Fraunhofer
CHALMERS
Research Centre
Industrial Mathematics

Annual Report 2010

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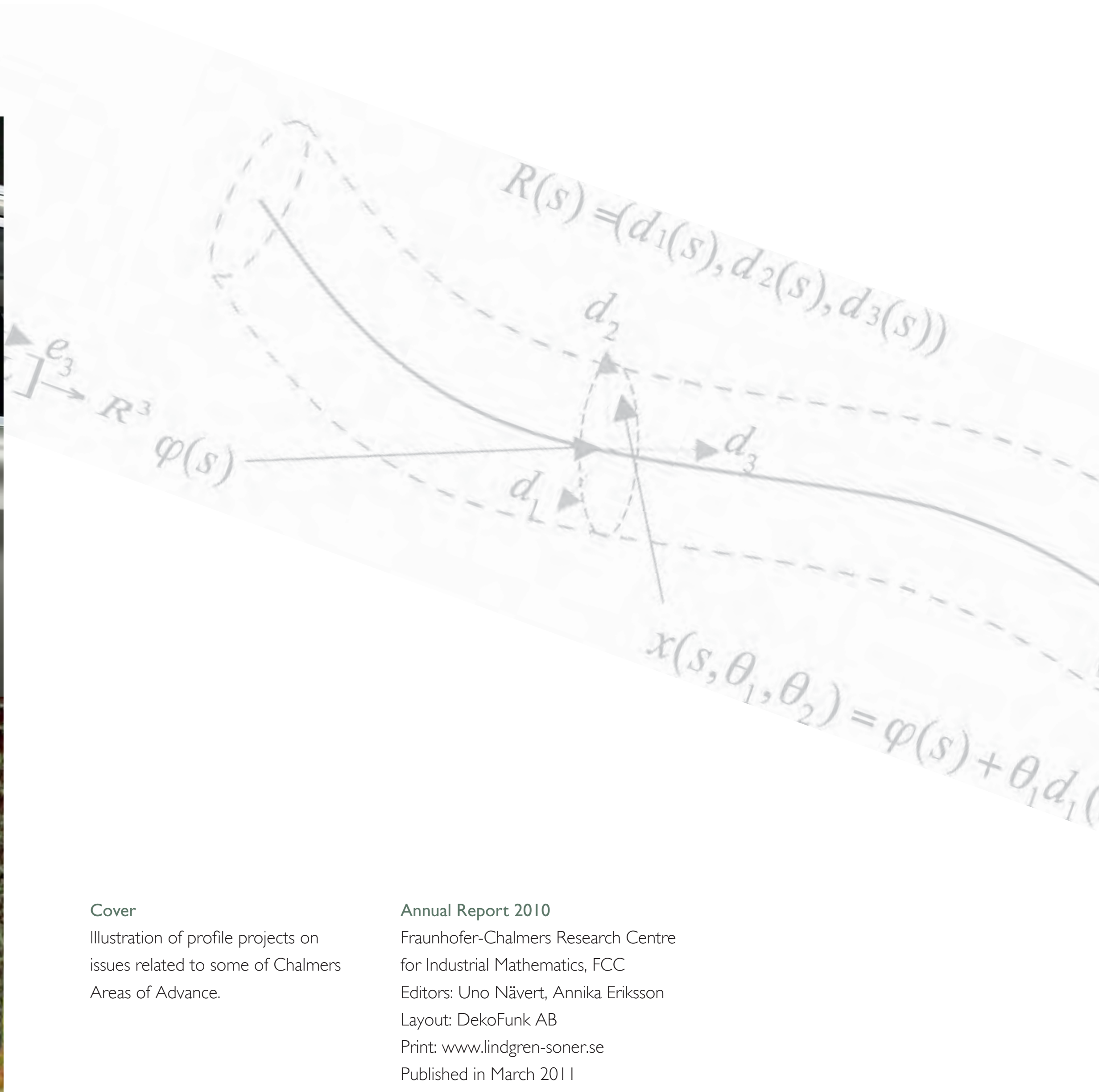

Cover
Illustration of profile projects on issues related to some of Chalmers Areas of Advance.

Annual Report 2010
Fraunhofer-Chalmers Research Centre for Industrial Mathematics, FCC
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Contents

Preface and profile

FCC has since start 2001 completed more than two hundred industrial and public projects. We have successfully cooperated with more than seventy companies from different branches. We have seen the power of our vision "Mathematics as Technology" and we are impressed and proud of the trust we enjoy from our founders Fraunhofer-Gesellschaft and Chalmers, from industrial partners, and from public research agencies. In 2010 both founders decided to continue their present annual joint support of one million euros for another five years 2011-2015. At the same time Fraunhofer expressed the wish to widen the scope of the cooperation.

Our mission is to undertake and promote scientific research in the field of applied mathematics to the benefits of industry, commerce, and public institutions. We do this as a business-making, non-profit, Swedish institution. The year 2010 was again a successful one, with annual turn-over reaching all-time high.

We note a continued increase of public projects in absolute and relative numbers. At the same time the industrial income has levelled out, with industry to a large extent present as contracted partners in the public projects. We expect it will take two to three years to re-establish the normal level of an industrial income around forty percent through a campaign aiming at a broader base of industrial clients including small and medium-size companies.

Together with our partners Chalmers and the Fraunhofer industrial mathematics institute ITWM we cover a wide range of applications. In 2010 we have intensified our cooperation further, including joint actions with all ITWM departments, with Chalmers Wingquist Laboratory, Chalmers Systems Biology, Chalmers Mathematical Sciences and Gothenburg Mathematical Modelling Centre, Chalmers Fluid Dynamics, and Chalmers Biomedical Engineering.

In 2008 we started the industrial partner group IPG as a successor of the former Swedish Association of Industrial Mathematics STM. The group meets two to four times a year in Kaiserslautern and in Gothenburg to propose a research programme from research scenarios, industrial scenarios, and making a synthesis. The first year was on inverse problems, parameter identification, and optimization, the second year on uncertainty, reliability, risk, and quality, and the third year 2010 was on visualization.

Last year we were fortunate to recruit six new coworkers. Our staff of applied researchers is a mix of PhDs and Masters of Science, where about half have a doctor's degree. We believe in a model where an MSc first works in industrial and public projects for two to five years. In this period we encourage participation in conferences and submitting papers to get a research flavour. If a proper project then appears, which would naturally include a PhD student, we are well positioned to offer the project a candidate who would contribute significantly from start, and the interested staff member a possibility for bringing her or his education one step further. Seven of our employed MScs have started PhD studies in this way: five at Chalmers and two on leave abroad.

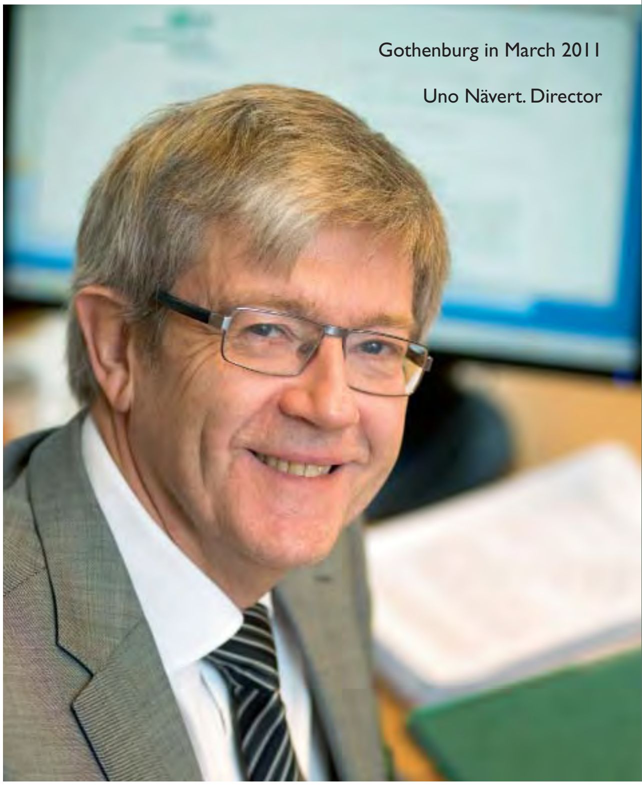
In 2008 we initiated a campaign to offer an interesting option to Chalmers students while boosting our base for future recruitments. We invite master students from a handful of Chalmers and Gothenburg University international programs with a mathematical profile to information meetings "Earn Money on Mathematics". We describe FCC and our activities, including the possibilities for talented students to be contracted on ten percent of full time, or half a day per week, for work in the Centre, and to do master thesis projects at the Centre with joint supervision from Chalmers and FCC. In 2010 we had thirteen Swedish students and twelve students from abroad working on this type of contract, including 64% male and 36% female students.

I thank my coworkers at FCC for your excellent work and my colleagues at Chalmers and Fraunhofer ITWM for our fruitful collaboration. Since start the Centre has earned more than twenty million euros including forty percent industrial and thirty percent public income. Together we are well positioned for the challenges to come!

Below we give a flavour of our activities through describing four profile projects on issues related to some of Chalmers Areas of Advance. We also present our competences organized in three departments. Enjoy your reading!

Gothenburg in March 2011

Uno Nävert. Director



The department Geometry and Motion Planning works in close cooperation with the Chalmers Wingquist Laboratory and the Chalmers Production Area of Advance. The department participates in the ten-year Wingquist Laboratory VINN Excellence Centre for Virtual Product Realization 2007-2016. In 2010 the department continued and extended several public projects, e.g., on virtual paint, flexible materials, coordinate measuring machines, and intelligently moving manikins. The software platform IPS for rigid body motion planning, robotics path planning, and flexible cable simulation is recognized through licensing by industrial clients in Europe, United States, and Japan. The department has substantial joint development with the ITWM department Mathematical Methods in Dynamics and Durability.

The department Computational Engineering and Design has expanded its work on multi-physics applications involving fluid-structure and fluid-electromagnetics interaction, in particular through projects with Swedish and other European industrial partners together with the ITWM departments Optimization and Flow and Material Simulation. The department runs a three-year project on innovative simulation of paper with Swedish paper and packaging industry, in 2010 supported by a companion project on dynamic fiber network modeling in a finite element setting through the Gothenburg Mathematical Modelling Centre. The department is also a key partner in the project on virtual paint with Swedish automotive industry.

