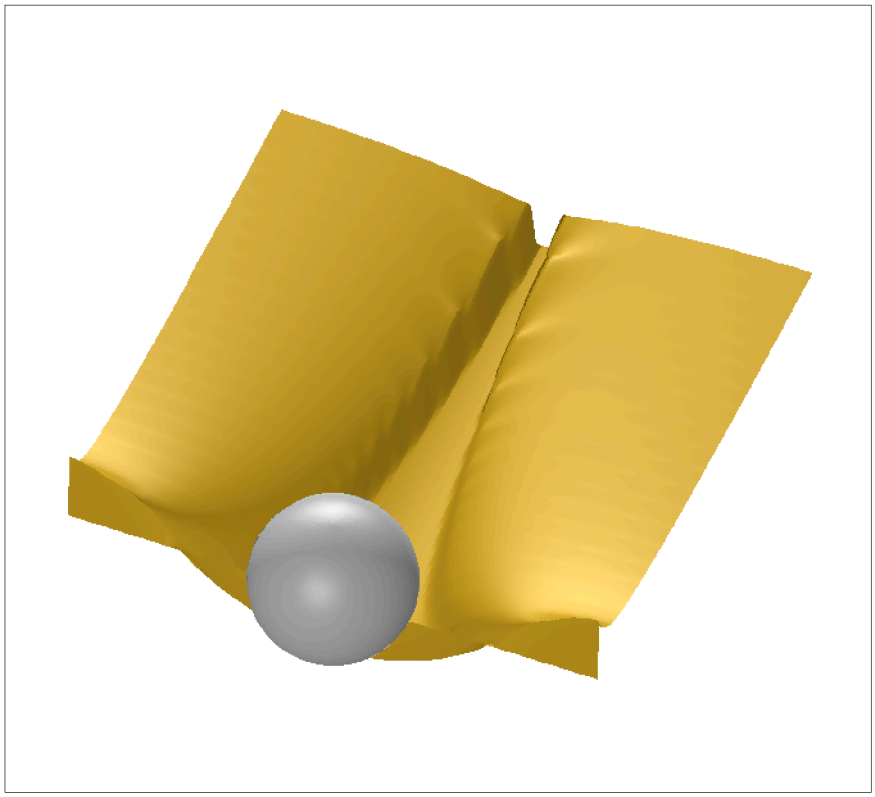
Fraunhofer ITWM

CHALMERS
Research Centre
Industrial Mathematics

Annual Report 2004



FCC

Fraunhofer-Chalmers Research Centre for Industrial Mathematics

Contents

Cover

Simulation of the lubricant replenishment in a ball bearing, cf page 13.

Annual Report 2004

Fraunhofer-Chalmers Research Centre
for Industrial Mathematics, FCC

Editors: Annika Eriksson, Uno Nävert
Layout: Annika Eriksson
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Preface

Having started its operations in September 2001, FCC has now successfully completed its start-up phase. The Centre has grown from the initial staff of six people and an annual turnover of 1200 kEUR to nineteen people and 2100 kEUR in 2004.

Together with our partners Chalmers and the Fraunhofer industrial mathematics institute ITWM we cover a wide range of applications. From the beginning in 2001 we have started more than hundred projects, seventy of which have been completed, with companies and organizations of different size and from different branches.

The Centre has received public grants from SSF (Swedish Foundation for Strategic Research), Vinnova (Swedish Agency for Innovation Systems), STEM (Swedish Energy Agency), and EU (Network of Excellence Biosim). FCC works together with academic partners in Linköping, Lund, Stockholm, and Uppsala. We have served clients in Denmark, France, Germany, Italy, and Norway.

Our business area Quality Engineering, working in close co-operation with the Chalmers Wingquist Laboratory, has continued its success story in 2004 and generated a financial net in the order of 100 kEUR. Together with Fraunhofer ITWM we have successfully started to build up the Finance and Insurance area at FCC, working together in several projects with Swedish financial industry.

In line with the Fraunhofer model, the profile of the Centre is controlled by its income structure. The result of 2004 is well in line with the business plan of March 2001, scientifically as well as commercially. The project volumes from industry (44%), public financieers (17%), and Fraunhofer and Chalmers (39%) are well in balance.

Before ending this preface I take the opportunity to thank my co-workers at FCC for their enthusiastic commitment to form our new Centre, and express my appreciation of the fruitful collaboration with our friends at Chalmers and Fraunhofer ITWM on a local as well as European scale.

Göteborg in June 2005

Uno Nävert
Director

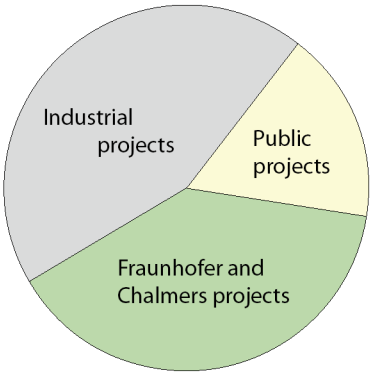
FCC operates in Chalmers Science Park.

Uno Nävert, Director of FCC.

www.fcc.chalmers.se

Profile

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



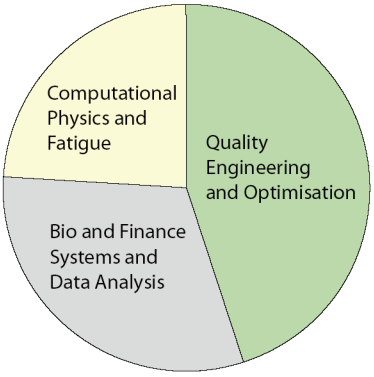
Project mix by income.

The Fraunhofer Society and Chalmers have founded FCC to promote the application of mathematical methods in industry. To do so the Centre undertakes scientific research and marketing financed by the founders and works on projects defined by companies and public institutes 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 2004 the staff was nineteen full-time equivalents, including one scientist contracted from Fraunhofer ITWM and four scientific advisers from Chalmers, each one working 10% - 20% of full time at FCC.

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



Scientific areas 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.

The Centre has organized six research programmes within three scientific areas. The Centre has received public grants from SSF (Swedish Foundation for Strategic Research), Vinnova (Swedish Agency for Innovation Systems), STEM (Swedish Energy Agency), and EU (Network of Excellence Biosim).

Entrepreneurial competence

FCC works on projects defined by companies and public institutes on a commercial basis.

The Swedish Society for Applied Mathematics, STM, is a consortium of companies with business in Sweden, cf page 5. This consortium is the largest individual industrial client of FCC and represents almost thirty percent of the total industrial income.

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 less than ten percent of the total industrial income.

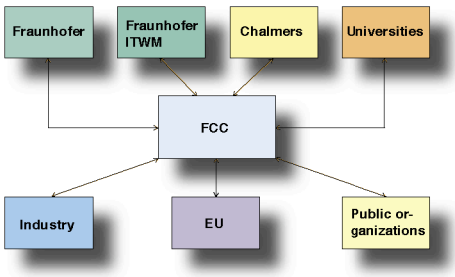
The Centre has served international industrial clients from Denmark, France, Germany, Italy, and Norway.

Professional networking

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

The Centre has a very close relation to its founders Chalmers and Fraunhofer ITWM, cf pages 6 - 9, 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, cf pages 14, 15, 21, and 31. It also promotes research and education in industrial mathematics at institutions outside the Centre, cf pages 8 - 9, 12 -13, 19, 21, 23, and 29.



Financial mix

FCC earns approximately 40% from its founders, 40% industrial income, and 20% public income.

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.

According to the business plan of March 2001, the annual turnover of the Centre should increase from 1700 kEUR in 2001 - 2002 (18 months) to 2000 kEUR in 2004. The outcome has been above expectations. In particular, the industrial income has been higher than expected, cf pages 34 - 35.

Acknowledgements

The Centre is a Swedish foundation established by Chalmers and 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.

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
- Aerotech Telub
- AP2 Second Swedish National Pension Fund
- AstraZeneca R&D Mölndal
- AstraZeneca R&D Södertälje
- Atlas Copco Rock Drills
- Bombardier Transportation
- Consorzio Politechnico Innovazione (I)
- Elforsk
- Elmo Leather
- Ericsson
- Ericsson Microwave Systems
- Faurecia Exhaust Systems
- FOI
- Fortum Power and Heat OY
- Front Capital Systems
- InNetics
- Innovativ Vision
- IVF Industriforskning
- Jernkontoret
- KP Pension and Insurance
- NMCT
- Novo Nordisk (DK)
- Optimization Partner Stockholm
- PlanIt
- PSA Peugeot Citroën (F)
- Saab
- Saab Automobile
- Saab Ericsson Space
- Safe Technology
- Saint-Gobain Sekurit Scandinavia
- Sandvik Steel
- SCA
- Scania
- Simula Research Laboratory AS (N)
- SKF
- STM Forskningsservice
- SP Sveriges Provnings- och Forskningsinstitut
- StoraEnso Corporate Research
- Sveriges Försäkringsförbund
- Sydkraft
- Uddcomb
- Universitetssjukhuset MAS
- Volvo Aero Corporation
- Volvo Car Corporation
- Volvo Trucks

- Chalmers tekniska högskola
- Chalmers Finite Element Centre
- Chalmers Industriteknik
- Chalmers Matematik
- Chalmers Wingquist Laboratory
- EU Biosim / DTU (DK)
- EU Visicade / Fraunhofer IGD (D)
- Fraunhofer ITWM (D)
- ITM
- Kungliga Tekniska Högskolan /PSCI
- Linköpings Universitet / Beräkningsbiologi
- Linköpings Universitet / Reglerteknik
- Lunds Universitet / Matematisk statistik

STM

The Swedish Society for Applied Mathematics (STM) has financed projects at FCC with 750 kEUR in the period 2001 - 2004.

Members and shares 2004:

Engineering and transport

Volvo	5
SKF	5
ABB	3
Saab	3
SP Swedish National Testing and Research Institute	1

Pharmaceuticals

AstraZeneca R&D Mölndal	5
AstraZeneca R&D Södertälje	2

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

37

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Fraunhofer-Gesellschaft

Professor Helmut Neunzert, ITWM, Vice Chairman of FCC.

The Fraunhofer-Gesellschaft is Germany's leading organization of institutes of applied research. It undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

Roughly two thirds of the 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 was founded in 1949 and is a recognized non-profit organization. It maintains roughly 80 research units, including 58 Fraunhofer institutes, at over 40 different locations throughout Germany. A staff of some 12,500, predominantly qualified scientists and engineers, works with an annual research budget of over one billion euros. Of this sum, more than 900 million is generated through contract research.

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 (2004) a budget of nine million euros and a staff of 100 persons including 82 scientists and researchers. The Institute further engages 200 students and diploma workers, including 44 PhD students. 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

A key element in the operation of FCC is its close co-operation with Fraunhofer ITWM. In 2004 the project volume was 240 kEUR.

Image Processing

In quality engineering, FCC and ITWM run a joint industrial project on surface inspection, where we develop an automatic grading system for leather manufacturing, cf page 27.

Dynamics and Durability

In quality engineering, FCC develops methods and software for automatic path planning and interactive simulation of the motion of robots. As a subcontractor, ITWM has developed improved methods for the simulation and vizualisation of robot cable motion based on compliant objects. The new method includes (1) realistic visual appearance of cable motion, for robot arm contacts and approximately constant cable lenght, (2) accurate prediction of the position of the cable segments during robot arm motion, for realistic collision checks, (3) fast algorithm, for interactive computation of cable motion, cf page 25.

Finance and Insurance

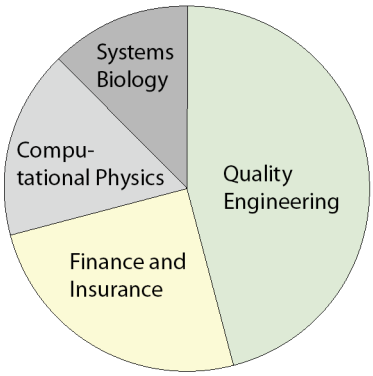
FCC and ITWM run several joint projects in finance and insurance mathematics, where we develop asset liability management tools and risk measures for solvency assessment with Swedish industrial partners, cf page 33.

Flow in Complex Structures

FCC runs serveral projects with industrial partners on fibre flow modelling and fibre flow measurements. As a subcontrator, ITWM has performed a numerical study to evaluate the potential of the state-of-the-art fibre orientation model for being developed into an industrial sensor designing and positioning tool, cf page 12.

Adaptive Systems

FCC and its Swedish partner InNetics develop methods and software (Pathway Lab) in systems biology for the identification and analysis of biochemical reaction networks. ITWM has developed software (Analog Insydes) for the reduction of complex signal networks, based on advanced symbolic computation and approximation techniques. In a joint project we study the coupling of these two software packages for pharmaceutical and biotech applications, cf page 30.



ITWM income from FCC projects in 2004, in total 240 kEUR.

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 8000 students for engineering and architecture degrees, and more than 1100 PhD students it is one of Sweden's two leading technology universities.

