of the initial value parameters when identifying a system close to a Hopf bifurcation, IEE Proc Syst Biol 153(6), 448-456, 2006.

M Anguelova, G Cedersund, M Johansson, C-J Franzen, and B Wennberg:
Conserved Moieties May Lead to Unidentifiable Rate Expressions in Biochemical Models, submitted, 2006.

G Cedersund, P Strålfors, and M Jirstrand:
Core-box Modeling for Biosimulation of Drug Action, Biosimulation in Drug Development, Wiley-VCH, Eds. Bertau et al. (accepted for publication).

E Abenius, F Edelvik,:
Thin Sheet Modeling Using Shell Elements in the Finite-Element Time-Domain Method, accepted for publication in IEEE Transaction on Antennas and Propagation, 54(1):28-34, January 2006.

F Edelvik, E Abenius:
On the Modeling of Thin Sheets and Coatings in the Time-Domain Finite-Element Method. In The first European Conference on Antennas and Propagation (EuCAP 2006), Nice, France, November 2006.

S Jakobsson:
Frequency optimized computation methods Journal of scientific computing Vol 26, Num 23, March 2006.

S Jakobsson and O Amoignon:
Mesh deformation using radial basis functions for gradient-based aerodynamic shape optimization,Computers and Fluids Vol 36 (accepted November 2006).

M Kvarnström, and C A Glasbey:
Estimation of centres and radial intensity profiles of spherical nano-particles in digital microscopy, Biometrical Journal (to appear).

R Nisslert, M Kvarnström,
N Lorén, M Nydén, and M Rudemo:
Identification of the three-dimensional gel microstructure from transmission electron micrographs, Journal of Microscopy (to appear).

M Holmgren, E Johnson, G Kjell,
K Lundh, S Lorén, T Svensson:
Misalignment in Fatigue Testing Machines, a Nordic Laboratory Intercomparison, SP Report 2006:25, SP Swedish National Testing and Research Institute, Borås.

Gwenaëlle Genet, Pär Johannesson, Mac Lan Nguyen-Tajan:
Multi-Input Equivalent Fatigue Loadings Proceedings of the 9th International Fatigue Congress 2006, Elsevier Ltd, 2006.

R Laulajainen, och J Johansson:
Worldscale: what does it actually measure?, Maritime Policy & Management, vol 33, no 5, 477-495, Dec 2006.

J Johansson:
"Some ideas from statistics for efficient front calculations under uncertainty" (submitted for publication).

M Holmgren, E Johnson, G Kjell, K Lundh, S Lorén, T Svensson:
Misalignment in fatigue testing machines, a nordic laboratory intercomparison, SP report 2006:25, Swedish national testing and research institute, Borås, Sweden.

A Lundberg, M Fermér, J de Maré, T Svensson, A Karlström, P Sjövall:
Statistical Approach to Fatigue Life Prediction of Spot Welds, Proceedings of the 9th International Fatigue Congress 2006, Elsevier Ltd, 2006.

T Larsson and M Patriksson:
Global optimality conditions and Lagrangian heuristics for nonconvex optimization, Operations Research, vol 54, no 3 (2006), pp 436-453.

P Marcotte and M Patriksson:
Traffic Equilibrium, in Handbooks in Operations Research and Management Science, North-Holland (to appear).

H Schmidt, S Baddon: High Performance Simulation for the Systems Biology Toolbox for Matlab, Bioinformatics, doi:10.1093/bioinformatics/btl668, 2006.

L Nedbal, J Cervený, U Rascher, and H Schmidt:
A modeling approach to understand chlorophyll fluorescence transients and complex dynamic features of photosynthesis in fluctuating light, submitted to Photosynthesis Research, 2006.

S Danø, M Madsen, H Schmidt, and G Cedersund:
Reduction of a biochemical model with preservation of its basic dynamic properties, FEBS Journal, 273(1), 4862-4877, 2006.

H Schmidt, M Jirstrand, and O Wolkenhauer:
Information Technology in Systems Biology, invited article for it–Information Technology, 48(3), 133-139, 2006.

H Schmidt and M Jirstrand:
Systems Biology Toolbox for Matlab: A computational platform for research in Systems Biology, Bioinformatics, 22(4), 514-515, 2006.

M Ullah, H Schmidt, K-H Cho, and O Wolkenhauer:
Deterministic Modelling and Stochastic Simulation of Pathways using Matlab, IEE Proceedings - Systems Biology, 153(2), 53-60, 2006.

A Kobetski, D Spensieri, and M Fabian :
Scheduling Algorithms for Optimal Robot Coordination – a Comparison, IEEE Conference on Automation Science and Engineering, October 7-10, 2006, Shanghai, China.

PhD students

G Cedersund (Chalmers); supervisor M Jirstrand. Core-box Modelling - Theoretical Contributions and Applications to Glucose Homeostasis Related Systems, PhD thesis, October, 2006.

G Genet (PSA Peugeot Citroën, Chalmers); advisers J de Maré, P Johannesson. A statistical approach to multi-input equivalent fatigue loads for the durability of automotive structures, Doctoral thesis, Department of Mathematical Sciences Division of Mathematical Statistics Chalmers University of Technology and Göteborg University, October 2006.

M Karlsson (Volvo 3P, Chalmers); advisers J de Maré, T Svensson. Load Modelling for Fatigue Assessment of Vehicles - a Statistical Approach, (in progress).