The department Reliability and Risk Management has focussed on fatigue life and load analysis of mechanical structures in, e.g., automation and automotive industry. In 2010 we co-ordinated a pre-study "Virtual Measurement Campaigns for Trucks" with the Chalmers Stochastic Centre, Fraunhofer ITWM Dynamics and Durability, SP Technical Research Institute of Sweden, and five industrial partners from Germany, the Netherlands, and Sweden. This department was closed in the mid of the year due to unsatisfactory economic development and the main project following the pre-study will be run by a consortium led by Fraunhofer ITWM.

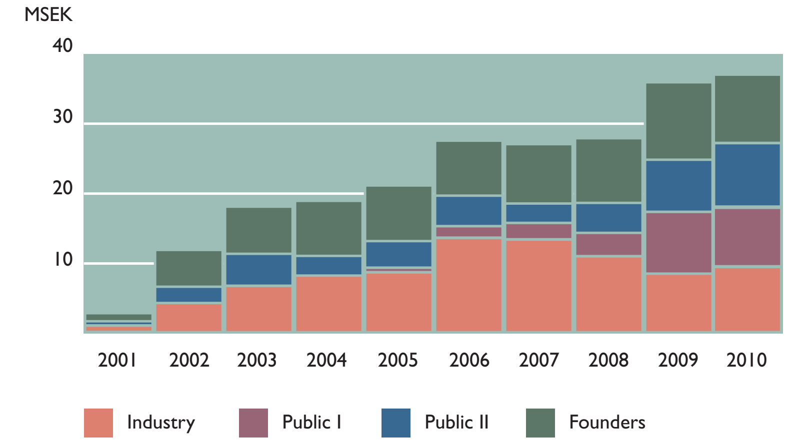
The department Systems Biology and Bioimaging works in close cooperation with the Chalmers Life Science Area of Advance. The department has continued to grow, in particular through EU projects. Our cooperation with the ITWM department System Analysis, Prognosis and Control has intensified through a strategic project on integration of systems biology, biotechnology, mathematics, and image processing in fundamental animal cell protein production. Work on interactive pharmacokinetics and pharmacodynamics and the software Maxsim2 developed for pharmaceutical industry is presented below.

Facts and figures

Total income

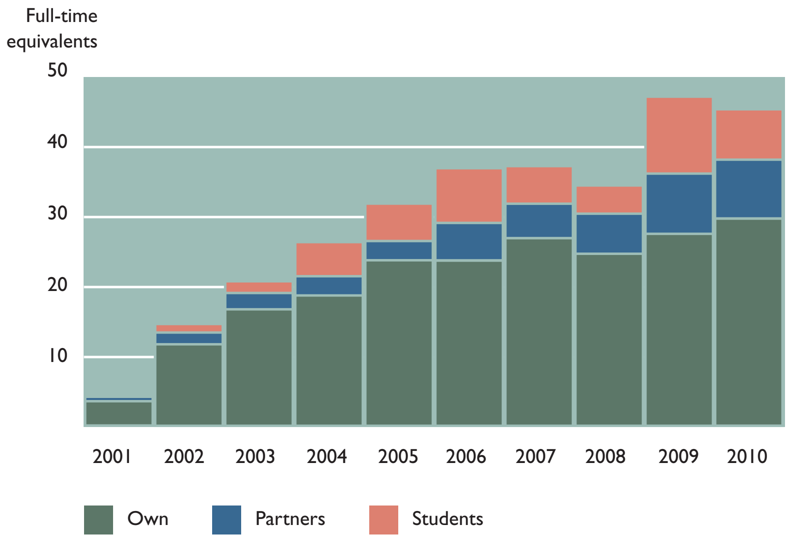
In 2010 the total income increased to thirty-seven million Swedish crowns or four million euros which was once more all-time-high. The result was a small positive net, as has been the case every year since our start in 2001.

The profile of the Centre is controlled by its income structure. We note a continued increase of public projects, half of which (I) are under industrial command. With the financing from the founders set to 1.0, the income is 3.8 in total, including 0.9 industry, 0.9 public I, and 1.0 public II.



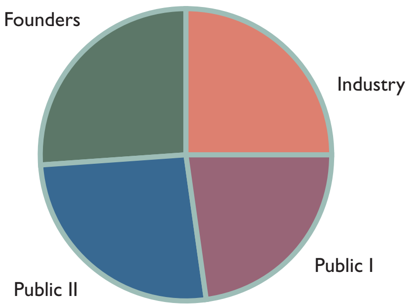
Staff – full-time equivalents

In 2010 the number of staff was forty-five full-time equivalents. We were happy to recruit six new coworkers. The reduction of student time was due to fewer master´s thesis projects. The number of master students doing contracted work increased to twenty-five people, including 64% male and 36% females, and included students from Sweden(13), China (3), Iran(2), Germany(2), Egypt(1), France(1), Iceland(1), Lebanon(1), and Romania(1).



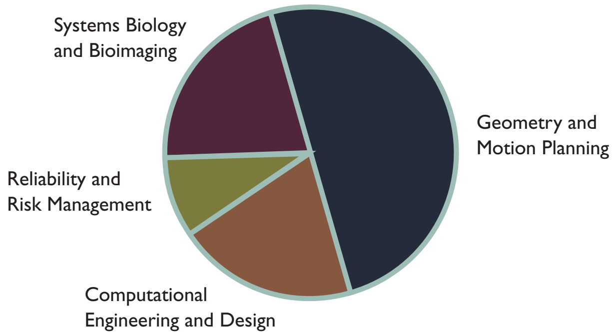
Project mix by income 2010

The profile of the Centre is controlled by its income structure. Here the last two years deviate drastically from the previous ones by having a significant part of public projects (I) under industrial control. The project volumes 2010 were: industry (25%), public I (23%), public II (26%), and Fraunhofer and Chalmers (26%); the basic funding was approximately unchanged.



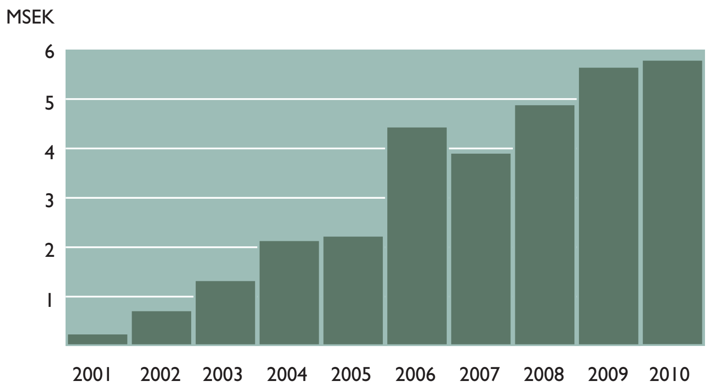
Departments by income 2010

The Centre had four departments, one of which was closed during the year, cf page 3, 20, 22, and 24. The relative income of the departments varied between 9% and 50% of the grand total.



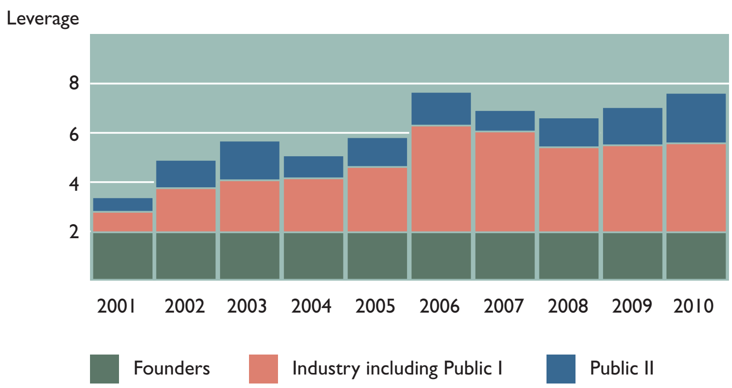
ITWM project income from FCC

The basic funding to FCC is equally shared between Fraunhofer and Chalmers, in 2010 being 0.5 million euros from each founder. The project flow from FCC to ITWM, shown in the diagram to the right, is in line with the development of the total FCC income, with a modest increase in 2010. The ITWM project income from German automotive industry based on the IPS software has increased significantly.



Chalmers benefits and basic funding

The Centre works to promote the brand name “Mathematics” and has substantial cooperation with the Areas of Advance “Production” and “Life Science”. The Centre contributes to the Campus Johanneberg environment, where we operate with thirty-five staff members and twenty-five students in Chalmers Science Park. The turnover is almost eight times the Chalmers basic funding. This includes industrial projects and public projects under industrial command near to four times Chalmers basic funding.



Central services

Jenny Ekenberg, MSc
Economy and IT

Anette Söderlund
Economy

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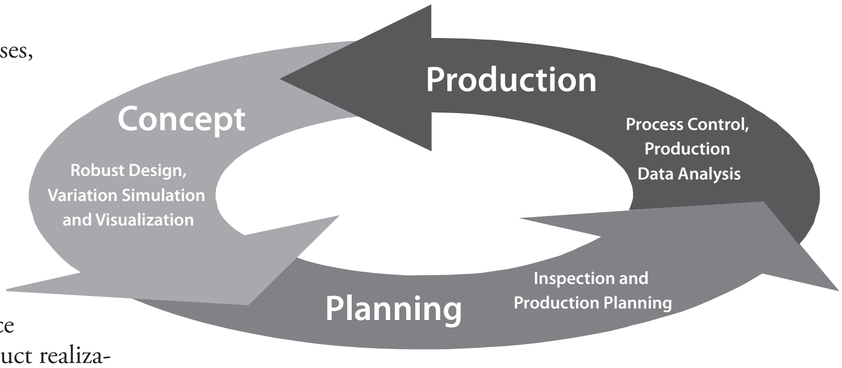
Administration and Personnel

Lars Löwenadler, MSc
Technical administration

Efficient Geometry Inspection and Off-line Prog

Volvo Cars is now implementing a new process and software support based on RD&T and IPS for Inspection Preparation and Automatic Off-line Programming of CMMs. The return of investment will be faster inspection preparation, programming and improved measurement equipment utilization. The implementation is based on validated research results from FCC, Wingquist Laboratory at Chalmers, SWEREA IVF, Volvo Cars, and Saab Automobile within the VINNOVAs MERA program.