Most of Chalmers' resources come from contracts with the state of Sweden (68%), but Chalmers also has strong support from non-governmental research organizations (21%) and industry (11%). The annual (2004) turnover is 240 million euros. More than two thirds of the budget are alotted to research and to graduate studies. With its staff of 2355 full time equivalents, including 159 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 Society 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 2004 there were five advisers: four senior scientists from the School of Mathematical Sciences and one senior scientist from the School of Mechanical Engineering.

In several cases FCC staff members act as co-advisers for PhD students at Chalmers. FCC also finances PhD projects at Chalmers.

FCC has supervised six master thesis projects where the students have worked five months each at the Centre. The work has been related to industrial projects in quality engineering and computational physics.

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

Statistical Fatigue of Materials

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. FCC and Chalmers run several projects in fatigue life together including an industrial PhD student work.

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, as well as for the industrial partners, cf pages 18 - 19.

In September 2004 Chalmers Mathematics applied to the Swedish Foundation for Strategic Research for a "Gothenburg Mathematical Modelling Centre (GMMC)" based on co-operation between Chalmers Mathematics, Chalmers Stochastic Centre, Chalmers Quality Sciences, and FCC.

Optimisation

FCC and Chalmers have a very close co-operation in optimisation, where FCC staff co-advises one PhD student and several Master students, cf page 21.

Computational Physics

FCC partly finances an industrial PhD project on finite element methods for thin film flows, cf page 13.

In connection with an industrial project, FCC has financed a Master thesis project on fibre flow modelling, cf page 12.

Computational Biology

Dr M Alexandersson and Dr M Jirstrand at FCC have been appointed Docents at Chalmers.

Quality Engineering

Chalmers started 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.

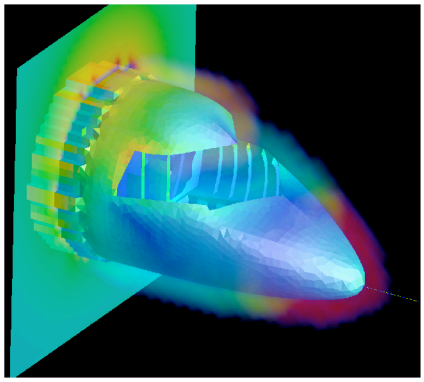
FCC and Wingquist have a very close co-operation in quality engineering focusing on product- and production system modelling, robust design and variation simulation, and flexible production and automation systems, cf pages 22 - 27.

FCC has partly financed a PhD (Licentiate) project on inspection data feedback and analysis. FCC has also financed five Master thesis projects in geometry assurance and robot path planning, cf pages 22 - 27.

"Together, FCC and Wingquist Laboratory possess a unique set of competence that enables industrial projects with extraordinary requirements in the field of simulation and analysis to be carried out successfully."

Professor Rikard Söderberg,
Director Wingquist Laboratory,
Scientific adviser FCC

Computational Physics



- Fluid dynamics
- Electromagnetics
- Geometry (optimal design)

Many industrial processes and product properties rely on the fundamental understanding of the development of field variables such as temperature, pressure, forces, and velocities. Traditionally this understanding is achieved by trial-and-error approaches and hands-on engineering, but the increased competition on the market requires a more systematic approach to guarantee success.

Computational Physics means mathematical modelling of physical phenomena, such as fluid mechanics and electromagnetics, and computer simulation based on these models, which typically are in the form of partial differential equations (PDE). The development of scientific computing enables solution of complex systems of PDEs, making real industrial problems tractable to scientific analysis and optimisation based on simulations.

Many problems exhibit multiscale behavior. For instance, a composite material may be described by fibres in a matrix on the microscale and linear elasticity on the macroscale. Multiscale computational methods are techniques to handle such problems. Typically, these techniques involve solutions on the microscale to compute the transfer of microscale effects to the macroscopic properties.

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 systems involving chemical reactions and compressible flows. In industrial systems, like paper making, energy production, or other manufacturing facilities, understanding the physics of fluid dynamics holds one key to drastically improve the process with respect to production speed, environmental impact, or product cost.

Different problems require differens 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

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cases, this tool is a commercial flow solver, e g, a general PDE-solving package like FEMLAB, 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 2004, FCC has focused on two areas within fluid dynamics: fibre flows and topology optimisation of fluid systems.

Electromagnetics

Simulation of electromagnetic propagation and interaction is an emerging technology in application areas such as wireless technology, antenna analysis, electromagnetic compatibility, micro electronics, and radar signature.

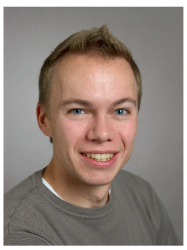
The main challenge in computational electromagnetics is that the frequencies of interest are often large and accurate modeling of small geometrical details have a crucial impact on the results. This implies very large systems with possibly several million or even billion degrees of freedom. This puts high demands on the numerical methods and the available computer resources.

FCC participates as sub-contractor in the national research and code development project GEMS (General ElectroMagnetic Solvers) run by the Stockholm-Uppsala Parallel Scientific Computing Institute PSCI since 1998. This project, finishing June 2005, has produced an internationally recognized state-of-the-art software and has brought Sweden (and FCC) to the forefront in electromagnetic simulations.

The Computational Physics Research Group

- Robert Rundqvist, PhD, mainly working on computational fluid dynamics
- Erik Höök, MSc Engineering
- Anders Ålund, Lic, mainly working on numerical methods and high speed computing
- Mats Larson, Docent in mathematics at Chalmers, scientific adviser at FCC
- Leonid Gershuni, PhD student
- Andreas Mark, Master student


Robert Rundqvist


Erik Höök


Anders Ålund


Mats Larson


Leonid Gershuni


Andreas Mark

Fibre flows

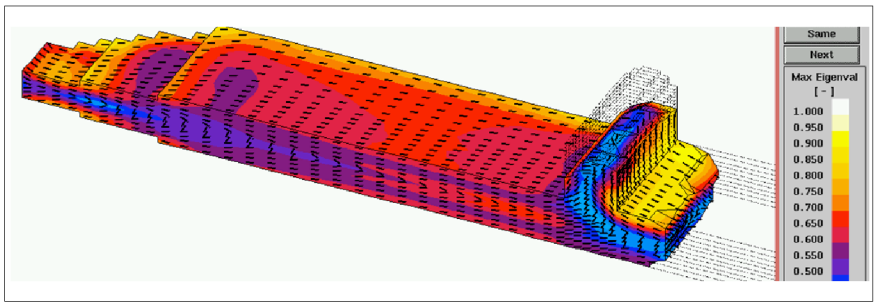
Flows involving fibres are common in industrial processes, for instance in laydown of nonwoven, in paper forming, and in some reinforcement molding processes. To improve the manufacturing processes with respect to speed or cost, or to investigate alternative production strategies, simulation of the processes is a valuable tool. However, the scale is typically too big, and the number of fibres is too large to allow for simulation of all individual fibres in an entire system. It is instead more efficient to study the distribution function for the three dimensional orientations of the fibres under the influence of a flow field. The dynamics of the distribution function is described with the help of a Focker-Planck equation. The microscopic properties of the fibres, e g length, thickness and interaction between fibres enter the description via effective parameters. Based on this ansatz the ITWM has developed a software module for the calculation of the fibre orientation during injection moulding of fibre enforced thermoplasts.

An example for a simulation of such materials is shown in the figure below, which demonstrates the influence of a rib within a piece of material on the orientations of fibres. The different degree of orientation in boundaries and bulk can be clearly seen. The pronounced change of directions due to the flow field around the rib would not have been able to obtain within a two dimensional model of fibre orientations.

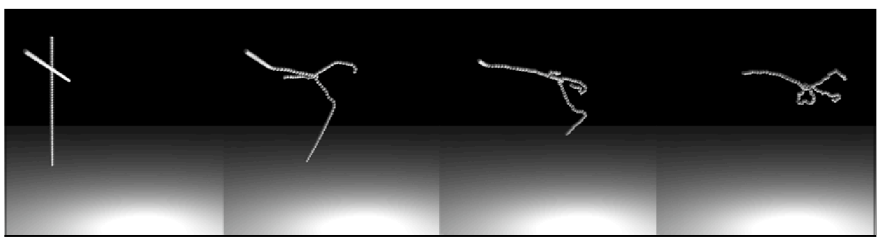
In a project with BTG Pulp and Paper Sensors, the use of this model has been expanded towards pulp suspension flows, which tend to be more turbulent and exhibit more of fibre-fibre interaction. To model such flows, other properties of the fibre flows must be considered, and the original Folgar-Tucker equation must be adjusted. For instance, the inertia of the fibres can no longer be disregarded, meaning that the velocity field of the fibres may differ from the fluid velocity field. This project has been run as a co-operation between FCC and ITWM.

In many pulp flows, there is also a strong tendency for the fibres to form flocs of many fibres. In a project with SCA Personal Care, macroscopic models for floc formation and flow has been simulated and compared to experiments. In this case the flow is a turbulent air flow with suspended cellulose fibres, the industrial application beeing manufacture of absorbtion cores for hygiene products.

Modelling of fibre orientation and of flocculation are two of the main keys to understanding pulp flow phenomena. To better understand these problems, and to be able to form adequate models, the dynamics of fibre flows must be studied in more detail. By modelling each fibre as a chain of spheres connected by elastic hinges, micromodelling of elastic fibres can be accomplished. Coupled to the flow equations will then be a system of ordinay differential equations describing the motion of the spheres. If the fibres are less flexible, the system will be stiff and thus a stiff ODE solver must be used. Taking this approach, FCC has advised a masters thesis work at Chalmers, to implement a simulation tool that resolves flexible fibre motion in a given flow. The application has been programmed in C++, and follows interaction between an arbitrary number of fibres of arbitrary length and stiffness. The image sequence below show results from a simulation of two colliding fibres in a homogeneous shear flow.



Fibre orientation simulation. The main orientation of the fibres is indicated by the arrows. The projection of the orientations on the main axis can be read off the colour scale on the right. Simulation by Fraunhofer ITWM.



Collision and entanglement of two flexible fibres. Simulation by Andreas Mark.

Simulation of Thin Films with Application to Lubrication in Bearing Components

Lubricated contacts are common in many machine elements such as cam-followers, gears, engine cylinders, and bearings. The separating lubricating film is crucial for the function of the product since the lubricant strongly influence the separation and friction in the contact. In the contact the behavior of the fluid is determined by interaction of elastic bodies and lubricant, the so called elastohydrodynamic lubrication (EHL) problem, and outside of the contact the flow is mainly governed by effects of acceleration and surface tension.

The motion of the lubricant is governed by the three dimensional Navier-Stokes equations, which is a system of nonlinear partial differential equations for the velocity field. Using the fact that the velocity in a thin film is approximately tangent to the surface we derive a nonlinear fourth order partial differential equation, called the thin film equation, for the thickness of the film. The thin film equation takes forces due to acceleration and surface tension into account. Further terms modeling the effects of, for instance, the curvature of the surface and van der Wahl´s forces, which play an important role when the film is very thin, can also be included.

We have implemented a finite element solver particularly designed for simulation of thin film flows. The solver can handle combinations of dry and wet regions and guarantees a non-negative solution for all times as well as conservation of mass. The modeling and solver has been verified using comparisons with experiments performed at SKF, Holland.

Using the thin film solver we have investigated the behavior of lubricants in realistic bearing application. In particular, the reflow behind a ball has been studied and the dependency of critical parameters in initial data and acceleration fields has been investigated. Furthermore, the code is currently being implemented into BEAST, a state of the art multi body solver for dynamic simulation of bearings developed by SKF.

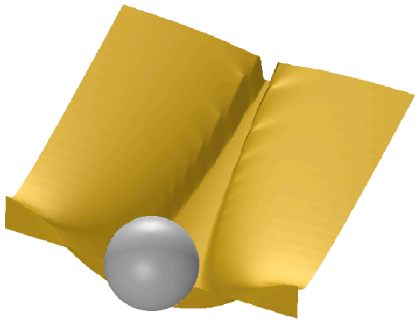
In the next phase of the project the modeling and solver will be extended to:

- Detailed simulation of the flow close to the contact zone. This simulation can then be coupled to the thin film solver outside of the contact.

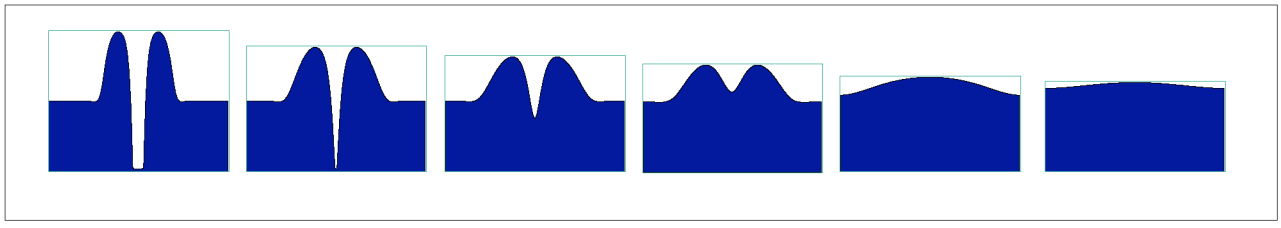
- Modeling and numerical simulation of grease. Here the basic mathematical modeling is still an open issue.