P Lindroth (Volvo 3P, Chalmers); advisers M Patriksson and A-B Strömberg. Product Configuration with respect to multiple criteria in a Heterogeneous and Dynamic Environment (in progress).

A Nahmany (Göteborg University); co-supervisor H Schmidt. Dynamic modelling of thiamine regulation in yeast (in progress).

Master students

J Almquist and N Lämås (Chalmers); supervisor H Schmidt. Mathematical Modeling of a Xenopus laevis Oocyte Expressing the NBC and MCT Membrane Transporters - Towards a Better Understanding of the Neuron-Glial Interplay (in progress).

G Drews (University of Rostock); supervisor H Schmidt. A JAVA based graphical user interface for the SBML export of SBmodels, Bachelor Thesis, November 2006.

M Eckerljung och T Nordlund (Datalogi, Chalmers); supervisor J Johansson. Development of an integrated environment for a mathematical simulation language (in progress).

F Eriksson (Chalmers, Göteborg University); supervisors M Jirstrand and S Nelander. Modelling Molecular Pathways by Combining Epistasis Analysis and Protein Interaction Data, Master Thesis, February 2006.

E Guðfinnsson (International Masters Programme Computational Mathematics) and N Á Sigfússon (Chalmers), GMMC Master thesis; supervisor A-B Strömberg , examiner M Patriksson. Construction of an Optimal Linkage Arm Using Structural Optimization, May 24, 2006.

T Jansson (Volvo Aero Corporation, Chalmers); M Patriksson and A-B Strömberg supervisors, Optimization of resource allocation in multi-task machines, Master Thesis, March 2006.

H Noor (Chalmers, Göteborg University); supervisors M Jirstrand and S Nelander. Network Identification and Regulatory Inference From Systematic Gene Perturbation Experiments, February 2006.

C Roth and J Edman, Master thesis; supervisors J Carlson and R Bohlin, examiner S Ekered, Optimering av robotceller, June 22, 2006.

M Sunnåker (Teknisk Fysik, Chalmers), GMMC Master thesis; supervisor H Schmidt, examiner K Lindgren (Physical Resource Theory Chalmers). New Approaches to Model Reduction of Biochemical Reaction Systems, December 2006.

E Svensson (Linköping University); supervisor H Schmidt. Parameter estimation of biological pathways (in progress).

B Söderberg (Bioteknikprogrammet, Chalmers), GMMC Master thesis; supervisor H Schmidt. Model Reduction of Nonlinear Biochemical Systems – Rate Expression Complexity Reductions (in progress).

A Westergård (Chalmers), Master thesis; supervisor M Kvarnström, Simulating diffusion with Brownian dynamics using an adaptive time-stepping algorithm, June 2006.

E Yazdani and C Edlund (Chalmers, Spotfire); supervisors M Axelson-Fisk and M Jirstrand. Development of an Enhanced Microarray Data Analysis Environment, Master Thesis, March 2006.

P Zarrineh (Chalmers); supervisor Mats Jirstrand. Parameter Estimation Methods for Biochemical Systems (in progress).

Other assignments

F Edelvik:
Reviewer for IEEE Transactions on Antennas and Propagation.

F Edelvik:
Appointed Docent (“Associated Professor”) at Uppsala University.

S Jakobsson:
Reviewer for Zentralblatt.

M Jirstrand:
Member of the PhD-thesis committee for Bodil Nordlander "Integrative analysis of yeast osmoregulation", Göteborg University, May 2006.

H Schmidt:
Opponent for Licentiate Thesis: Mika Gustafsson "Large-scale topology, stability and biology of gene networks", Linköping University, June 2006.

A-B Strömberg:
External expert reviewer of applications for a position as research assistant in optimisation at Chalmers mathematics.

Courses

P Lindroth, M Patriksson, and A-B Strömberg:
Optimization, Basic course, Chalmers and Göteborg University.

M Patriksson:
Mathematical optimization models for maintenance management, PhD course at KTH.

FCC staff on December 6, 2006.

From left to right; Johan Carlson, Michael Patriksson, Ann-Christine Karlsson, Robert Rundqvist, Johan Segeborn, Sara Lorén, Fredrik Edelvik, Erik Höök, Tomas Hermansson, Mikael Wallman, Domenico Spensieri, Sebastian Tafuri, Joachim Almquist Fredrik Ekstedt, Daniel Segerdahl, Carl Lindberg, Mats Jirstrand, Annika Eriksson, Joachim Johansson, Rikard Söderberg, Mats Kvarnström, Ann-Brith Strömberg, Stefan Jakobsson, Magnus Karlsson, Martin Eckerljung, Pär Johannesson, Robert Bohlin, Tomas Nordlund, Mikael Sunnåker, Jonas Hagmar, Thomas Weibel, Thomas Svensson, Nils Lämmås, Henning Schmidt, Uno Nävert

We have used thirteen Swedish inventions to illustrate our departments and research areas:

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The purpose of FCC is to promote the application of mathematical methods in industry. To do so the Centre will undertake pre-competitive scientific research in the field of applied mathematics and work on projects defined by companies or public institutes.

The Centre, in close co-operation with Chalmers in Göteborg and Fraunhofer ITWM in Kaiserslautern, shall be a leading partner for international industry and academia to mathematically model, analyse, simulate, optimise, and visualize phenomena and complex systems in industry and science, to make development of products and processes more efficient and secure their technological and financial quality.