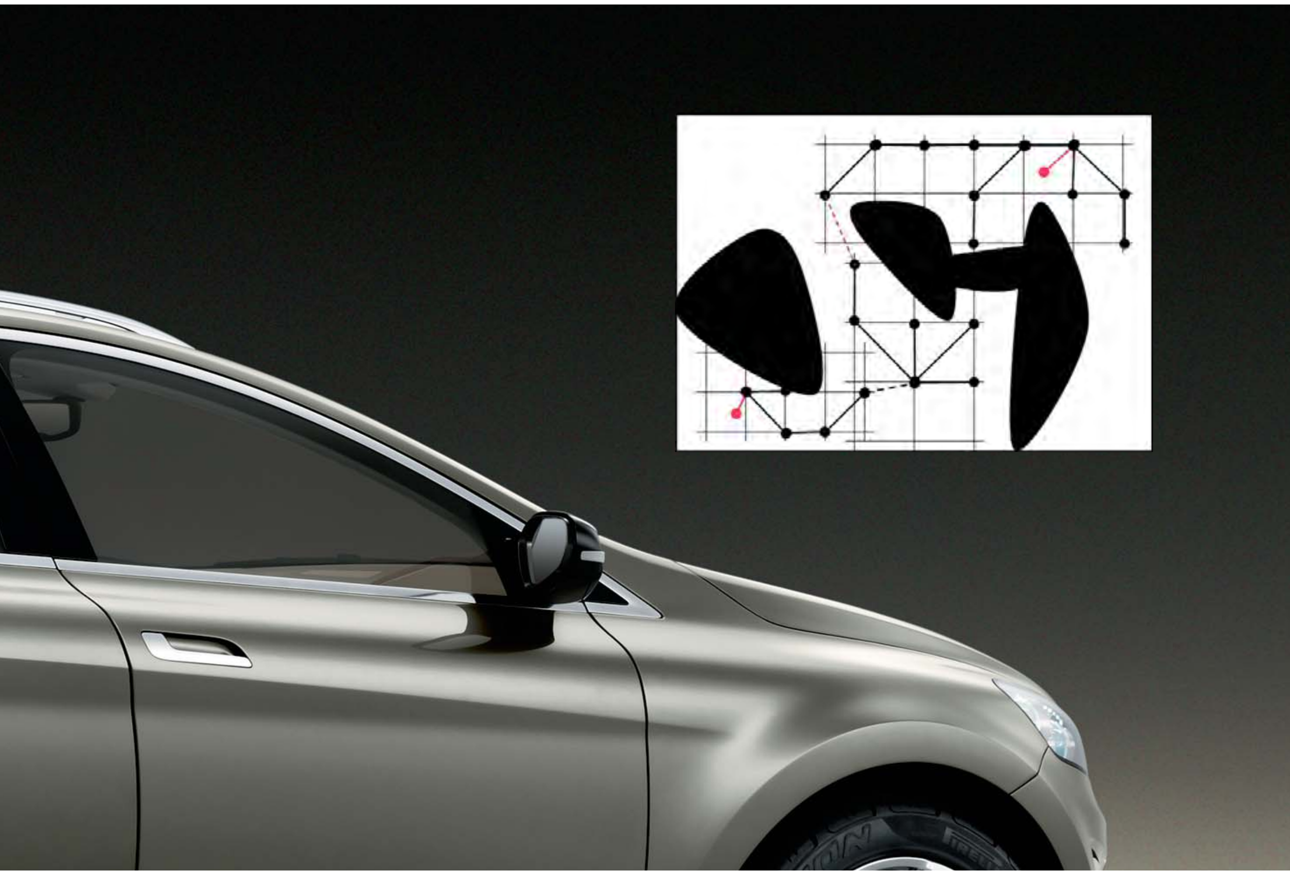
gramming



Since variation is inherent in all production processes, consistent efforts in styling, design, verification and production aiming at less geometrical variation in assembled products, is a key to shortening development time of new products, as well as for choosing an efficient and resource-economic production process. The activities aiming at controlling geometrical variation throughout the whole product realization process are called the geometry assurance process. The figure shows a general model for product realization consisting of a concept phase, a verification phase and a production phase. In the concept phase the product and the production concept are developed. Product concepts are analyzed and optimized to withstand the effect of manufacturing variation and tested virtually against available production data often based on carry over type of inspection. In this phase, the concept is optimized with respect to robustness and verified against assumed production system by statistical tolerance analysis.

The visual appearance of the product is optimized and product tolerances are allocated down to part level. In the verification and pre-production phase the product and the production system is physically tested and verified. Adjustments are made to both product and production system to adjust errors and prepare for full production. In this phase inspection preparation takes place. This is the activity when all inspection strategies and inspection rules are decided. In the production phase all production process adjustments are completed and the product is in full production. Focus in this phase is to control production and to detect and correct errors by analyzing inspection data.

As we can see, it is necessary to feed the geometry assurance process with reliable inspection data in all phases which makes the inspection preparation and measuring an extensive and important activity. At Volvo Cars a new vehicle program is inspected with typically 700 inspection programs containing up to 25 000 features.

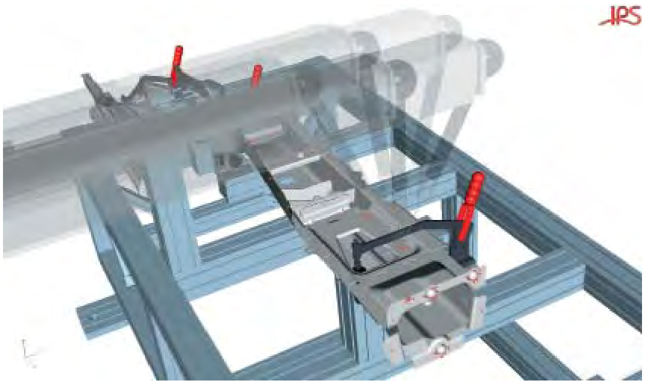


The inspection preparation contains three steps; (i) the inspection task is defined by breaking down product and process requirements to geometrical inspection features, e.g., a hole or a slot, on part and subassembly level, (ii) the inspection rules defines how a feature should be measured, i.e., number of points, local measuring coordinate systems, and allowed probe configurations, (iii) the final step is to program the motions and sequence of the Coordinate Measurement Machines (CMMs) that performs the actual measurement.

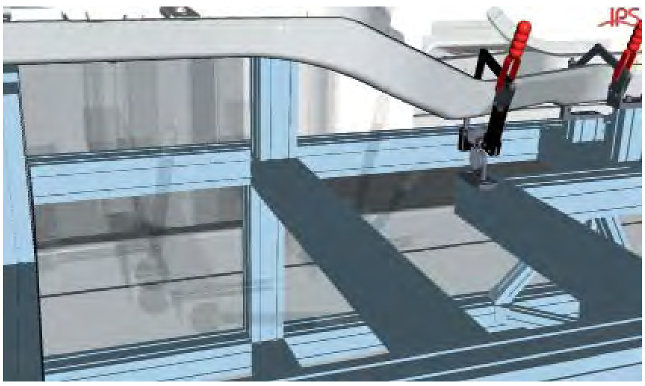
The automatic CMM programming contains three main math based algorithms for motion planning and combinatorial optimization. The first step is a feature accessibility analysis to find a set of probe configurations of minimum size that can reach all inspection points with collision free CMM configurations. This can be done by solving a binary LP problem.

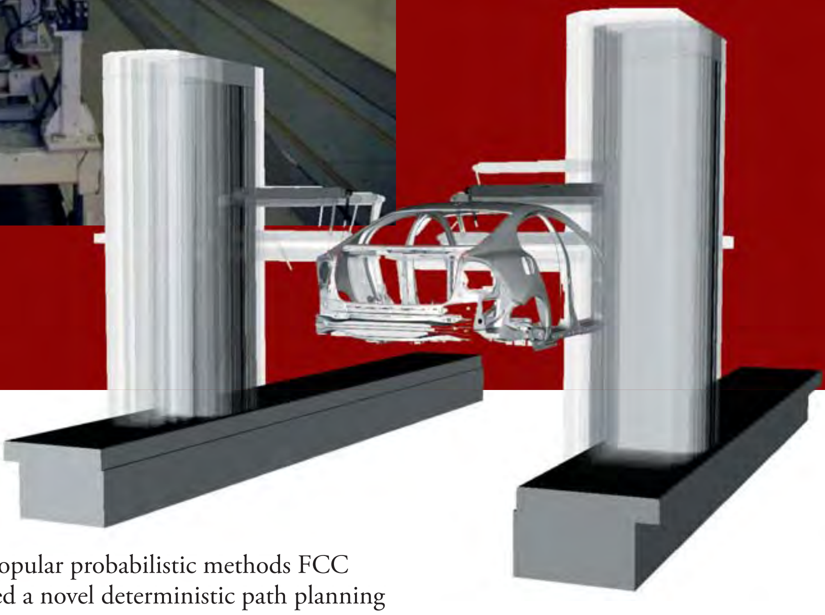
The next technology used is Path Planning where the collision free CMM motions are generated by automatically finding via points and probe reorientations between the inspection features. Complete path planning algorithms, which always find a solution or determine that none exist, are of little industrial relevance since they are too slow. In fact, the complexity of the problem has proven to be PSPACE-hard for polyhedral object with polyhedral obstacles. Therefore, sampling based techniques trading

Feature accessibility analysis resulting in five different collision free probe configuration inspection alternatives (courtesy of Volvo Cars).



An automatic generated collision free path between two features containing a non trivial necessary probe change in the middle (courtesy of Volvo Cars).

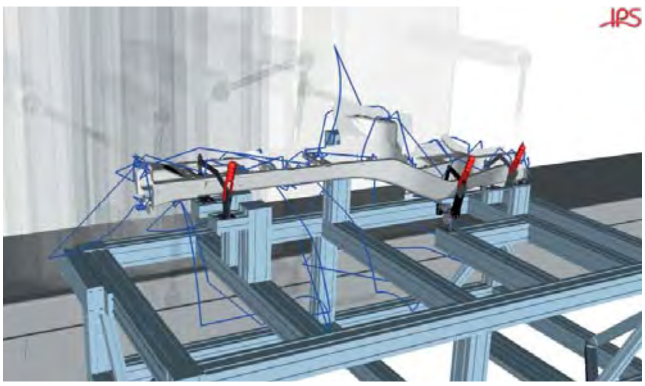




completeness for speed and simplicity is the choice. Inspired by both the two most popular probabilistic methods FCC has since 2003 developed a novel deterministic path planning algorithm implemented in the IPS software.