This work is done as a PhD project by MSc Leonid Gershuni, advised by Professor Mats Larson, Chalmers.

In a companion project, Fraunhofer ITWM has elaborated on thin film models based on a asymptotic theory.



Reflow after the ball.



Sequence of pictures illustrating the reflow after the ball.

Electromagnetics

FCC is sub-contracted by Parallel and Scientific Computing Institute, PSCI, project 24082-62591, for code development in the GEMS3 project.

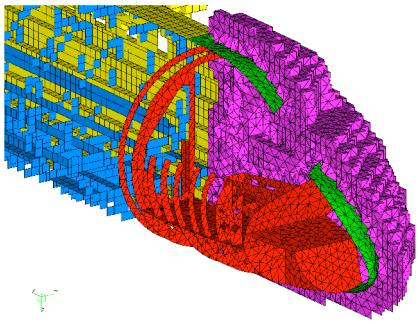
The objective of this project is to do frontline research and to develop a software suite, based on Maxwell´s equations, for Radar Cross Section (RCS), antenna design, and microwave applications. The software is based on formulations in both time-domain and frequency-domain using hybrid grids composed of structured body-conforming grids near to the physical objects and unstructured grids in the far-field.

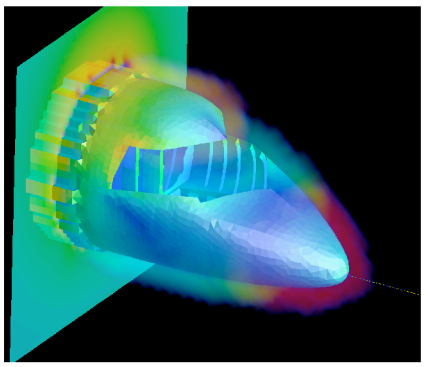
The research group in Stockholm-Uppsala focuses on boundary integral methods and multipole acceleration. The work in 2004 has resulted in improved stability and convergence properties by new formulations, e g, edge elements and combined field integral equations (CFIE) together with impedance boundary conditions to avoid the resolution of thin layers. The functionality of the code has been augmented by accepting inhomogeneous material descriptions including complex material parameters to allow for losses.

The group at Chalmers develop optimisation tools to minimize radar cross section with respect to shape, design, and material properties. The figure below shows an example where a certain amount (area) of absorbing material is distributed over a wing profile made by steel to minimize the radar cross section.

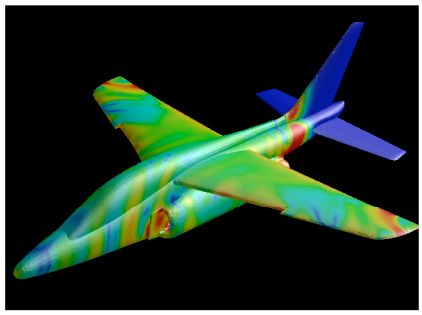
FCC is responsible for the software development and the integration of software into the environments of the industrial partners.

The project has resulted in about ten PhD theses and state-of-the-art software, e g, GEMSTD (time-domain) and GEMSFD (frequency-domain).

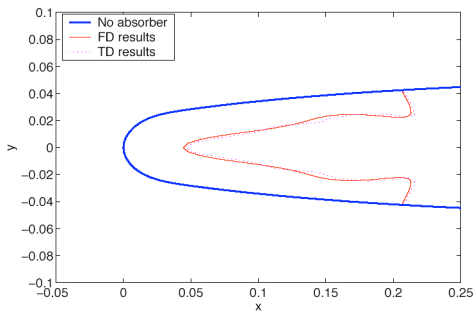


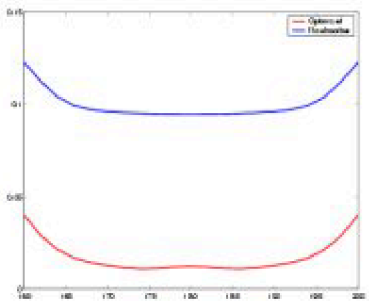


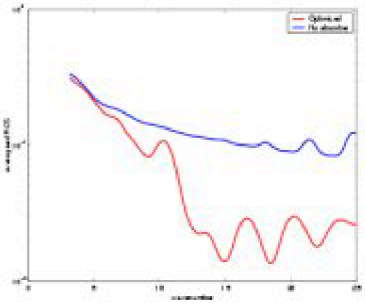
A hybrid grid of the SAAB 2000 aircraft (left). In this case an unstructured grid is used only in the vicinity of the nose and a structured grid is used for the rest of the domain. A thin wire is attached to the nose of the SAAB 2000 aircraft and a current injection is used to simulate a lightning strike (right). A hybrid solver has been used combining finite differences and finite volumes.



An electromagnetic pulse hits an aircraft head on with horizontal polarization. The surface currents are shown when the main pulse reaches the tail. A hybrid method of finite elements and finite differences has been used.







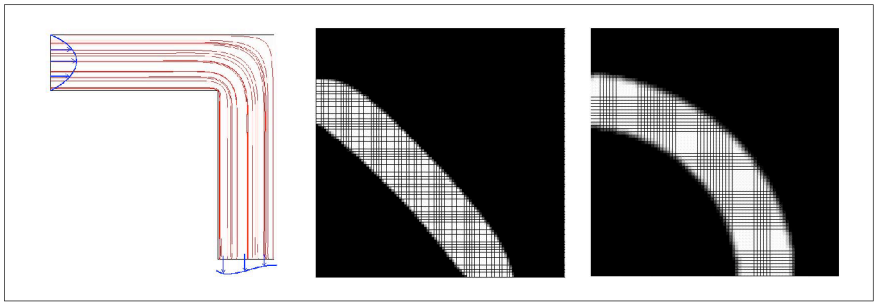
Optimal distribution of a fixed amount of absorbing material to minimize radar cross section (left), comparison between original RCS (middle, upper curv) and optimal RCS (middle, lower curv) as a function of angle at a fixed frequency, and comparison between original RCS (right, upper curv) and optimal RCS (right, lower curv) as a function of frequency at a fixed angle.

Topology optimisation

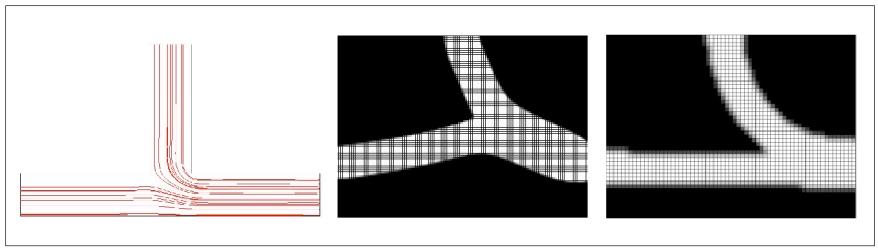
FCC has studied topology optimisation for fluid flow together with a partner in Linköping. In particular, we have worked on an extension of Navier-Stokes flow models based on recent theoretical results presented in a PhD thesis at Chalmers. The work has been done in a pre-study commissioned by STM Research.

The Navier-Stokes system of equations is in it self inherently unstable and computationally expensive. The further interference from and numerical cost accumulation due to the optimisation procedure restricts (so far) the range of applications to low/moderate-Reynolds-flows. A numerical tool for handling general continuum mechanical problems with tailored objective function(s) and constraint(s) for single physics or multi-disciplinary problems is being evaluated for the purpose of introducing the concept of topology optimisation into industrial design and evaluation work.

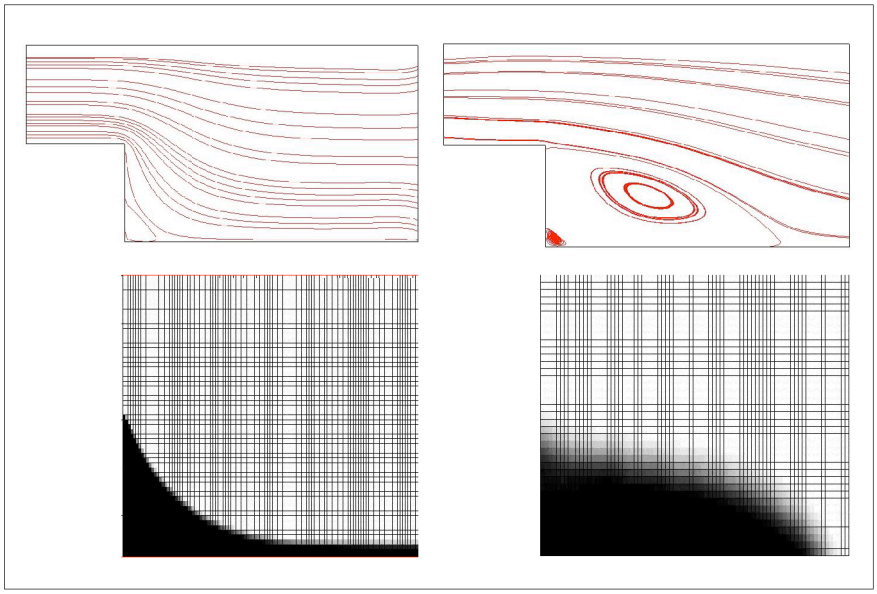
The figures show topology optimisation applied to three test problems: a bend, a branch, and a backward facing step at low and intermediate Reynolds number Stokes and Navier-Stokes flows. Typical gain in pressure loss or energy efficiency were between 40 percent and 70 percent for the optimal geometry compared to the reference geometry.



Bend: original geometry and optimal geometries for laminar Stokes flow at Re = 0,5 (left) and laminar Navier-Stokes flow at Re = 1000 (right).



Branch: original geometry and optimal geometries for laminar Stokes flow at Re = 0,5 (left) and laminar Navier-Stokes flow at Re = 1000 (right).



Backward-facing step: original geometry including stream lines and optimal geometry including stream lines for laminar Stokes flow at Re = 0,5 (left) and laminar Navier-Stokes flow at Re = 1000 (right).

Fatigue

Fatigue from a Statistical Point of View

Statistical methods can help to build a complete picture of the reliability of mechanical constructions with respect to fatigue resistance, and hence show where it is most efficient to take steps to improve the quality of a product.

The reliability is a combination of loading and strength. The strength is determined through fatigue tests, while the loadings are obtained through measuring loads in service or on proving grounds. The relation between loading, strength, and fatigue life is modelled using simple physical models. The determination of the strength as well as the loading is a difficult task; hence the two quantities are attached with a certain amount of uncertainty. A statistical perspective makes it possible to combine all uncertainties and variations in a total reliability analysis, and update the models with reports on failures in service. Within this overall perspective, the FCC fatigue group in particular focuses on the following areas:

- *Analysis of service loads.* We use the theory of stochastic processes, rainflow count analysis, and work on questions concerning on-board logging, acceleration of fatigue tests, and the relation between laboratory tests and service loads.
- *Planning and evaluation of fatigue tests.* We apply well established statistical methods, like statistical design of experiments, measurement system analysis (MSA), analysis of variance (ANOVA), regression analysis, prediction and confidence intervals, which we adopt to the particular engineering application.
- *Modelling of fatigue life.* We develop and make use of statistical methods for fatigue life prediction for spectrum loads, as well as methods for estimation of the fatigue limit.
- *Scatter versus model complexity.* A statistical methodology makes it possible to compare uncertainties of models with random variations in the loading and the material, in order to find an optimal complexity in the modelling.
- *Reliability and design.* The load and the strength variables may be combined in a statistical reliability approach, where the design targets can be evaluated. Feedback from failure reports can be beneficial, and the use of Bayesian updating techniques makes it possible to improve future modelling of the phenomena.

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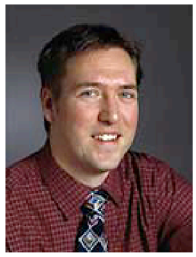
The Statistical Fatigue Research Group

The statistical fatigue research group do consulting and perform research tasks, especially for the engineering industry. The group consists of

- Thomas Svensson, PhD, mainly working on variable amplitude fatigue, measurement uncertainty, and statistical methods in engineering
- Pär Johannesson, PhD, mainly working on modelling of fatigue loads, rainflow count analysis, and reliability in engineering
- Magnus Karlsson, PhD student, virtual description of road environment of trucks, independent of vehicle and driver
- Jacques de Maré, Professor in mathematical statistics at Chalmers, scientific adviser at FCC


Thomas Svensson


Pär Johannesson


Magnus Karlsson


Jacques de Maré

Reliability in Fatigue – Statistical analysis of loads and strengths

The customer distribution of loads and the strength distribution for produced components may be combined to a reliability statement about the life in service. For several years we have worked with projects for PSA Peugeot Citroën on improving and evaluating their stress-strength reliability approach. This type of load-strength reliability model has proved to be a powerful tool, and has been used also by others. However, still open questions remain, for example how to take care of the uncertainties in the distributions. In April 2004, we held a half-day seminar on this topic, where many participants from the Swedish automotive industry participated.

The evaluation of material strength properties within a company includes the use of statistical tools such as methods for comparisons of populations, modelling by linear regression techniques, and comparisons by means of the analysis of variance. These methods are often easily available in commercial software, but knowledge about the theory behind them is necessary for their correct use and interpretations. We have developed a three days course, Statistics for experimenters, on these subjects for industrial practitioners which were given at one occasion during 2004.

Another course, developed in co-operation with UTMIS (the Swedish Fatigue Network), is based on four statistical problems originating from the automotive industry; namely, 1) load, strength and extreme customers, 2) uncertainties in load, strength, and fatigue life, 3) estimation of Wöhler curve, 4) extrapolation of extreme loads. This course consisting of four half-days was given for the third time in June 2004

Generation of Load Histories

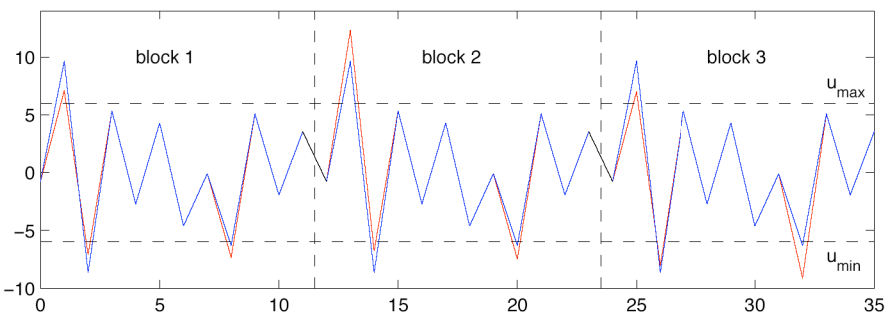
A variety of projects in this area has been performed during 2004. For PSA Peugeot Citroën, we worked on a virtual description of their test track. In a project with Bombardier Transportation, the task was to reconstruct load signals with the properties of identical rainflow matrices and sequence of the large cycles, while the order of the small cycles should be random. In a project for an Italian partner we developed methods and software for extrapolation of load signals and conversion of spectrum loads to standard fatigue tests.

The life of a component can be experimentally found by performing fatigue tests. In order to get reliable predictions of the life in service, the tests should be performed using variable amplitude loadings that are representative for the service loads. A new method has been developed together with Bombardier Transportation and an Italian partner, for extrapolation of a measured load history to a longer period of time, for example to a full design life. It is customary to use a measured load history, and repeat this load block until failure. This does not allow all possible load cycles. In the new method, load blocks are also repeated, however the largest maxima and the lowest minima of each block are regenerated in a random way based on statistical extreme value theory; see the figure below for an example.

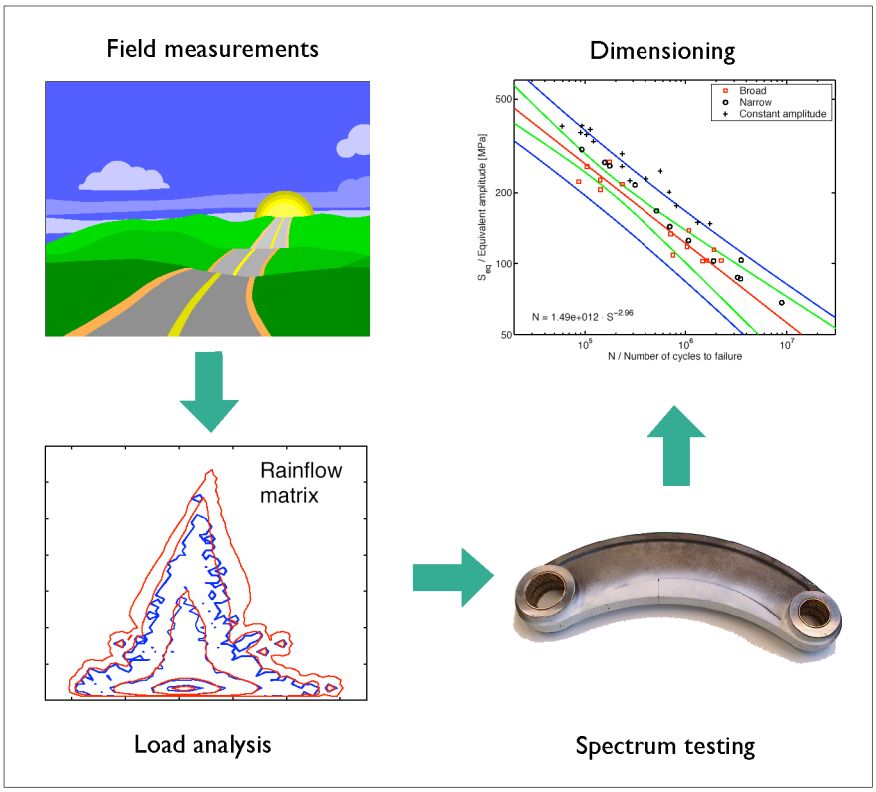
Life Prediction for Service Loads

Design against fatigue should be performed based on loads that are representative for the use in service. In most applications the amplitude of the loads varies with time, and the component is exposed to a spectrum of different amplitudes. The topic is often referred to as spectrum fatigue. During 2002 and 2003 the fatigue group at FCC conducted, in co-operation with a number of industries and institutes, projects with the goal to develop a new methodology that takes care of the spectrum effects by directly making fatigue tests with spectrum loads. The methodology was successfully applied to a number of case studies. During 2004 we developed a course on spectrum fatigue together with SP Swedish National Testing and Research Institute; this course was held for the first time in September 2004.

The course is based on the idea that fatigue design against spectrum loads must be based on fatigue tests and that these tests must be performed close to the service situations, both with respect to load spectrum and with respect to the multiaxial states of stress and strain at critical locations. This is because the theories behind fatigue mechanisms are too complicated to be useful for accurate life predictions.



An example of extrapolation of a load history. Three repetitions of a measured load block (blue), compared to three extrapolated blocks (red). The horizontal dashed lines are the threshold levels, where the extrapolation starts.



Optimal Model Complexity – Scatter vs Complexity

There is an increasing interest to use finite element solutions for fatigue design purposes. However, this approach gives rise to several problems: 1) the ability of modelling the fatigue behaviour is highly limited, 2) The knowledge about the service environment is poor and 3) the weakest points in the structure, defects sensitive for fatigue damage, are not represented at the drawing. All these problems put limitations on the possibility of modelling the fatigue phenomenon and it is necessary to find an optimal choice of model complexity. Statistical tools for such investigations are established in the statistical literature and often applied in for instance time series problems. But, in mechanical engineering these methods are often unknown and the FCC group has started with the application of such criteria for optimal complexity in the fatigue context. During 2004 a paper was written on this subject, and we discussed the ideas at several occasions, both among academics and among industrial engineers, see the reference list below.

This complexity problem is highly recognized in industry and five partners from the Swedish industry agreed to participate in an application for funding at VINNOVA, namely Volvo Aero, Siemens, Sandvik Materials Technology, SP Swedish National Testing and Research Institute, and Volvo Cars.

Measurement Uncertainty

Material strength specifications are primarily based on experimental results, obtained from tests at the material manufacturer laboratory, their customers, or at specific test institutes. In order to get agreeable results, the measurement uncertainty must be evaluated to control both internal variations and laboratory specific biases. Statistical theory is helpful for such evaluations and our group both give courses on the subject for industry, and help companies to evaluate measurement uncertainties for their specific equipment.

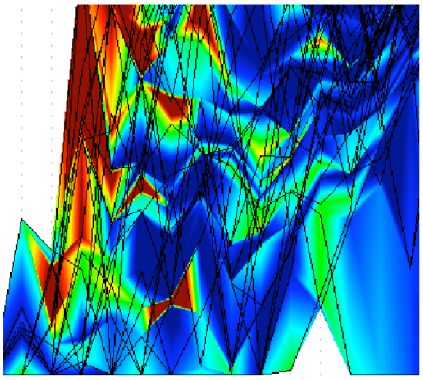
During 2004 we have given lectures on the statistical properties of measurement uncertainty within two different courses and in addition started the development of a handbook and a new course for industrial practitioners.

An important task in the overall evaluation of measurement uncertainties is comparisons between different laboratories. Round-Robin tests are regularly organized by different organizations: A number of specimens from the same material are distributed to different laboratories and after their tests the results are evaluated by means of statistical methods to get estimates on the within-laboratory variation, and the between-laboratory variation, respectively. The fatigue group is involved in such projects working with the statistical evaluation and interpretation of the results.

PhD Projects

Several graduate students are connected to the group. Sara Lorén, who defended her PhD thesis June 2004, studied the statistical properties of fatigue limit problems, partly in co-operation with Sandvik Material Technology, Magnus Karlsson, who presented his Licentiate thesis December 2004, works in a project with Volvo Trucks, dealing with the problem of specifying markets with respect to their different severities, Johan Svensson, who presented his Licentiate thesis December 2004, studies the problem of air engine maintenance at Volvo Aero in co-operation with a parallel PhD project on optimisation, Gwenaëlle Genet works with descriptions of multivariate fatigue loads in a project with PSA Peugeot Citroën in France, and Jenny Andersson, who presented her Licentiate thesis January 2004, studies statistical properties of point processes with applications in fatigue properties of the grain structures in metallic materials.

Optimisation



The area of industrial applications of optimisation is very broad. Optimisation problems arise as stand-alone problems in many contexts, and optimisation is used in a large variety of fields in applied mathematics and natural, medical, economical and technical sciences in order to model, solve and analyse (sub)systems.

Optimisation under uncertainty

Many optimisation problems depend on circumstances that can not be controlled. An example is given by the operation of a hydro power system which is influenced by uncertainties in reservoir inflows due to weather conditions, energy consumption, and electricity prices. The classical approach is to find the optimal strategies for a set of possible scenarios and choose a reasonable compromise. FCC has co-ordinated a two-year project to develop more modern methods based on stochastic programming and scenario tree generation.

Optimisation in engineering and product development

In engineering optimisation, it is quite often the case that the objective value is a measure of the performance of a system which is described in terms of simulations of a physical, mechanical, or chemical process. The variables in the optimisation problem correspond to design parameters that are used as input to the simulation, which may be in the form of a PDE or ODE system.

The optimisation group is developing an expert system for optimisation in product development which will integrate the simulation and optimisation routines and guide the user to the (category of) algorithm(s) that is best suited for the problem at hand. As a first application, the efficiency profile for the engine of a passenger car has been studied and optimised in a master's thesis project with two Chalmers students completed in 2004.

Maintenance planning

Large savings can be gained using optimal maintenance and replacement strategies. Central questions are then the frequency of service stops and which parts shall be replaced at a stop. Typically, some parts are definitely worn out and need to be replaced, while some may hold until the next planned service stop, but with the risk that it needs to be replaced in between. The problem is a demanding combined statistics and optimisation problem often including a wide variety of constraints. The optimisation and fatigue groups study efficient methods for maintenance of aircraft engines in a paired PhD student project.

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Optimisation of power systems under uncertainty

The deregulation of the Nordic electricity market has turned the planning of power generation into a more delicate problem. This new situation for the power producers necessitates the development of new planning and decision tools, incorporating the management of portfolios of energy contracts, among others.

This project has focused on the seasonal planning of a power system with hydro and thermal power generation, and with sales and purchase of power. It considers a time horizon of 1-1.5 years, with a time resolution of one week. The stochasticity of the reservoir inflows, the spot price for electricity, and the demand for electric power all have a large impact on the decision model on this time scale, and are therefore explicitly modelled.

The aim of the project was partly to meet the ever increasing demand for more advanced decision support tools in the power business. The project developed the software tool SPOT (seasonal planning optimisation tool) for decision-making in power systems planning under uncertainty. The user of SPOT can make prognoses for, e g, cash flows, energy production, water levels in reservoirs, and the amount of energy bought and sold, for each week during the planning period. The input data includes inflow and price history, technical specifications for the generating units and the reservoirs, jurisdictional constraints on the river system, and the user's risk preferences. The prognoses are graphically and numerically presented for all the different future scenarios considered. The use of SPOT also yields an increased understanding of the effects of uncertainty in inflows on water release policies, power prices, and the pricing of energy contracts.

The optimisation model employed is a multi-stage stochastic program defined on a scenario tree representing an approximation of the possible outcomes of the uncertain parameters during each week of the planning period. It is a very large scale optimisation problem, which calls for advanced decomposition methods and high-performance computing. A stochastic model based on historical, weekly data has been developed; it is adapted to the simulation of the reservoir inflow and electricity spot prices. The model employs moment matching and, in order to receive an optimisation model that is computationally managable, the scenario tree is reduced using principal component analysis and an optimal scenario reduction. The optimisation techniques then employed are based on nested Benders decomposition which attempts to partition the model into one planning problem for each week and scenario; these problems are linked through balance constraints for the water and energy systems and for the contract portfolios.

The project ran between May 2002 and April 2004 and was a joint project between Optimization Partner Stockholm AB, Lund Institute of Technology, and FCC. It was financed by the Swedish Energy Agency (STEM) and the industrial partners Elforsk, Sydkraft, Fortum Power and Heat OY, and STM Research.