The last step is sequencing where it is decided in which order and with what probe configuration the CMM should inspect to minimize cycle time. This is a generalization of the classical Traveling Salesman Problems (TSP) which has been solved by a new direct method for grouped problems with node alternatives.

An optimized collision free inspection sequence for 20 features containing 115 points, calculated by IPS (courtesy of Volvo Cars).



RD&T Technology

RD&T is a tool for statistical variation simulation that allows manufacturing and assembly variations to be simulated and visualized long before any physical prototypes are being made. RD&T supports the geometry assurance process in all its phases. www.rdttech.com

IPS is a math based tool for automatic verification of assembly feasibility, design of flexible components, motion planning and optimization of multi-robots stations, and simulation of key surface treatment processes. IPS succesfully implements the potential of the virtual world. www.industrialpathsolutions.com

Interactive Pharmacokinetics an

Mathematical modeling and simulation of what the body does to a drug after administration, such as its absorption, distribution, metabolism, and excretion, also known as pharmacokinetics, or models of what the drug does to the body, i.e., how the drug concentration is translated into a medical effect, also known as pharmacodynamics, are of increasing importance in drug development. The explanation is to be found in the promise of reduced costs and accelerated drug development due to better experimental design, improved understanding of results, and models of stronger predictive power.

The aim of the Maxim2 project is to develop a software platform for simulation of the temporal behavior in pharmacological, pharmacodynamic, and pharmacokinetic processes. The models are physiological flow models, which means that the pharmacokinetic and pharmacological processes are defined in terms of physiologically, anatomically, and biochemically interpretable parameters and mechanisms. These models are used in medical applications to describe the potency or efficacy of a substance and how it is transported and distributed via the blood to different organs in the body as a function of time. Pharmacokinetics can for example be used in medical applications to calculate optimal dosage for different therapeutic situations.

Each organ is represented by one or several compartments, which are interconnected by blood flows. These models are excellent tools for real-time presentation of the interplay between physiology, pharmacology, and pharmacokinetic processes. Traditionally empirical models, such as one and two compartment models, have been the most common types used in pharmacokinetic or pharmacodynamic (PKPD) applications.

d Pharmacodynamics

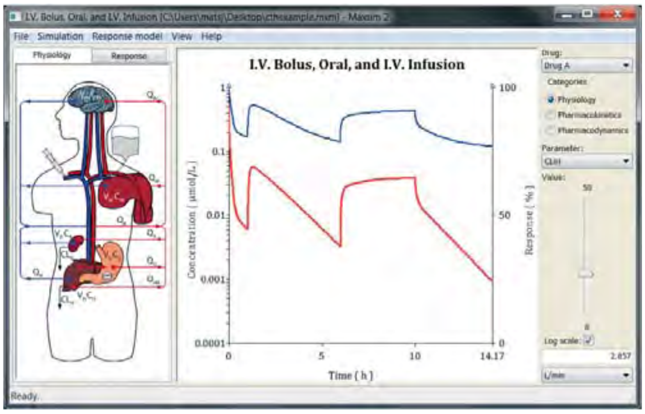
$$R = E_0 + \frac{E_{max} \cdot C}{EC_{50} + C}$$

$$R = E_0 + \frac{E_{max} \cdot C^n}{EC_{50}^n + C^n}$$

$$R = E_0 - \frac{I_{max} \cdot C^n}{IC_{50}^n + C^n}$$

Instantaneous pharmacodynamic response models.

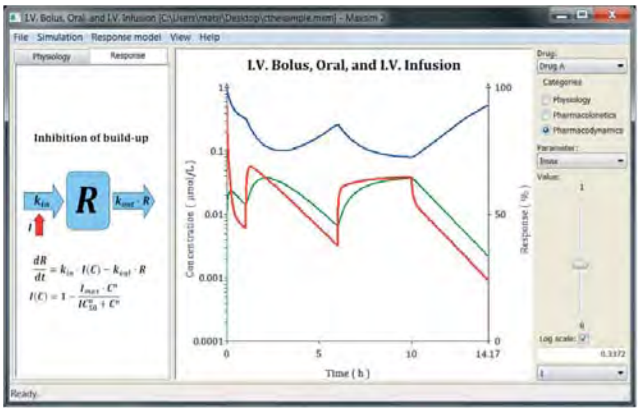
The graphical user interface of Maxsim2 showing a simulation of plasma drug concentration (red) and drug effect (blue) after three consecutive dose administrations: intravenous bolus, oral, and intravenous infusion, respectively. The slider, in this example, controls hepatic clearance, i.e., how fast the liver is able to remove the drug from the blood. Changes in this parameter is reflected in real time in the corresponding changes of the curves in the time-concentration/effect diagram.



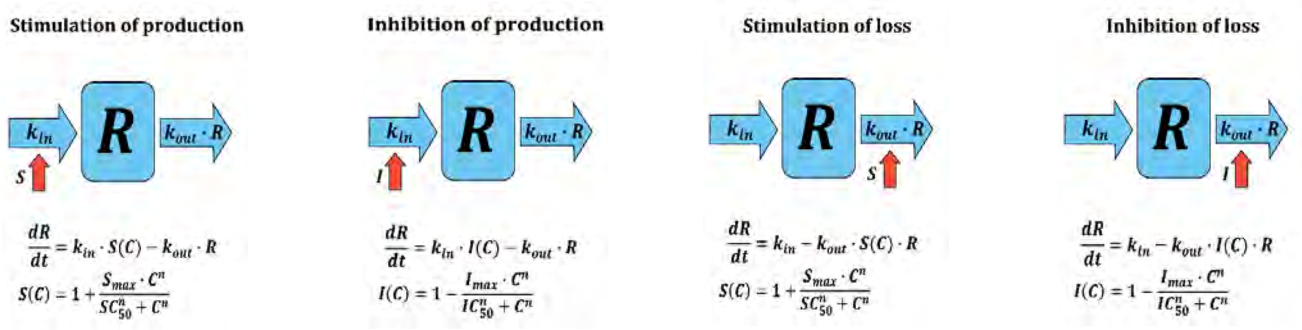
The increasing need for mechanism-based models calls for more detailed models and models with better predictive power. Here so called physiologically based pharmacokinetic/pharmacodynamic (PBPKPD) modeling and simulation offers an oftentimes excellent tradeoff between too empirical models and too detailed partial differential equation based models.

The resulting software, developed within the Maxsim2 project is an easy to use, intuitive, and interactive application for physiologically based pharmacokinetic and pharmacodynamic simulation. The user interacts with the model and runs simulations using sliders, check boxes, and number fields. Physiological parameters such as organ sizes/volumes, tissue-to-blood partition coefficients, pharmacodynamic parameters, and parameters related to absorption and dosage regimens can be changed, which in real time is mirrored by changes of the temporal concentration profiles shown in a plot. This interactivity and direct feedback of "what-if" scenarios gives

A simulation of plasma drug concentration (red) and muscle tissue drug concentration (green). The effect is modeled by a so called indirect response model with inhibition of build-up giving the drug effect (blue).



Indirect pharmacodynamic response models.



the user a good physiological understanding for how different parameters impact the concentration-time or response-time courses; an understanding which has a large impact both from a therapeutic perspective as well as health economics perspective.

The user interface of Maxsim2 makes it easy to specify different dosage schemes such as single dose, repeated dose, or varying amounts of dose but also specifying different dosage regimens such as oral, intravenous bolus, intravenous infusion, or combinations.

The pharmacodynamic models available in Maxsim2 are both instantaneous concentration-response models and indirect concentration-response models also known as turnover models. The indirect models include both inhibition and stimulation of build-up and loss, respectively. The instantaneous models feature both stimulatory and inhibitory sigmoidal *Emax* models.

Using state-of-the-art graphical user interface controls, it is easy to set up simulation scenarios such as repeated oral dosage of a specific compound to study the dynamic effect of a missed dose as well as a "double dose" compensation – under what conditions does this lead to toxic effects? Or, what is the difference in temporal profiles of the plasma concentration of the drug given an oral dose, intravenous bolus dose, or intravenous infusion for a limited period of time.

We envision Maxsim2 as an ideal application for both educational and commercial use where thorough understanding of pharmacodynamic and pharmacokinetic interplay is important. For more information please visit www.maxsim2.com.

The software Maxsim2 has been developed in close collaboration with Prof. Johan Gabrielsson, Gothenburg University, a world leading authority in the field of pharmacokinetic and pharmacodynamic data analysis.

The aim of this ongoing project is to develop novel tools for simulation of papermaking and paperboard package quality that are based on microstructure models of the fiber web. A consortium has been formed consisting of the four companies Albany International, Eka Chemicals, Stora Enso and Tetra Pak that span the entire production chain from pulp to package, and FCC and Franhofer ITWM.

Innovative Simulat

To perform microstructure simulations to predict paperboard properties represent a new approach to product and process development in paper industry. The software resulting from the project will make it possible to perform a larger portion of product development by computer simulation. Substantial progress in the fundamental understanding of the papermaking process can be achieved, which is particularly important to be able to develop products with increased functionality but with less material and energy input. This is crucial for the competitiveness of renewable packaging materials in order to meet the increasing threat from fossil fuel based packaging materials such as plastics.

The software is based on an object-oriented C++ framework and consists of the following tightly coupled modules: PaperGeo for virtual structure generation, IBOFlow for fluid dynamics simulation, and FeelMath for structural dynamics. The IPS platform is used for pre- and post-processing. Specifically, the software will be used to investigate how the build-up of the fiber web in the forming section, and certain properties of paperboard packages such as resilience to edge penetration and structural dynamics, depend on fiber properties and process conditions. In the longer term this means that paperboard packages with better functional properties can be developed.

Stochastic realization of the microstructure of a paper in the PaperGeo module of the Fraunhofer ITWM software GeoDict.