PhD Project

The PhD student Niclas Andréasson at Chalmers Mathematics has received co-advisement from FCC. In May 2004 he presented his licentiate thesis "Optimization of opportunistic replacement activities in deterministic and stochastic multi-component systems".

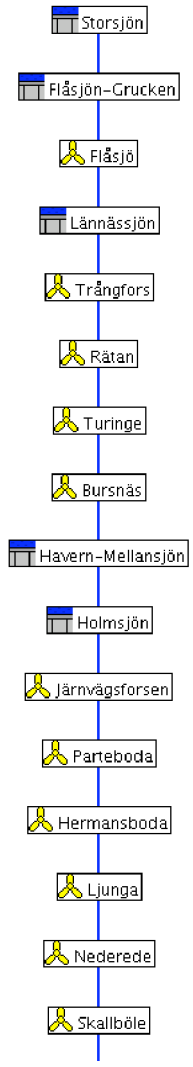
The Optimisation Research Group

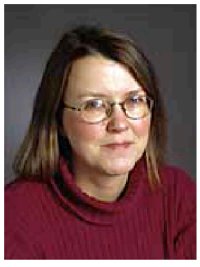
- Ann-Brith Strömberg, PhD, mainly working on combinatorial optimisation and optimisation under uncertainty
- Michael Patriksson, Professor in applied mathematics at Chalmers, scientific adviser at FCC

Public funding - acknowledgements

In 2004, the Optimisation Research Group has received substantial funding from the Swedish Energy Agency.

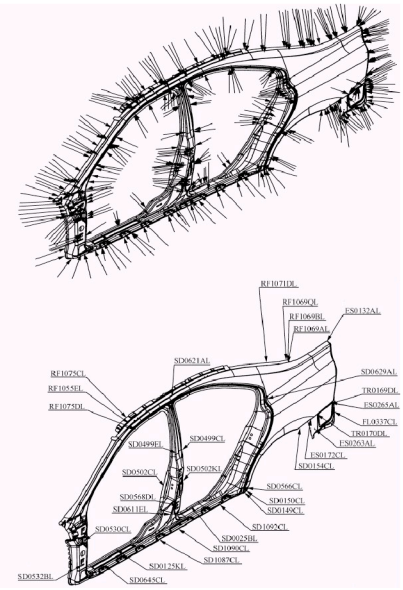
A schematic picture of the river Ljungan with symbols for reservoirs and plants.




Ann-Brith Strömberg


Michael Patriksson

Quality Engineering



- Geometry assurance
- Robotics path planning
- Surface inspection

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Quality Engineering and Robotics

Sensitive product and production concepts often result in quality problems with delays in market introductions and lost revenue as a consequence. The opportunity to virtually program, simulate, optimize and verify, product and production concepts in early design phases results in easy-to-build high-quality products meeting the demands on short ramp up time, throughput and quality. Less variation in products and processes gives a substantial return on investments in form of lower costs for adjustment, rejects and claims. Furthermore, since quality is one of the most important customer decision factors, employing quality as a part of the business strategy is highly motivated.

Robust design, variation simulation, inspection planning and diagnosis of sources of variation are important quality assurance activities in the product realization process. Geometrical variation, originating from individual manufacturing and assembly processes, propagates and accumulates during production, resulting in non-nominal products and production equipment.

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 still not reached. A major limitation is programming time. Most programming of motions and paths for robots and equipment is still generated 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.

Today, all virtual models used for robot and assembly simulation and verification are nominal. However, in the real world, all equipment, parts and subassemblies are inflicted by geometrical variation, often resulting in conflicts and on-line adjustments of off-line generated paths. To meet future demands on accuracy and throughput geometrical tolerances and variation need to be considered during path planning. This is a first step in going from nominal to production adopted virtual models, and hence connecting the production loop including styling, design and manufacturability.

In many products also the visual quality of surfaces is important for customer satisfaction. To detect visual defects as soon as possible is vital, and up to recently this has only been done by human inspection. But with the advance of computers and image processing, an on-line system for automatic surface inspection can be set up in the factory.

The system consists of cameras producing high quality images which are processed by advanced image analysis algorithms to detect and rate visible defects on the surface.

Public funding - acknowledgements

In 2004, the Quality Engineering Research Group has received substantial funding from the Swedish Foundation for Strategic Research (ProViking) and Vinnova (Komplexa sammansatta produkter).

The Quality Engineering Research Group

- Johan Carlson, PhD, Vice Director FCC
- Robert Bohlin, PhD
- Rikard Söderberg, Professor in product and production development at Chalmers, Director Wingquist Laboratory, scientific adviser FCC
- Fredrik Ekstedt, Lic
- Domenico Spensieri, MSc Engineering
- Tomas Hermansson, MSc Engineering
- Kristina Wärmefjord, PhD (licentiate) student
- Johan Havner, Master student
- Ola Karlsson, Master student
- Daniel Segerdahl, Master student
- Sebastian Tafuri, Master student
- Johan Svenberg, Master student


Johan Carlson


Robert Bohlin


Rikard Söderberg


Fredrik Ekstedt


Domenico Spensieri


Tomas Hermansson


Kristina Wärmefjord


Johan Havner


Ola Karlsson


Daniel Segerdahl


Sebastian Tafuri


Johan Svenberg

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

Robust Design & Variation Simulation

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.

Inspection Planning and 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.

Statistical Process Control and Root Cause Analysis

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.

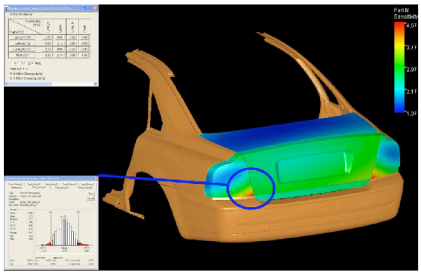

Figure 1. Colour Coding, based on sensitivity analysis, of the Volvo S80 Car Body. Sensitive areas were to dimensional variation are indicated with red colour (courtesy of Volvo Car Corporation).

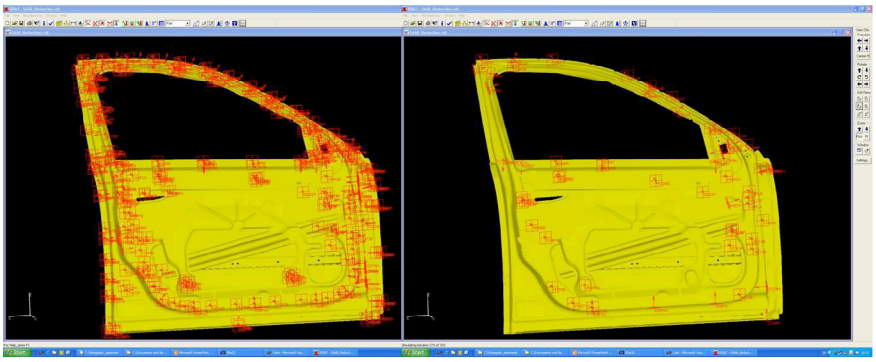

Figure 2. Inspection point reduction in action on car body door (courtesy of Saab Automobile).

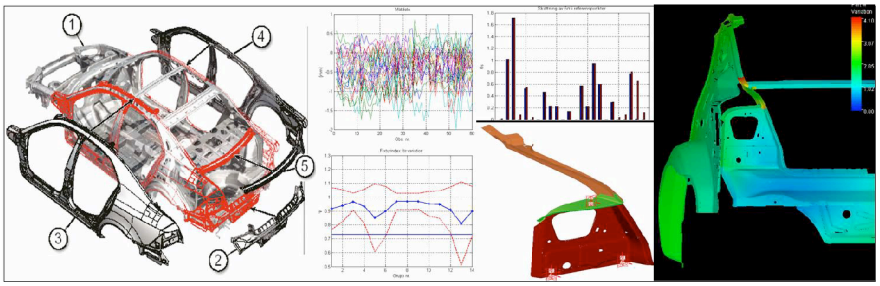

Figure 3. A multi-fixture assembly where a number of parts are assembled. From left to right: Assembly, production data, multivariate statistical process control, root cause analysis, assembly fixture fault, simulated effect of correction (courtesy of Saab Automobile).

Automatic Path Planning for Rigid Bodies and Industrial Robots

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 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

Assembly Visualization/ Verification/Design

This project with our partner Volvo Car Corporation has resulted in simulation software for automatic path planning, viewed in figure 4. The software is based on a virtual 3D model describing the kinematics and the geometry in the assembly cell, interacting with a collision tester.

Assembling with Robot

In addition to collision avoidance and kinematic constraints, automatic robot programming involves minimization of cycle time, robot wear and joint forces. Benefits can also be achieved in fixture design, gripper design, and reachability analysis, see figure 5.

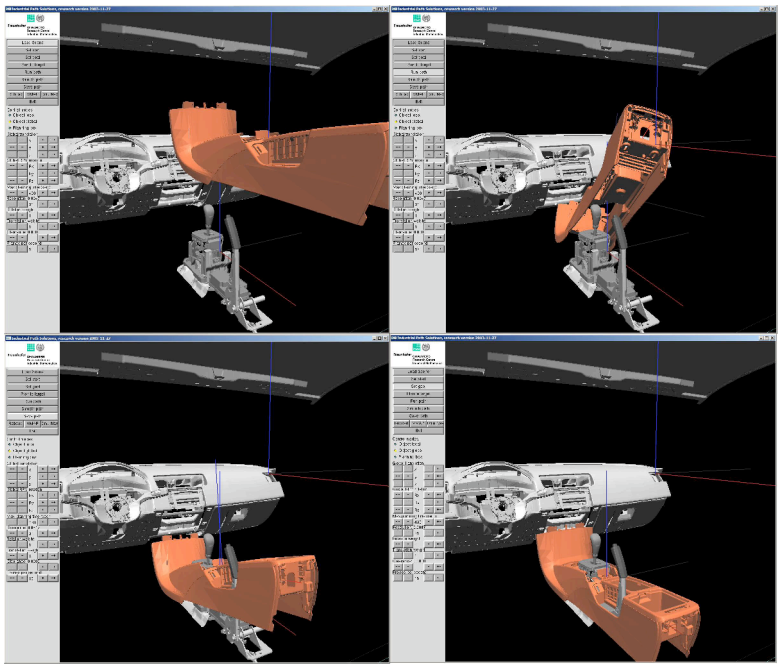

Figure 4. Is it possible to assembly the tunnel bracket? The FCC path planner finds a solution in less than 5 minutes. Even an experienced simulation engineer will struggle for days with this assembly verification (courtesy of Volvo Car Corporation).

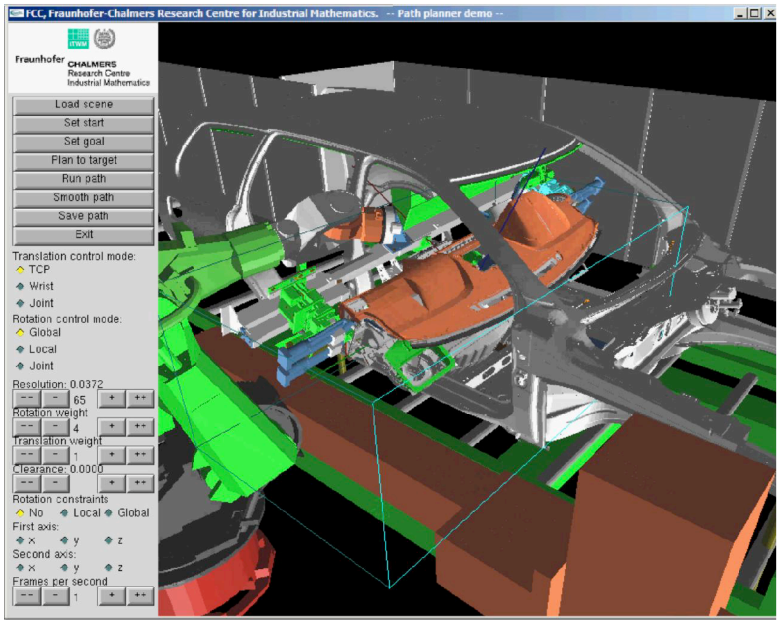

Figure 5. In this station, the driving unit is assembled into the car body. Due to the narrow door opening, the clearance is very small and programming without support from a path planner is difficult. This demo application developed by FCC finds a solution in 5 minutes (courtesy of Volvo Car Corporation).

Welding and Sealing

Arc welding and sealing are examles of path following operations in which process parameters are important to take into account. Deviation from the prescribed path are allowed within certain limits, and the challenge is to use this freedom in combination with sequencing in order to generate efficient solutions in a global scope, see figure 6.

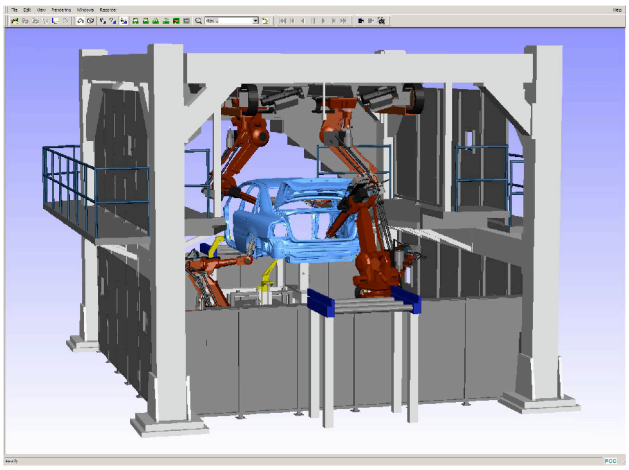

Figure 6. Automatic path planning and optimisation of a sealing station (courtesy of Volvo Car Corporation).