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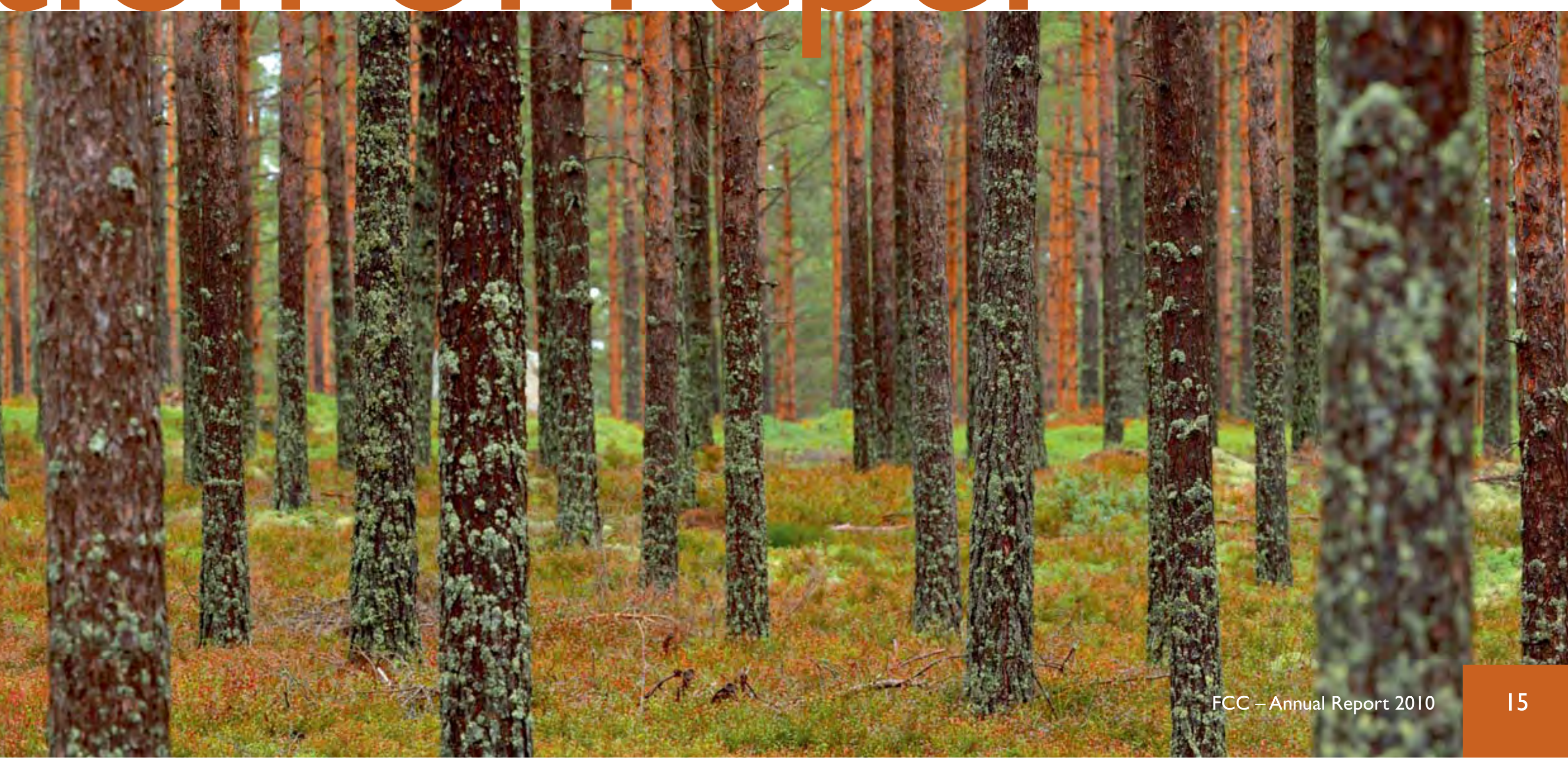
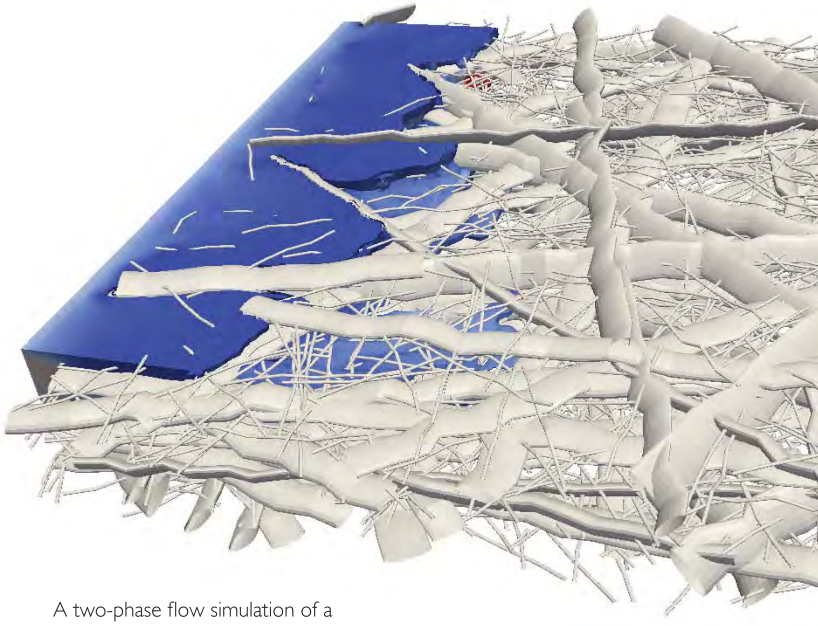


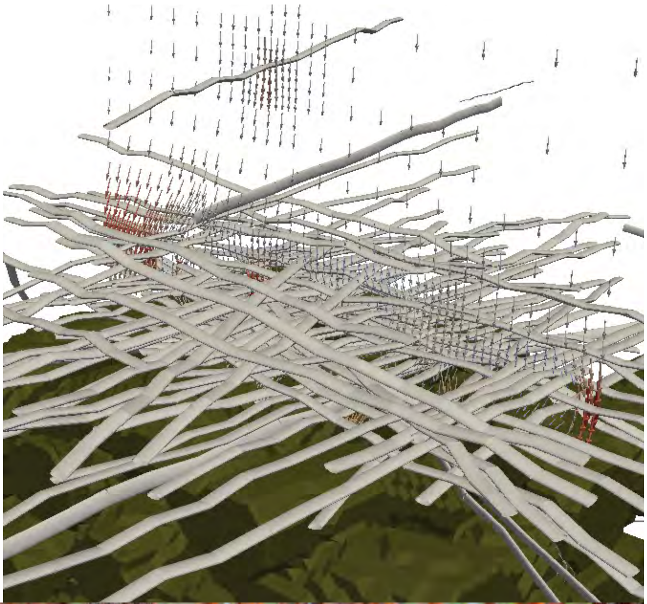
Paper forming

In the paper forming section of the paper machine a fiber suspension in the form of a free jet leaves the headbox and impinges on a permeable belt called a forming fabric. The initial forming influences the properties of the fiber web and the subsequent dewatering, and depends on fiber characteristics, chemical additives, forming fabrics and other process conditions. Since the effective paper properties depend on the micro-structure a continuum model is inadequate.



A two-phase flow simulation of a water front penetrating the open edge of a paper using the Volume of Fluids (VoF) module in IBOFlow.

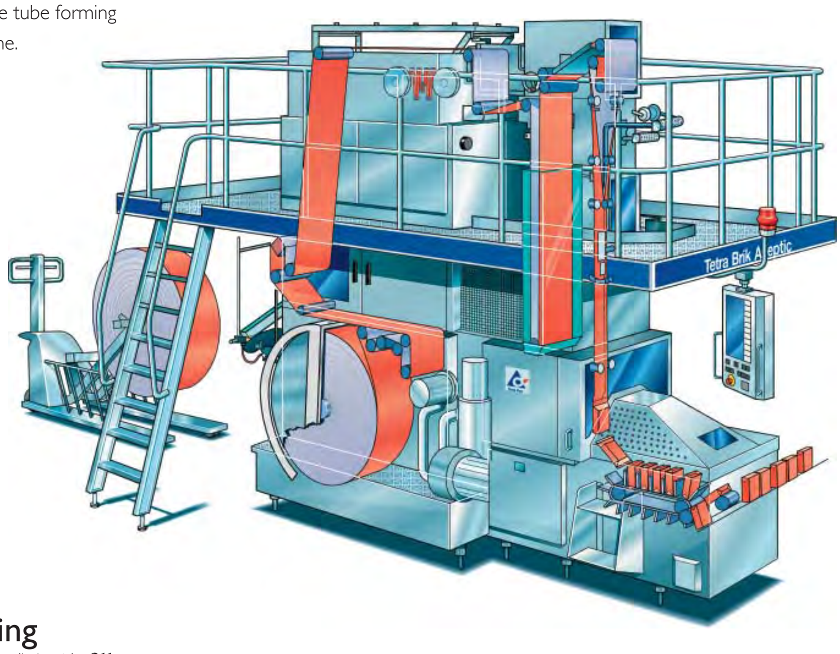
A fluid-structure interaction simulation of the initial laydown of fibers on a forming fabric. In the cutting plane the arrows show the velocity field, where red color indicates higher and blue color lower velocity (forming fabric geometry courtesy of Albany International).



The fluid-structure interaction of flow and moving fibers and flocs needs to be accurately modeled in this application. The fact that the fibers are buoyant with the same density as the surrounding water makes this a very challenging problem.

Our in-house Navier-Stokes software, IBOFlow, is perfectly suited for this application. The flow around the moving fibers is resolved by the adaptive octree grid and immersed boundary methods are used to model the presence of fibers in the flow. The fibers are approximated as slender bodies represented by hollow elliptical segments. The fluid force on each fiber segment is calculated by integrating the pressure and the viscous stress tensor around the segment surface. An Euler-Bernoulli beam model in co-rotational formulation is used and discretized in a FEM framework to calculate the large fiber deformations. The fiber-fiber and fiber-fabric couplings are modeled by Langrangean multipliers. In the simulation software, individual fibers are generated and visualized in the process of laying down onto the forming fabric. The buildup of surface density of paper material across the forming fabric as well as fiber orientations are computed and used as a measure for comparison with experiments. The first version of the paper forming simulation software will be delivered to the industrial partners during the spring 2011.

An outline of the Tetra Brik Aseptic filling machine. The paperboard material enters the peroxide bath located to the top right before the tube forming and filling take place in the machine.



Product quality – edge wicking

During startup of the Tetra Brik Aseptic (TBA) filling machine after a short stop the bath is filled with a liquid mixture of water and peroxide, and the liquid starts to penetrate the open edge of the paperboard. Only a few millimeters penetration can be allowed otherwise a tube break might occur that destroys the aseptic environment in the filling machine. The resulting penetration depends on fiber properties, chemical additives, sheet structure and other process parameters.

To simulate the edge penetration a multi-scale framework has been developed. Small pieces of 3D paper microstructure are generated using PaperGeo. For these microstructures a pore-morphology model generates active pore radius and saturation levels for different pressure drops. One-phase flow simulations are then performed on active pores to calculate relative permeabilities. These results are validated with two-phase flow simulations using the Volume of Fluids (VoF) module in IBOFlow. A virtual macro sheet (2D distribution of surface weight and anisotropy) is then generated based on the micro properties. Simulations on the macro sheet give the water front as a function of time. The first version of the edge wicking simulation software will be delivered to the industrial partners during the summer 2011.

A paper machine located at the Stora Enso Kvarnsveden paper mill. The three main steps in papermaking are forming, pressing and drying. In the forming section a fiber suspension leaves the headbox and impinges on a forming fabric. Here the fiber web starts to form and the initial dewatering occurs. In the pressing section additional water is squeezed out of the web under high pressure. The remaining water is evaporated as the web runs through heated dryer rollers in the drying section.

Virtual Measuren for Trucks

Transport vehicles are exposed to dramatically different operating conditions in different parts of the world and in different transport missions. Our vision is to facilitate virtual measurement campaigns by describing and analyzing worldwide load environments for trucks based on vehicle independent geographic, economic, and legislation data.

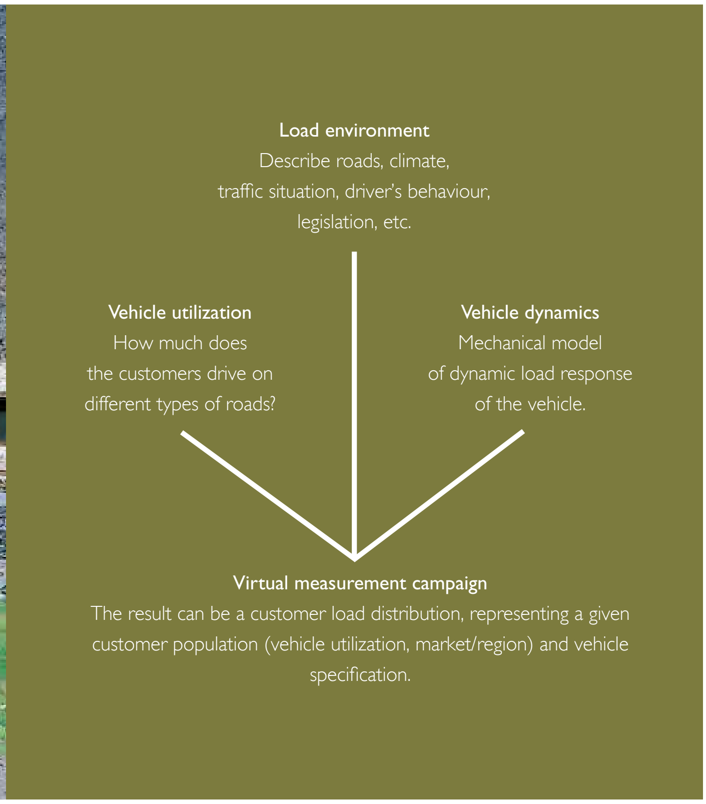
A pre-study was co-ordinated by FCC in April – September 2010. Working partners were Fraunhofer ITWM Dynamics and Durability, the Chalmers Stochastic Centre, SP Technical Research Institute of Sweden, and industrial partners DAF, Daimler, MAN, Scania, and Volvo. Project leader was Dr Michael Speckert, Fraunhofer ITWM.

Background

In the period January 2006 to December 2009 the project "Guide to Load Analysis for Automotive Applications" was financed by six European truck manufacturers, cf FCC Annual Report 2009.

In parallel at Fraunhofer ITWM there has been research and development financed by Fraunhofer towards using vehicle independent geographic and economic data (maps, satellite data …) to enhance the possibilities of modelling the usage variability for cars and trucks as well as for construction and agricultural machinery.

ment Campaign



Objective

In order to learn about the load environment, the truck manufacturers perform physical or real measurement campaigns, where a truck is equipped with measurement devices and observed during more or less ordinary service life. The advantage of this procedure is that accurate data is collected for a lot of different spots of the truck. Disadvantages are that this is expensive and the data depends on the truck used for the measurement.

This is the starting point for the idea of a virtual measurement campaign for trucks (VMCT). If we had a (more or less simple) mathematical model of the truck, a mathematical model of the driver behaviour, a model of the traffic flow, and descriptions of the roads including roughness, curvature, slope, speed limit, traffic light etc., we could simulate the truck ride in any region of the world and collect data in the computer.

The pre-study was established to evaluate the possibility for developing a dedicated software tool VMCT for truck engineering based on combining the above ideas.

The figure illustrates the scope and the basic relations between vehicle utilisation, load environment, and vehicle dynamics. It highlights the fact that the focus is on the truck- and company-independent load environment. Vehicle dynamics and vehicle utilisation are taken into account only in a very simple and generic way.

Result

The final report of the pre-study discusses how to describe the load environment, what information is needed, how to access the data, which applications should be supported, and what functions are required. Thus, it lays the foundation for the main project developing and implementing the corresponding software tool.

Geometry and Motion Planning

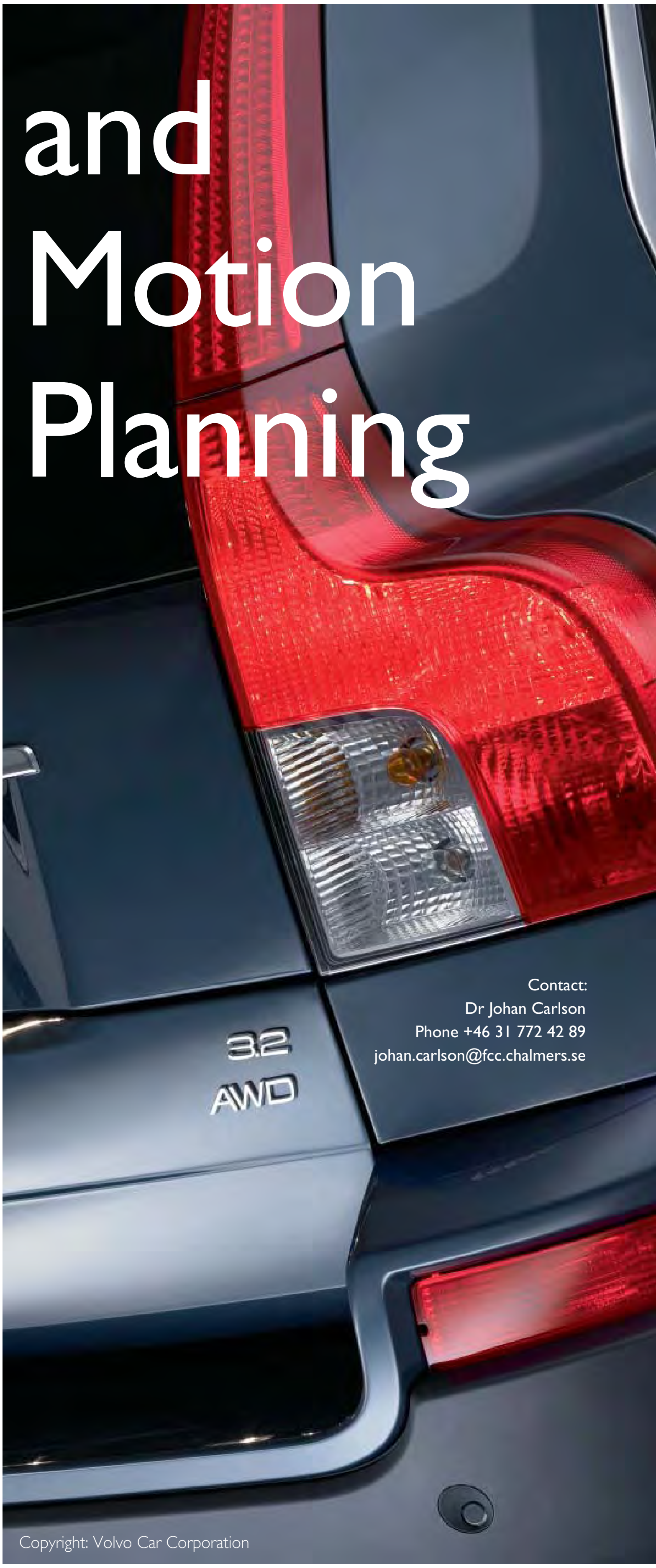
Many products such as car and truck bodies, engines, medical prosthesis, mobile phones, and lumbering equipment depend visually and functionally on its geometry. Since variation is inherent in all production, consistent efforts in styling, design, verification and production aiming at less geometrical variation in assembled products is necessary to achieve easy-to-build high-quality products. Also, the demand on short ramp up time, throughput, and equipment utilization in the manufacturing industry increases the need of effectively generate and visualize collision-free and optimized motions in the assembly plant. During 2010 the department of Geometry and Motion Planning have successfully developed methods, algorithms and tools supporting these activities within four main subjects:

- Packing and Assembly Path Planning
- Robotics and Discrete Optimization
- Computer Graphics
- Geometry Assurance

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

The group is also active within the Chalmers Production Area of Advance which commits to increase economical, ecological and social sustainability. In particular, the research has been focusing on assembly motions consider biomechanical load and human diversity, geometrical quality and factory throughput during assembly and joining, paint and surface treatment processes simulation, and scanning technology.

Another important research area is related to real time simulation of flexible parts and motions. The FCC technology developed together with ITWM has been successfully implemented as a cable simulation module in the IPS software with capability to analyzing and optimizing hoses, cables and wiring harness related to for example engine packing, electrical packaging and robot cables. IPS is now used in Sweden, Germany, US, and Japan supporting virtual product realization.



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The Geometry and Motion Planning Research Group

Johan Carlson
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Head of Department

Rikard Söderberg
Professor in Product and Production Development at Chalmers,
Director Wingquist Laboratory,
Scientific Adviser at FCC

Cooperation

During 2010, the successful collaboration with Wingquist Laboratory Vinn Excellence Centre has continued with Geometry and Motion Planning as one of its four main research groups. Also the collaboration with the Industrial Research and Development Corporation (IVF), the Virtual Ergonomics Centre (VEC) and the ITWM departments Dynamics and Durability has grown by working together on common projects.