Coordinate Measurement Machine

FCC develops methods for automatic generation of collision free coordinate measurement machine and the cycle time is minimized with respect to probe orientations and feature sequence. The motive is to make the important activity of dimensional inspection within the geometry assurance process as efficient as possible, see figure 7.

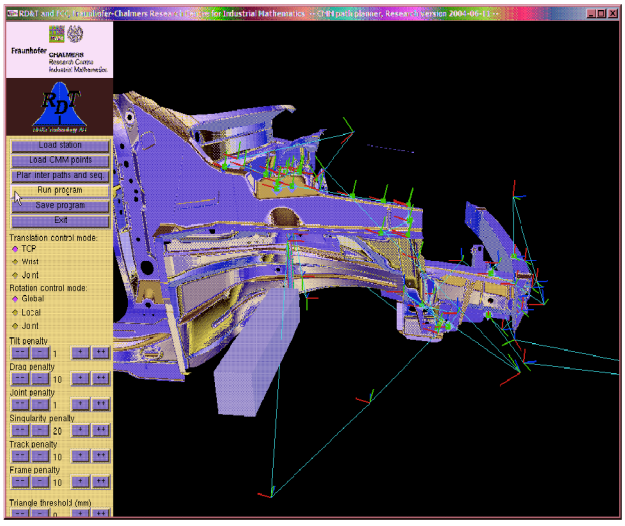

Figure 7. Automatic path planning of an inspection program used for evaluating geometry of a Volvo XC90 (courtesy of Volvo Car Corporation).

Surface Inspection

Estetic 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 is of vital importance, and in particular surface quality control.

The quality control of produced objects´ surfaces is currently performed mostly by humans, via visual and/or tactile 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 use an automatic system, as depicted in figure 8. High-quality surface images are acquired by means of a number of high-resolution digital cameras. These images are thereafter fed to a number

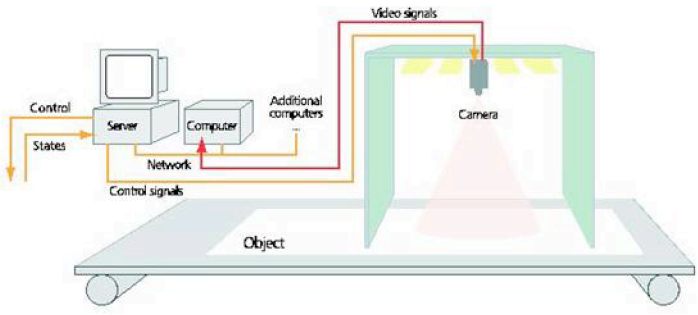

Figure 8. Schematic description of an automatic visual inspection system.

of computers employing advanced image processing algorithms. Detected defects are presented on a GUI. In figure 9, an example of an industrial system is showed.

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 enables gathering of detailed statistical data over the occurrances of various defects.

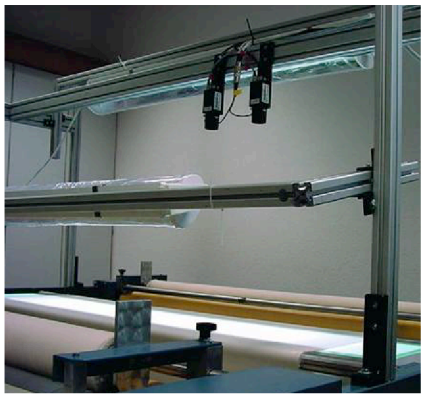

Figure 9. An automatic inspection system for fabrics.

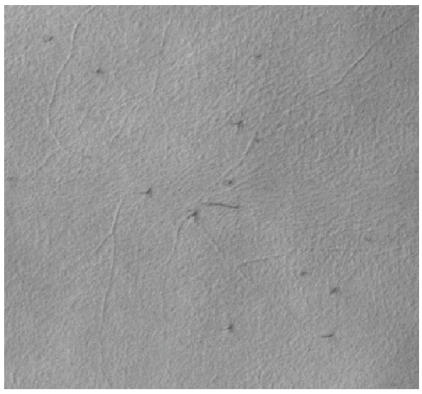

Figure 10. Piece of a hide with insect bites and a small scratch.

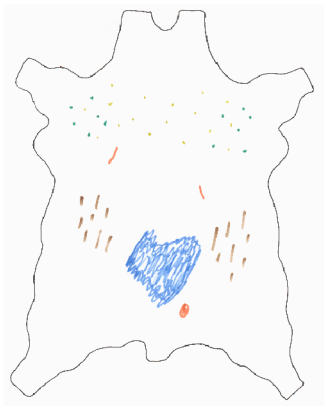

Figure 11. A scetch of detected defects.

Inspection and Grading of Leather Hides

Currently, FFC and ITWM are jointly involved in a project for developing an automatic inspection and grading system for a major Swedish leather hide manufacturer. The system's task is to sort the incoming hides early in the production process into a number of quality classes. The quality class determines 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 diveded into two steps:

- Automatic detection of all relevant defects (for instance scratches, insect bites, and warts, see figure 10). This will result in a list of defects describing their type, intensity/severity, and position on the hide. A (virtual) example of such a list is visualized in figure 11.
- Selecting the correct quality class based on this defect list. This decision should take the number of defects, their types, and their distribution on the hide, into account.

During 2004, the possibilities to carry out these tasks were investigated, with positive results. During 2005, a small test system will be set up at the company to further assure the feasibility of such a system.

Computational Biology

With the massive amount of biological and medical data generated today the biotech and pharmaceutical industry is faced with a number of new problems. Besides handling the sheer volume of data, the types of analyses one wants to perform are often strikingly different than what was anticipated just a few years ago. Applied research in systems biology and bioinformatics is the key to make the vast, diverse, and complex data more understandable and useful, since many existing tools are not adapted to the new situation.

- Systems Biology
- Bioinformatics

Systems Biology

Combining model based signal processing, system identification, local mechanistic models, and sensitivity analysis with novel measurement platforms provides a strong competitive edge for researchers in the pharmaceutical and biotech industry. The development of novel measurement technology can in fact be guided by biological questions in combination with adapted computational methods to enable raw-data to be compiled into a meaningful context – e g pathway diagrams. A typical example is the growing awareness of the limitations of measuring levels of biochemical entities just before and after a perturbation to a system and not during the transition. The latter may in some cases allow for at most classification of cause-effect mechanisms but this is not sufficient for a true understanding of the roles of different biological entities. These are however crucial to the decision about how to intervene the process in order to accomplish a desired effect.

The activities in systems biology at FCC are focused on the application and development of computational methods and mathematical models of biological systems on sub-cellular, cellular, tissue, organ, and whole body level, utilizing system level measurements. The in-house competences are in the area of control and dynamic systems with 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 local 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.

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Bioinformatics and biostatistics

Bioinformatics combines genetics, mathematics and computer science to handle the sequence and gene expression data produced by the bio-tech and pharmaceutical industry. Biostatistics is partly overlapping with bioinformatics and is concerned with the development and use of statistical methods for the analysis of biological data. Our vision is to bring together the disparate disciplines and cultures of mathematics and biology, to help get a better understanding of the processes and residues involved in the organization of an organism.

The structure and function of a gene is often revealed by studying their parallels in related organisms. With the microarray technology at hand today, researchers focusing on a specific disease or cell process are often left with an extensive list of candidate genes. Therefore, there is an increasing need to identify similarities and differences between the human and various model organisms, in order to identify and analyze factors involved in different processes.

We develop methods to identify complete gene structures, predict function and structure of the corresponding proteins, detect co-regulated gene candidates, and identify process-specific regulatory elements.

We are one of the key developers of cross-species gene finding software SLAM, and were part of the analysis group in the Mouse Sequencing Consortium and the Rat Genome Sequence Consortium.

Public funding - acknowledgement

In 2004, the Computational Biology Research Group has received substantial funding from the Swedish Foundation for Strategic Research.

The Computational Biology Research Group

- Mats Jirstrand, PhD, Docent, mainly working on systems biology
- Marina Alexandersson, PhD, Docent, mainly working on bioinformatics
- Henning Schmidt, PhD, mainly working on systems biology
- Alexandra Jauhiainen, Master student
- Sture Holm, Professor em, Chalmers, scientific adviser at FCC


Mats Jirstrand


Marina Alexandersson


Henning Schmidt

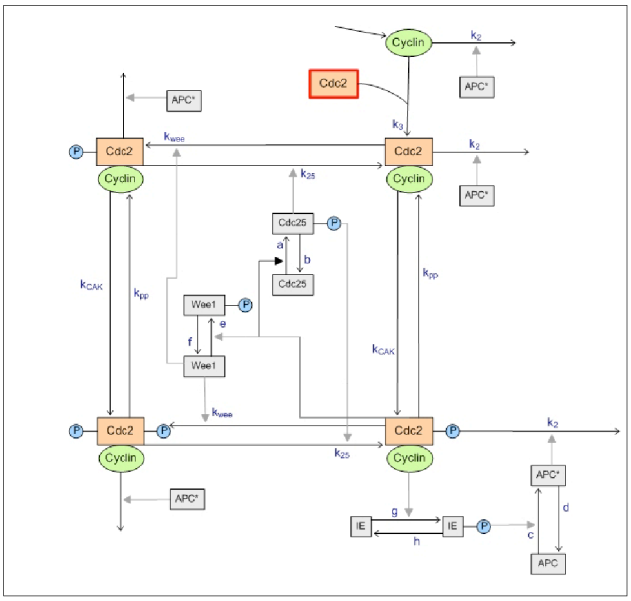

Alexandra Jauhiainen


Sture Holm

Identification of Biochemical Reaction Networks

Many cellular processes can be described in terms of networks of interacting biochemical entities such as proteins, genes, and metabolites. The interactions can be very explicit in nature such as an enzymatic reaction, where an enzyme transforms one molecule into another but also more implicit such as a gene regulating another gene, where the interaction is an abbreviation of a large number of even unknown steps and processes. Certain classes of networks are given names like metabolic and signaling pathways, gene regulatory networks, and protein-protein networks. To better understand the function and behaviors of these networks mathematical models in terms of dynamic systems is a valuable tool.

System identification is the science of building mathematical models of dynamic systems based on measured data from the systems. In this project we are investigating how existing methods from system identification can be adapted and tuned to handle typical properties of data from biological systems such as low signal-to-noise ratio and non-uniform sampling rates. Furthermore we also study how to incorporate prior knowledge in utilized model structures and developed algorithms. An important part of the work in this project is to evaluate the findings on synthetic data, i e, data generated by computer models mimicking the behavior of real biological systems. In this way one has a definite answer to what the system identification algorithms are trying to estimate. Once an algorithm has been evaluated on synthetic data one could then approach real data in more applied projects with much more confidence. One recent outcome of this project is a master thesis by Alexandra Jauhiainen entitled "Evaluation and Development of Methods for Identification of Biochemical Networks".



Biochemical reaction network involved in the cell cycle of Zenopus frog eggs.

Model Reduction in Biochemical Networks

Analog Insydes is a Mathematica add-on package, originally developed for modeling, analysis, and design of analog electronic circuits. The software is based on mixed symbolic/numerical algorithms for linear and nonlinear differential-algebraic systems of equations (DAE systems) which mean that it can also be used in other application fields. In a joint work with the developers of Analog Insydes at Fraunhofer ITWM an interface between the systems biology software PathwayLab and Analog Insydes has been developed, which allow the application of symbolic methods for the analysis of complex biochemical reaction networks.

So far, the methods have been applied to a model for the cell cycle in Xenopus frog eggs. This model shows oscillations of physiological significance. Applying symbolic techniques the sources of oscillations and especially those parameters which significantly influence the oscillations have been identified in a straightforward approach, showing the potential of the new method.

Starting with the transient model the static solution has been calculated. This static solution shows instabilities, leading to the described oscillatory behavior. Thus, the reason of the oscillation can be found by a linear stability analysis, which can be carried out symbolically by using Analog Insydes. For this the system has been linearized with respect to the static solution. After performing a Laplace transformation the reason for the oscillations was identified to be a conjugate complex pair of roots of the determinant with positive real parts. By allowing small deviations on the location of the roots and applying symbolic approximation techniques the system can be reduced to be described by only a few system variables which dominantly influence the oscillations.

Using this approximation an analytic formula for the characteristic polynomial of the system matrix can be computed. After applying further symbolic approximation steps, the characteristic polynomial can be solved for the corresponding zeros symbolically, leading to a formula showing the influence of the dominant parameters (e g reaction constants). Such a formula allows for a much deeper insight into the mechanisms behind complex systems in comparison to knowledge which can be achieved by pure numeric simulations.