Acknowledgement

In 2010, the Geometry and Motion Planning group has received substantial funding from the FFI and Vinnex program within Vinnova and the ProViking program within the Swedish Foundation for Strategic Research (SSF).

Robert Bohlin
PhD

Fredrik Andersson
MSc

Staffan Björkenstam
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Fredrik Ekstedt
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Tomas Hermansson
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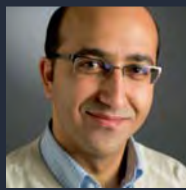


Babak Saboori
MSc

Daniel Segerdahl
MSc

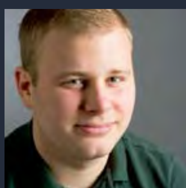
Evan Shellshear
PhD

Domenico Spensieri
MSc

Sebastian Tafuri
MSc

Johan Torstensson
MSc

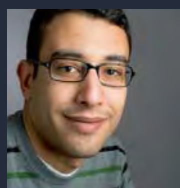
Igor Rychlik
Professor
Mathematical Statistics Chalmers,
Affiliated expert FCC



Martin Andersson
Contracted student

Fadi Bitar
Contracted student

Stefan Gustafsson
Contracted student



Bassel Mannaa
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Peter Mårdberg
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Molood Noori
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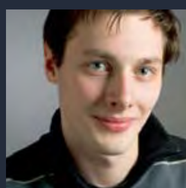

Martin Nordström
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Simona Tamasoiu
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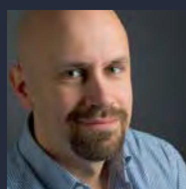
Christian Bengtsson
MSc student

Niclas Delfs
MSc student

Kristoffer Hahn
MSc student



Johan Segeborn
Lic, Volvo Cars,
PhD student

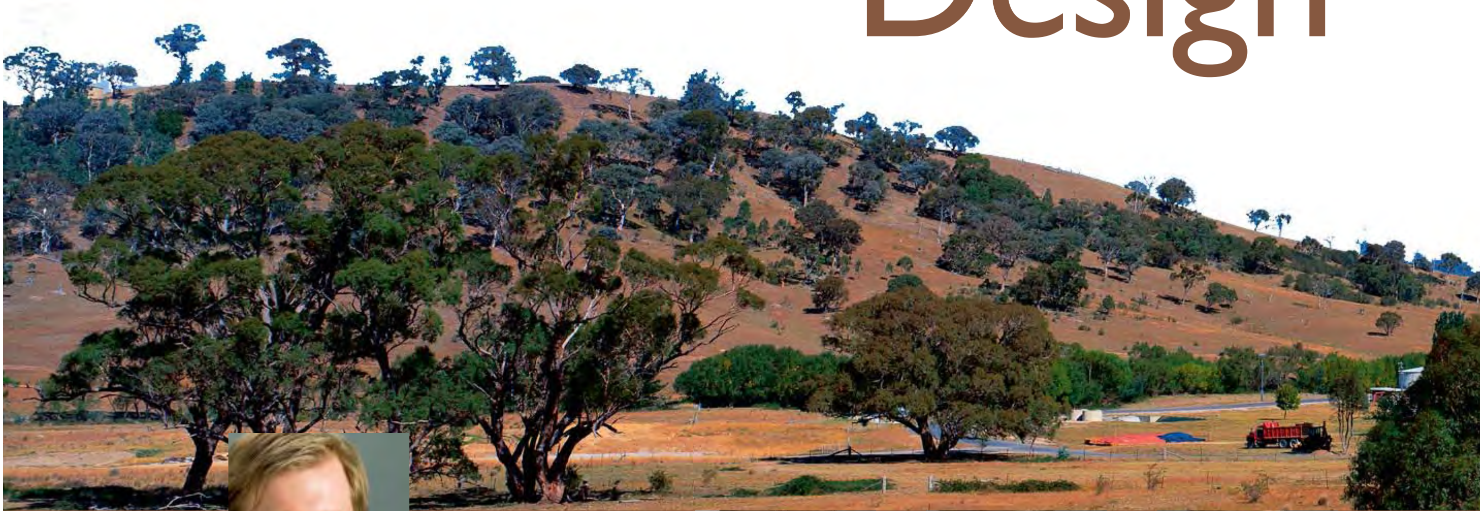
Cooperation

During 2010, the successful collaboration with the department of Geometry and Motion Planning at FCC has been strengthened through joint projects on Virtual Paint Shop. Also the collaboration with the departments of Optimization and Flow and Material Simulation at Fraunhofer ITWM has grown by working on joint projects. Other collaborations include the Chalmers divisions of Fluid Dynamics and Biomedical Engineering.

Acknowledgement

In 2010 the department received substantial funding from Vinnova through the FFI Sustainable Production Technology program, from the Swedish Foundation for Strategic Research (SSF) through the Gothenburg Mathematical Modeling Centre (GMMC), and from the Sustainable Production Initiative and the Production Area of Advance at Chalmers.

Computational Engineering and Design



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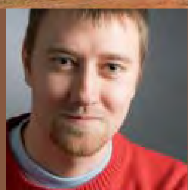
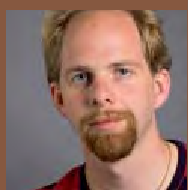


Björn Andersson
MSc

Klas Engström
PhD

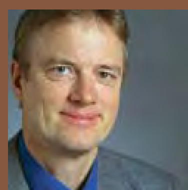
Stefan Jakobsson
PhD

Andreas Mark
PhD



Robert Rundqvist
PhD

Robert Sandboge
PhD



Anders Ålund
Lic

Modern product design and process operations are heavily based on computational mathematics through work in the virtual world. Traditional hands-on engineering is replaced by systematic approaches based on computer simulations, which provide additional insight in the design phase and reduce the need for expensive measurements. The department of Computational Engineering and Design has key competences in applications that can be mathematically modeled by partial differential equations (PDEs). Novel numerical methods, fast algorithms and engineering tools are developed to enable efficient simulation and optimization of industrial applications, and thereby support virtual product and process development in various industrial sectors. The work is organized in three areas:

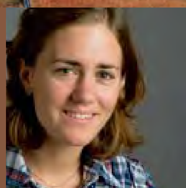
- Fluid Dynamics
- Electromagnetics
- Optimization

The research in fluid dynamics is focused on the development of methods and algorithms for multi-phase flows, free surface flows, and fluid-structure interaction. The department strives to provide an innovative software that integrates state-of-the-art research on grid-free techniques and offers unique possibilities for efficient simulation of complex industrial flow applications. The IBOFlow (Immersed Boundary Octree Flow Solver) software is tailored for applications involving moving objects interacting with the flow and sets a new standard for CFD software by avoiding the cumbersome generation of 3D volume meshes. During 2010 the efforts on simulation of paint and surface treatment processes in automotive paint shops continued and resulted in the delivery of an updated version of the IPS Virtual Paint software to our industrial partners. Another major activity was the project on simulation of papermaking and paperboard package quality (cf pages 14-17) with industrial partners Albany International, Eka Chemicals, Stora Enso and Tetra Pak, that had an excellent progress during the year.

In electromagnetics research is performed for electrostatic applications for which an in-house adaptive finite element software package is being developed and for high frequencies based on the platform developed in the GEMS project. The department collaborates with the company Efield that commercializes the GEMS software and activities during 2010 included continued work on the joint project with Lund University, within the framework of the Swedish National Aerospace Research Program (NFFP), on improved simulation software for analysis of sensors and antennas integrated on platforms.

In optimization the research is focused on simulation-based optimal design and multiple criteria optimization. This includes novel optimization algorithms, coupling of simulation and optimization software and development of decision support systems that integrate multiple criteria optimization and simulation. The main applications in 2010 were multi-objective optimization of oven curing and EEG-based localization of epileptic foci in the human brain.

The Computational Engineering and Design Research Group



Emma Bengtsson
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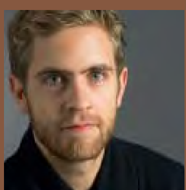

Samuel Lorin
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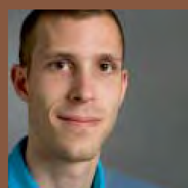

Erik Svenning
Contracted student

Systems Biology and

The application of tools and techniques, borrowed from engineering disciplines such as systems and control theory, signal processing, and computer science, for studying biological and biochemical systems has received an increasing attention over the last couple of years. This is due to a number of factors such as recent advancements in measurement technology, a need for pharmaceutical companies to find alternative strategies to beat current shortcomings in early drug development and increase competitiveness, and the improved understanding of living systems due to the sequencing of genomes and characterization of the function and role of corresponding proteins. FCC provides an integrated approach to the study of biochemical and physiological processes, from the characterization of single parts to the analysis of dynamic phenomena on a systems level. The work at the department includes both biological/biomedical modeling applications as well as development of computational tools and algorithms. The department is organized in two areas:

- Systems Biology
- Bioimaging

We are currently involved in several modeling projects, including modeling of ion-channels and action potential propagation related to atrial fibrillation, signaling pathways involved in liver cancer, and kinetic modeling of the secretion pathway for improved protein production. The modeling is carried out in close collaboration with our partners who are producing high quality experimental data from, among others, yeast *(Saccharomyces cerevisiae)*, frog oocytes *(Xenopus laevis)*, human hepatocytes, and CHO cells (chinese hamster ovary cells). The computational tools and algorithms developed at the department can be divided in four main areas: system identification, model reduction, image analysis, and software tools.

The department takes part in three EU funded projects: UniCellSys – Eukaryotic unicellular organism biology – systems biology of the control of cell growth and proliferation, CancerSys – Mathematical modeling of beta-catenin and ras signaling in liver and its impact on proliferation, tissue organization and formation of hepatocellular carcinomas, and SysInBio – Systems Biology as a Driver for Industrial Biotechnology.