BIOSIM

BIOSIM is the acronym for a project with the title "Biosimulation – A New Tool in Drug Development", which is a recently initiated network of excellence financed by the European Commission under the 6th Frame Program. The network consists of almost 40 partners from academia and industry with a total budget of 10.7 MEUR over the next five years. The research that FCC is involved in deals with the development of mathematical models, which better describe the glucose-insulin control system in the human body than current available models – an activity carried out together with Novo Nordisk and the Technical University of Denmark (DTU), among others. The other research area we are involved in comprise quantitative modeling of mechanisms for how the electrical activity and hormonal secretion in pancreatic alpha- and beta-cells are regulated, which is carried out in co-operation with research groups at the University of Oxford, among others.

The baker´s and the brewer´s yeast is an important model organism for human genetics.

Comparative Gene Finding in Yeast

For several decades the baker's and brewer's yeast, *Saccharomyces cerevisiae*, has been a popular and important model organisms for much molecular genetics research. Nearly half of the proteins known to be defective in human heritable diseases show sequence similarity to yeast proteins, and the basic cellular mechanics are generally conserved between yeast and human. The awesome power of yeast genetics is partially due to its advantages as an experimental system. It is unicellular and can be grown on readily controlled media, and PCR-mediated gene replacement techniques can obtain the precise deletion of an entire gene, yielding a unique single-deletion mutant for each of its 6000 genes.

Moreover, due to the compactness of its genome, the gene finding task in yeast is much more straightforward than in most higher organisms. But although being the most analyzed genome among eukaryotes, it is still far from characterized. The most difficult features to detect are regulatory sites and very small genes, that is, stretches of functional sequences that are too short to be readily detected and evaluated by existing methods. In multicellular organisms, there is a rich diversity of short peptides including many hormones and antibacterial defensins.

As genes and other functional elements in the genome tend to be more conserved than non-functional regions between related species, yeast offer a unique opportunity to explore eukaryotic genome evolution and identify these sites by comparing the numerous yeast species that are now being sequenced.

In this project we are using a stochastic framework called hidden Markov models (HMMs) to perform comparative gene finding between several yeast species. One issue that arises includes the level of rearrangements between the genomes, where the sequences are seemingly randomly chopped and reassembled relative to one another. Another issue is the computational complexity that poses a problem already in a pairwise setting. We are working on an algorithm that "unscrambles" the genomes before further comparative analysis is undertaken, and we need to develop more efficient multiple feature finding algorithms as well as methods to reduce the search space of such algorithms. A future aim of this project is to extend the methods to multiple sequence comparisons between human and several other mammals.

Finance and Insurance

The financial and insurance sectors today are two of the largest industries in the world. In 2004, the global options and futures markets alone saw a turnover in excess of USD 1200 trillion, according to the Bank of 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 and pension plans and so on. Finance, especially the options and futures markets, needs to model interest rates, stocks, bonds, real estate etc in order to derive fair prices for its wide selection of products.

As the finance and insurance markets become increasingly intertwined, as can be seen for instance by the emergence of the CAT-bonds (catastrophe bonds) market and in the interest in ALM-modeling (asset liability management modeling), 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 European initiatives Basel II and Solvency II.

FCC and our associates, with a strong understanding of the underlying mathematics and experience in practical modeling, are valuable partners for financial and insurance institutes in Sweden and Europe.

- Derivatives
- Risk

The Finance and Insurance Research Group

- Per Hörfelt, PhD, (left January 2005)
- Gerald Kroisandt, PhD, ITWM department of finance mathematics
- Christer Borell, Professor at Chalmers, scientific adviser at FCC (until Dec 2004)

Per Hörfelt

Gerald Kroisandt

Christer Borell

Contact
Dr Joachim Johansson
Phone +46 31 7724255
joachim.johansson@fcc.chalmers.se

Pricing of Structured Equity Products

A derivative is a financial contract which, at some fixed future date, pays a certain amount to its holder. The size of the payoff depends on the price evolution of some underlying asset, e g an equity. In recent years there has been a drastic increase in the number of equity derivatives with complex payoff structures, known as structured equity products. Efficient risk management requires the ability to price these products quickly and reliably, which can be difficult since it often involves computing high-dimensional integrals.

FCC has implemented this type of pricing routines in several projects together with Front Capital Systems, a successful trading systems developer for banks and other financial institutions. The methods have mainly been based on finite difference and Monte Carlo methods, but approximation formulas have also been developed.

Standard Approaches to Solvency Assessment

Since early 2002 the International Actuarial Association has been working with the development of a global framework for insurer solvency assessment. One objective has been to find mathematical methods that determine the minimum level of capital that has to be maintained by an insurance company in order to meet its future payments. In addition, since the methods should be used in regulations they need to be simple and robust in the sense that they should include a minimum number of parameters and be analytically tractable.

During 2004 the Swedish Insurance Federation and FCC have been working together with questions related to the problem of finding and evaluating simple and robust methods for solvency assessment. The work includes several aspects of mathematics such as stochastic calculus, parameter estimation, and risk measures.

Asset and Liability Management (ALM) for the Second Swedish National Pension Fund (AP2)

The Swedish pension system is based on rules regulating the interest on pension rights of employees as well as the increase of the pension payments for the retired persons. The principle is to keep the system balanced in such a way that the inflow is not lower than the outflow. The calculation is based on the actual numbers for the demography and income evolution. However, the system is still such that the pension fees from the employees are directly taken to pay the pensions. Only a small proportion remains for the four Swedish Pension Funds (AP1-AP4). The pension funds are allowed to invest their money worldwide, but they must make regular ALM-studies.

The aim of the ALM-studies is to analyze the actual market conditions and the impact of changes for selecting the appropriate long-term strategy such that the pension system is always balanced and no breaking effect must take place. The procedure is to simulate the future developments of the assets worlwide and to model the average Swede in order to simulate the liabilities in the future. When the simulations have been performed, the investment strategy is chosen by looking at the expected returns and the risk in the scenarios describing the future development.

Traditionally, funds do not perform these simulations themselves, but rely on the results of external consultants. A consequence of this is that the simulation model is somehow a black box. Especially, modeling of the specific properties of the Swedish pension system is often not possible, because this is not included in the simulation models of external consultants.

FCC and its partner ITWM have run a project with AP2, where the main aim was to develop an ALM-model including all the properties of the Swedish pension system. The first step was the investigation of models for the different asset classes. The focus was on the ability to identify the parameters, because the number of parameters was rather high due to the fact that we simulated seven different economies. Another topic was 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 was important to choose the market price of risk.

The whole simulation model was implemented as a stand-alone application with a text-oriented user interface which allows the user to change, add or take away simulated processes without changing the code of the application.

After the implementation followed the estimation of the parameters. Although the program allows changing parameters, e g the covariance matrix is dependent on the situation of the markets, we restricted our estimates to one set of parameters, mainly from historical data, except for the parameters in the risk-neutral world which were derived from actual bond prices.

The final step was the modelling of the Swedish pension system. The difficulty here was the exact timing of the different calculations and to synchronize them with the simulations of the different markets. In reality, there are persons retiring before they turn 65 and we also observe immigration and emigration. However, to implement these features would have led to a too complex system. Therefore, we imposed several assumptions as e g that all persons retire at the age of 65. The result was still very close to reality in the past which justified our simplifications.

The final simulations showed the expected results concerning the periods when the balancing may be violated. Furthermore, we observed that the longer the simulation time-horizon was, the riskier the investment strategy became. This reflects the evolution of the demography, i e in the future, the number of employees does not increase as fast as the number of pensioners and therefore, the buffer-funds must fill an increasing gap.

Årsredovisning

för tiden 1 januari 2004 - 31 december 2004

Resultaträkning (kSEK)	040101-041231
Intäkter	
Erhållen basfinansiering	7 489
Fsg tjänster - ind proj	8 484
Fsg tjänster - publ proj	3 168
Övriga intäkter	5
Summa intäkter	**19 146**
Kostnader	
Personalkostnader	-11 277
Konsulter	-4 560
Lokaler	-1 050
Kontorskostnader	-1 104
Resor och representation	-415
Avskrivningar enligt plan inventarier	-84
Summa kostnader	**-18 490**
Rörelseresultat	**656**
Resultat från finansiella investeringar	
Ränteintäkter och liknande	67
Räntekostnader och liknande	-7
Resultat efter finansiella poster	**716**
Bokslutsdispositioner	-333
Årets skatt	-121
ÅRETS RESULTAT	262

Balansräkning (kSEK)	041231
Anläggningstillgångar	
Inventarier	302
Datorer	525
Summa anläggningstillgångar	**827**
Omsättningstillgångar	
Likvida medel	4 750
Kundfordringar	2 295
Förutbetalda kostnader och upplupna intäkter	959
Summa omsättningstillgångar	**8 004**
SUMMA TILLGÅNGAR	8 831
Eget kapital	
Stiftelsekapital	913
Balanserat resultat	157
Årets resultat	262
Summa eget kapital	**1 332**
Obeskattade reserver	333
Kortfristiga skulder	
Leverantörsskulder	3 395
Övriga kortfristiga skulder	1 149
Upplupna kostnader	2 622
Summa kortfristiga skulder	**7 166**
SUMMA SKULDER OCH EGET KAPITAL	8 831

Styrelsen för Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik, FCC, får härmed avge följande redovisning över verksamheten under tiden 1 januari 2004 – 31 december 2004, stiftelsens tredje 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 affärsplan från mars 2001 bygga upp en verksamhet som år 2004 omsätter två miljoner euro och omfattar arton anställda.

Årets omsättning har varit drygt nitton miljoner kronor. Medeltalet anställda har ökat från 18 personer (varav sex kvinnor) 2003 till nitton personer (varav fem kvinnor) 2004. Stiftelsen har hyresavtal med Fastighets KB Forskarbyn omfattande 818 kvm i Chalmers Teknikpark till och med den 31 mars 2005.

Fraunhofersällskapet har vid möte i november 2003 beslutat öka sin tidigare beslutade finansiering av centret för år 2004 samt beslutat reservera samma belopp för år 2005.

Styrelse och ledning den 26 februari 2004. Bakre raden: Dieter Prätzel-Wolters, Claes Ekman, Jöran Bergh. Mittenraden: Helmut Neunzert (vice ordförande), Johan Carlson (biträdande föreståndare), Lars-Göran Löwenadler. Främre raden: Uno Nävert (föreståndare) Peter Jagers (ordförande), Tomas Lefvert, Gunnar Andersson.

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 19 146 kSEK. Av detta utgör 44% industriprojekt, 17% offentliga projekt och 39% finansiering från grundarna.

Årets resultat efter skatt är 262 kSEK. Eget kapital uppgick den 31 december 2004 till 1 332 kSEK. Detta inkluderar enligt stiftelseurkunden tillskjutet kapital på 50 kEUR från vardera grundaren.

Stiftelsens styrelse har under verksamhetsåret sammanträtt tre gånger. Ersättning har utgått till ordföranden med 4 500 kronor per möte och till övriga ledamöter med 3 000 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.

Göteborg den 17 februari 2005

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

Räkenskaperna har granskats av Deloitte.

Result (kEUR)	040101-041231
Income	
Basic funding	824
Projects - industry	933
Projects - public	348
Others	1
Total income	**2 106**
Cost	
Staff	-1 240
Consultants	-502
Premises	-116
Office	-121
Travel and entertainment	-46
Depreciations	-9
Total cost	**-2 034**
Result of business	**72**
Result of financial investments	
Interest and similar income	8
Interest and similar cost	-1
Result including financial investments	**79**
Appropriations	-37
Tax	-13
TOTAL RESULT	**29**

Balance (kEUR)	041231
Fixed assets	
Furniture	33
Computers	58
Sum of fixed assets	**91**
Current assets	
Cash	523
Accounts receivables	252
Prepaid expenses and accrued income	105
Sum of current assets	**880**
TOTAL ASSETS	**971**
Equity capital and debts	
Foundation capital	100
Balanced result	17
Result of the year	29
Total equity capital	**146**
Appropriations	37
Short-time debts	
Debts to suppliers	374
Other debts	126
Accrued expense	288
Sum of short-time debts	**788**
SUM OF DEBTS AND EQUITY CAPITAL	**971**

Appendix

Presentations / Conferences

M Alexandersson:
Scientific Computing at Chalmers - Bioinformatics, UNICC lecture, Göteborg, March 25, 2004.

M Alexandersson:
Hidden Markov Models and Bioinformatics, Docent seminar, Göteborg, December 9, 2004.

J S Carlson:
Kan vi lita på fixturerna? Nordic DMIS Network seminar, IVF, April 2004.

J S Carlson:
IEEE International Conference on Robotics and Automation, New Orleans, April 2004.

J S Carlson and Robert Bohlin:
Path planning of rigid bodies and industrial robots, Opel development center, Rüsselsheim, September 2004.

J S Carlson:
Capability index, Saint-Gobain Sekurit Scandinavia AB, Eslöv, Oktober 2004.

J S Carlson:
Path Planning and Robotics,
STM och FCC höstmöte, Stenungsbaden, October, 2004.

J S Carlson:
Banplanering för mätmaskiner,
Wingquist annual seminar day, November 11, 2004, Göteborg.

J S Carlson:
Path planning and Robotics
ProViking steering commitee for Virtual Verification of Product and Production Systems, November 26, 2004, Goteborg.

J S Carlson:
Vad innehåller duglighetsindex? Möjligheter och fallgropar, Volvo Car Corporation, December 16, 2004.

P Hörfelt:
The Integral of a Geometric Brownian Motion is Indeterminate by Its Moments, Third Bachelier Conference, Chicago, USA, June 27, 2004.

P Hörfelt:
Standard Approaches to Asset & Liability Risk, STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

M Jirstrand, J Gunnarsson, and H Johansson:
PathwayLab - A Software for Modeling and Simulation of Biochemical Reaction Networks, Reglermöte 2004, Göteborg, May 2004.

M Jirstrand:
Systems Biology – An Overview, Invited Seminar at the Division of Vehicular Systems, Department of Electrical Engineering, Linköping University, June 2004.

M Jirstrand, J Gunnarsson, and H Johansson:
PathwayLab - A Software for Modeling and Simulation of Biochemical Reaction Networks, Bioinformatics 2004, Linköping, June 2004.

M Jirstrand:
Systems and Control Theory - From Gas Turbines to Biochemistry, Docent seminar, School of Electrical Engineering, Department Signal and Systems, Chalmers University of Technology, September 2004.

M Jirstrand, J Gunnarsson, and H Johansson:
PathwayLab - A Customizable Modeling and Simulation Tool, 5th International Conference on Systems Biology 2004, Heidelberg, October 2004.

M Jirstrand:
Systems Theory, Data Analysis, and Modeling of Biological, Financial, and Technical Systems, STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

M Jirstrand:
Systems Biology and Bioinformatics at FCC, STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

M Jirstrand:
Systems Biology at FCC, Invited Seminar at Neurokemlab at Mölndals Sjukhus, October 2004.

P Johannesson, T Svensson:
Probabilistic design, presentation at a seminar about the load/strength method at FCC, Göteborg, April 2004.

P Johannesson:
Extrapolation of load histories and spectra, presentation at the international conference ECF15 in Stockholm, August 2004.

P Johannesson:
Fatigue life prediction based on variable amplitude tests, presentation at the Smögen workshop, August 2004.

M Karlsson:
Modelling of lateral loads for fatigue life calculations, presentation at the Smögen workshop, August 2004.

M Karlsson:
Dimensionering mot utmattningslivslängd för fordon, presentation at the STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

R Rundqvist:
Modelling of dispersion of particles and flocculation of fibres, ERCOFTAC summer school Multiphase Flow, Göteborg, August 2004.

R Rundqvist:
Kvalitetssäkring av CFD-uppdrag ur ett Fraunhoferperspektiv, SIAMUF workshop, Båstad, October 2004.

A-B Strömberg:
Vårfloden skall bli lönsammare, talk at STM steering group meeting, May 13, 2004.

A-B Strömberg:
Att göra vårfloden mera lönsam - Optimering av energiproduktion under osäkerhet, invited talk at "Kontaktdag Högskola - Industri", Matematiskt Centrum, Chalmers, June 3, 2004.

A-B Strömberg:
Optimering av kraftsystem på kort och lång sikt, talk at STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

T Svensson:
Estimating crack closure characteristics – an example of optimal experimental design, invited presentation at IPPT (Inst. of Fundamental Tech. Research), Warsaw, Poland, February 2004.

T Svensson:
Statistical aspects on fatigue limit estimation, invited presentation at IPPT, Warsaw, Poland, February 2004.

T Svensson:
Complexity versus scatter in fatigue modelling, invited presentation at IPPT, Warsaw, Poland, February 2004.

T Svensson:
Klassificering av inneslutningar med hjälp av extremvärdesstatistik – ett nytt förslag till standardisering, presentation at the conference Stål 2004, Borlänge, May 2004.

T Svensson:
Kontroll över systematiska respektive slumpmässiga fel – för en effektivare produktutveckling, invited presentation at SP in Borås, June 2004.

T Svensson:
Complexity versus scatter in fatigue modelling, presentation at the Smögen workshop, August 2004.

T Svensson:
Mean value influence in fatigue – on the rational choice of model complexity, presentation at the international conference ECF15 in Stockholm, August 2004.

T Svensson:
Statistical modelling of measurement uncertainty, presentation at the international conference ENBIS, Copenhagen, Denmark, September 2004.

T Svensson:
Complexity versus scatter in fatigue modelling, presentation at the CEEES international conference in Stockholm, September 2004.

T Svensson:
Modellering och försöksuppläggning vid utmattningsdimensionering, presentation at the STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

T Svensson:
Optimal komplexitet vid modellering, presentation at the STM och FCC höstmöte, Stenungsbaden, October 13 - 14, 2004.

Publications

T Lang, M Alexandersson, G C Hansson, T Samuelsson:
Bioinformatic identification of polymerizing and transmembrane mucins in the puffer fish Fugu rubripes. Glycobiology 14(6), pp 521 - 527, 2004.

Rat Genome Sequencing Consortium (which includes M Alexandersson):
Evolution of the Mammalian Genome: Sequence of the Genome of the Brown Norway Rat, Nature 428(6982), pp 493 - 521, 2004.

C Dewey, J Q Wu, S Cawley, M Alexandersson, R Gibbs, L Pachter:
Accurate Identification of Novel Human Genes Through Simultaneous Gene Prediction in Human, Mouse and Rat, Genome Research 14(4), 661 - 664, 2004.

J S Carlson:
R Söderberg, L Lindkvist, and J Carlson, Managing Physical Dependencies through Location System Design. Accepted for publication in Journal of Engineering Design.

F Ekstedt, M Jirstrand, and A Wirsen:
Modeling Nonlinear Boundary Conditions for Bearings, FCC internal report, March 2004.

P Hörfelt:
The moment problem for some Wiener functionals; corrections to previous proofs (with an appendix by H.L. Pedersen). Accepted for publication in Journal of Applied Probability.

P Hörfelt:
The error in the Monte Carlo pricing of some familiar path-dependent options. Accepted for publication in Mathematical Finance.

M Jirstrand:
Modeling of Lipid Homeostasis Using PathwayLab, FCC internal report, April 2004.

P Johannesson:
Extrapolation of Load Histories and Sprectra, Proceedings of ECF15 (European Conference on Fracture), Stockholm, August 11 - 13, 2004.

P Johannesson, T Svensson, J de Maré:
Fatigue life prediction based on variable amplitude tests - Methodology. Accepted for publication in International Journal of Fatigue.

T Svensson, E Johnson:
Optimal experimental design for estimating crack closure features, International Journal of Fatigue, Vol 26, pp 705 - 716, 2004.

T Svensson, P Johannesson, J de Maré:
Fatigue life prediction based on variable amplitude tests - Specific applications,
Accepted for publication in International Journal of Fatigue.

T Svensson:
Complexity versus scatter in fatigue modelling, invited article to Fatigue and Fracture of Engineering Materials and Structures, Vol 27, pp. 981 - 990, 2004.

T Svensson, P Johannesson, J de Maré:
Mean value influence in fatigue - on the rational choice of model complexity, Proceedings of ECF15 (European Conference on Fracture), Stockholm, August 11 - 13, 2004.

PhD thesis

H Schmidt, Design and Analysis of Feedback Structures in Chemical Plants and Biochemical Systems, **PhD thesis**, December 7, 2004.

PhD students

K Wärmefjord (Chalmers, Saab Automobile AB); adviser J S Carlson. Inspection Data Feedback and Analysis, Multivariate Quality Control and Diagnosis of Sources of Variation in Assembled Products, **Licentiate thesis**, June 2004.

M Karlsson (Volvo Trucks, Chalmers); advisers J de Maré, T Svensson, P Johannesson: Statistical Modelling of Lateral Vehicle Loads, **Licentiate thesis**, December 2004:

L Gershuni (Chalmers, SKF); adviser M Larson. Lubricant Film Replenishment on Bearing Components (tentative title, in progress).

J Svensson (Chalmers, Volvo Aero Corporation); co-advisers D Anevski, T Svensson. Survival Estimation and Distribution Approximation for Optimal Maintenance, **Licentiate thesis**, December 2004.

G Genet (PSA Peugeot Citroën, Chalmers); co-adviser P Johannesson. Fatigue and load analysis of multi-dimensional loadings (tentative title, in progress).

N Andréasson (Chalmers, Volvo Aero Corporation); co-adviser A-B Strömberg. Optimization of opportunistic replacement activities in deterministic and stochastic multi-component systems, **Licentiate thesis**, May 2004.

B Grohe (Chalmers); co-adviser A-B Strömberg. Propagation methods for global constraints in Constraint Satisfaction Problems (tentative title of licentiate thesis, in progress).

R Halldin (LTH, Sydkraft, STEM); co-adviser A-B Strömberg. Scenario Trees for Inflow Modelling in Stochastic Optimisation for Energy Planning (title of lecentiate thesis, 2002) (PhD thesis in progress).

S Lorén (Chalmers): co-adviser T Svensson. Fatigue limit, inclusion and finite lives - a statistical point of view, **PhD thesis**, June 2004.

J Andersson (Chalmers): co-adviser T Svensson. Point processes and convex sets - Applications in fatigue, **Licentiate thesis**, January 2004.

Master students

J Svenberg (Chalmers, Volvo Car Corporation); adviser J S Carlson and R Bohlin, Path Planning for Coordinate Measuring Machines, **Master thesis**, June 2004.

O Karlsson (Chalmers); adviser J S Carlson and R Bohlin. Automatic correction of surface normals on 3D models (in progress).

J Havner (Chalmers); adviser J S Carlson and R Bohlin. Automatic correction of surface normals on 3D models (in progress).

D Segerdahl (Chalmers); adviser J S Carlson and R Bohlin. Development and Implementation of a Fast and Memory Efficient Sweep Volume Generation System (in progress).

S Tafuri (Chalmers); adviser J S Carlson and R Bohlin. Development and Implementation of a Fast and Memory Efficient Sweep Volume Generation System (in progress).

Master students:
Ola Karlsson (advised by Johan Carlson), Alexandra Jauhiainen (advised by Mats Jirstrand), Johan Havner (advised by Johan Carlson), Johan Svenberg (advised by Johan Carlson), Sebastian Tafuri (advised by Johan Carlson), Andréas Mark (advised by Robert Rundqvist), and Daniel Segerdahl (advised by Johan Carlson).

A Jauhiainen (Linköping University); adviser M Jirstrand. Identification of Biochemical Reaction Networks (tentative title, in progress).

A Mark (Chalmers); adviser R Rundqvist. Simulation of Fibres on Detail Level (tentative title, in progress).

A Johansson (Chalmers, SEB); adviser P Hörfelt. Pricing of Long Term Currency Options (tentative title, in progress).

A Svagan (Chalmers, Enera); examinator A-B Strömberg. Finding good under-estimates of resources required for winter road management, **Master thesis**, March 2004.

P Hugoson (Chalmers, Sydkraft Vattenkraft AB); examinator A-B Strömberg examinator. Optimization of operations in a hydro power system, **Master thesis**, March 2004.

J Engkvist (Chalmers, Volvo Car Corporation); advisers A-B Strömberg, M Patriksson. Black box optimization in engine development, **Master thesis**, December 2004.

C Bohman (Chalmers, Volvo Car Corporation); advisers A-B Strömberg, M Patriksson advisers. Black box optimization in engine development, **Master thesis**, December 2004.

Other assignments

M Alexandersson:
Appointed Docent ("Associate Professor") at Chalmers.

J S Carlson:
Member of the ProViking Steering commitee for Robust Design and Variation Simulation.

J S Carlson:
Reviewer for ASME International Design Engineering Technical Conferences.

J S Carlson:
Member of the reference board of Teknisk Matematik, Chalmers.

M Jirstrand:
Appointed Docent ("Associate Professor") at Chalmers.

T Svensson and J de Maré:
Members of the technical committee ESIS (European Structural Integrity Society) TC20, chaired by Professor Yukitaka Murakami, Kyushu University, Japan. Within this committee TS and JdM have contributed to the publication "Technical recommendations for the extreme value analysis of data on large non-metallic inclusions in steels".

FCC staff on December 17, 2004.

Back row, from left to right; Johan Carlson, Jacques de Maré, Anders Ålund, Daniel Segerdahl, Henning Schmidt, Sebastian Tafuri, Tomas Hermansson, Rikard Söderberg, Per Hörfelt, Thomas Svensson, Uno Nävert. Middle row, from left to right; Marina Alexandersson, Jenny Ekenberg, Ann-Brith Strömberg, Alexandra Jauhiainen, Martina Westman, Annika Eriksson. Front row, from left to right; Erik Höök, Johan Havner, Fredrik Ekstedt, Robert Rundqvist, Mats Jirstrand, Andreas Mark, Domenico Spensieri, Ola Karlsson.

Annika Eriksson and Uno Nävert, editors.

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The Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC has been founded by Chalmers and Fraunhofer-Gesellschaft as a business making, non-profit Swedish foundation.

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.