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Jonas Hagmar
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Mikael Sunnåker
MSc (on leave)

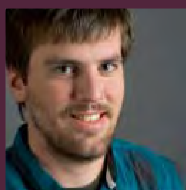
The Systems Biology and Bioimaging Research Group

Mikael Wallman
MSc (on leave)

David Wrangborg
MSc

Mats Rudemo
Professor, Mathematical Statistics Chalmers, Scientific Adviser FCC

Bioimaging



Heidar Eyjólfsson
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Shangwenyan Gong
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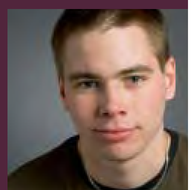

Niklas Jakobsson
Contracted student

Acknowledgement

In 2010, the Systems Biology and Bioimaging department has received funding from the Swedish Foundation for Strategic Research via Gothenburg Mathematical Modelling Centre, GMMC. Furthermore, the group has received funding for the UniCellSys, CancerSys, and SysInBio projects from the European Commission.

Cooperation

We have close collaboration with the Swedish company InNetics. Other collaborations include joint work with General Zoology at Kaiserslautern University; Bionanophotonics, Systems Biology, and Mathematical Sciences at Chalmers; Cell- and Molecular Biology at Gothenburg University; the Systems Biology Research Centre at University of Skövde; the Department of System Analysis, Prognosis and Control at Fraunhofer-ITWM; Fraunhofer-IME; Fraunhofer-FIT; and partners in the UniCellSys, CancerSys, and SysInBio EU-projects.

Atefeh Kazeroonian
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Dimitri Koch
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Sonia Kostenko
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Peidi Liu
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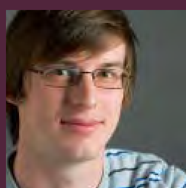

Nico Reissmann
Contracted student

Xin Zhao
Contracted student

Årsredovisning

Styrelse och ledning den 3 november 2010

Från vänster:
Uno Nävert, föreståndare FCC
Peter Jagers, ordförande, Chalmers
Dieter Prätzel-Wolters, Fraunhofer ITWM
Bo Johansson, Chalmers
Helmut Neunzert, vice ordförande, Fraunhofer ITWM
Johan Carlson, biträdande föreståndare, FCC

Styrelsen för Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik, FCC, får härmed avge följande redovisning över verksamheten under tiden 1 januari 2010 – 31 december 2010, stiftelsens nionde 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 utveckla och anpassa matematiska metoder för industrin. Stiftelsen bedriver konkurrensneutral forskning och marknadsföring med finansiering från stiftarna och offentliga finansiärer. Stiftelsen genomför projekt med företag på kommersiell grund.

Chalmers och Fraunhofersällskapet har under året beslutat fortsätta finansiera Stiftelsen med vardera 500 000 EUR per år under fem år 2011 - 2015. Fraunhofersällskapet har samtidigt uttryckt en önskan att bredda samarbetet. Stiftelsen och Chalmersfastigheter AB har under året tecknat en förlängning

Resultaträkning
100101 – 101231, (kSEK)

Intäkter	
Nettoomsättning	37 217
Summa intäkter	37 217
Kostnader	
Externa kostnader	-13 271
Personalkostnader	-23 058
Avskrivningar av materiella anläggningstillgångar	-350
Summa kostnader	-36 679
Rörelseresultat	**538**
Resultat från finansiella investeringar	
Ränteintäkter och liknande resultatposter	219
Räntekostnader och liknande resultatposter	-568
Resultat efter finansiella poster	**189**
Bokslutsdispositioner	9
Årets skatt	-112
Årets resultat	**86**

Balansräkning
101231, (kSEK)

Anläggningstillgångar	
Maskiner och inventarier	327
Summa anläggningstillgångar	327
Omsättningstillgångar	
Kundfordringar	4 268
Förutbetalda kostnader och upplupna intäkter	3 658
Övriga kortfristiga fordringar	41
Kassa och bank	7 329
Summa omsättningstillgångar	15 296
Summa tillgångar	**15 623**
Eget kapital	
Eget kapital vid årets ingång	3 081
Årets resultat	86
Summa eget kapital	3 167
Obeskattade reserver	1 180
Kortfristiga skulder	
Leverantörsskulder	4 051
Övriga kortfristiga skulder	413
Skatteskulder	116
Upplupna kostnader och förutbetalda intäkter	6 696
Summa kortfristiga skulder	11 276
Summa skulder och eget kapital	**15 623**

av nuvarande hyresavtal omfattande 1 096 kvm i Chalmers Teknikpark till och med den 31 mars 2014 .

Årets omsättning har varit drygt trettiosju miljoner kronor. Antalet anställda och studenter har motsvarat 37 heltidsekvivalenter varav fyra kvinnor, inklusive studenter i mastersprogram knappt fyra heltidsekvivalenter och industridoktorander tre heltidsekvivalenter. Under året har 25 studenter anställts till 10-20% för arbete inom projekt.

Rörelsens intäkter har uppgått till 37 217 kSEK (36 064 kSEK föregående år). Av detta utgör 25% (25%) industriprojekt, 23% (26%) offentliga projekt under industriell kontroll, 26% (21%) övriga offentliga projekt och 26% (28) finansiering från stiftarna. Årets resultat efter skatt är 86 kSEK (87 kSEK). Eget kapital uppgick den 31 december 2010 till 4 037 kSEK (3 957 kSEK) inkluderat kapitalandelen i obeskattade reserver.

Stiftelsens styrelse har under verksamhetsåret sammanträtt två gånger. Ersättning har utgått till ordföranden med 33 075 kronor och till övriga ledamöter med 16 538 kronor per person.

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

Göteborg den 16 mars 2011

Peter Jagers, ordförande
Helmut Neunzert, vice ordförande
Bo Johansson
Dieter Prätzel-Wolters

Räkenskaperna har granskats av Deloitte

Appendix

Publications

J Almquist, M Wallman, I Jacobson, M Jirstrand:
Modeling the Effect of Kv1.5 Block on the Canine Action Potential, Biophysical Journal, 99(9), pp 2726-2736, November 2010.

J Almquist, P Lang, D Prätzel-Wolters, J W Deitmer, M Jirstrand, H M Becker:
A Kinetic Model of the Monocarboxylate Transporter MCT1 and its Interaction with Carbonic Anhydrase II. J Comput Sci Syst Biol. 3(5), pp 107-116, December 2010.

B Andersson, S Jakobsson, A Mark, F Edelvik, L Davidson:
Modeling Surface Tension in SPH by Interface Reconstruction using Radial Basis Functions, In proceedings of the 5th International SPHERIC Workshop, pp 7-14, Manchester, UK, June 2010.

K Bodvard, D Wrangborg, S Tapani, K Logg, P Sliwa, A Blomberg, M Kvarnström, M Käll:
Continuous light exposure causes cumulative stress that affects the localization oscillation dynamics of the transcription factor Msn2p, Accepted for publication in Biochimica et Biophysica Acta (BBA) - Molecular Cell Research.

S Jakobsson, M Saif-Ul-Hasnain, R Rundqvist, F Edelvik, B Andersson, M Patriksson, M Ljungqvist, D Lortet, J Wallesten:
Combustion engine optimization: A multiobjective approach, Optimization and Engineering 11(4), pp 533-554, 2010.

S Jakobsson, M Patriksson, J Rudholm, A Wojciechowski:
A Method for Simulation Based Optimization Using Radial Basis Functions, Optimization and Engineering 11(4), pp 501-532, 2010.

S Jakobsson, B Andersson, F Edelvik:
Multiobjective Optimization Applied to Design of PIFA Antennas, In Scientific Computing in Electrical Engineering SCEE 2008, Mathematics in Industry, Volume 14, Part 4, pp 437-444, Springer-Verlag Berlin Heidelberg, Germany, 2010.

A Jansson, M Jirstrand:
Biochemical Modeling with Systems Biology Graphical Notation, Drug Discovery Today, 15(9-10), pp. 365-370, May 2010.

S Lorin, R Söderberg, J Carlson, F Edelvik:
Simulating Geometrical Variation in Injection Molding, Proceedings of NordDesign2010 International Conference on Methods and Tools for Product and Production Development, 8(2), pp 395-404, Gothenburg, Sweden, August 2010.

S Lorin, F Edelvik, J Carlson, R Söderberg:
Simulating Geometrical Variation in Injection Molding, In Proceedings of the NordDesign 2010 Conference, Gothenburg, Sweden, August 25-27, 2010.

A Mark, R Rundqvist, F Edelvik:
Comparison Between Different Immersed Boundary Conditions for Simulation of Complex Fluid Flows, 7th International Conference on Multiphase Flow (ICMF), Tampa, FL, USA, June 2010.

A Mark, R Rundqvist, F Edelvik:
Comparison Between Different Immersed Boundary Conditions for Simulation of Complex Fluid Flows, accepted for publication in Fluid dynamics & Materials processing, 2010.

R Rundqvist, A Mark, F Edelvik, J Carlson:
Modeling and simulation of viscoelastic fluids using Smoothed Particle Hydrodynamics, accepted for publication in Fluid Dynamics & Materials Processing, 2010.

R Rundqvist, A Mark, B Andersson, A Ålund, F Edelvik, S Tafuri, J Carlson:
Simulation of Spray Painting in Automotive Industry, In G Kreiss et al (eds), Numerical Mathematics and Advanced Applications 2009, pp 769-777, Springer-Verlag Berlin Heidelberg, 2010.

R Rundqvist, A Mark, F Edelvik, J Carlson:
Modeling and simulation of viscoelastic fluids using Smoothed Particle Hydrodynamics, 7th International Conference on Multiphase Flow (ICMF), Tampa, FL, USA, June 2010.

J Segeborn, D Segerdahl, J Carlson, A Carlsson, R Söderberg:
Load balancing of welds in multi station sheet metal assembly lines, Proceedings of the ASME 2010 International Mechanical Engineering Congress & Exposition, Vancouver, British Columbia, Canada, November 12-18, 2010.

J Segeborn, J Torstensson, J Carlson, R Söderberg:
Evaluating Genetic Algorithms that Optimize Welding Sequence with Respect to Geometrical Assembly Variation, In Proceedings of the NordDesign 2010 Conference, Gothenburg, Sweden, August 25-27, 2010

Y Shirvany, M Persson, F Edelvik, S Jakobsson, S Bergstrand, A Hedström, K Kowkabzadeh, A R Porras, H-S Lui:
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D Spensieri, R Bohlin, F Ekstedt, J Torstensson, J Carlson:
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M Sunnåker, H Schmidt, M Jirstrand, G Cedersund:
Zooming of states and parameters using a lumping approach including back-translation, BMC Systems Biology, 4:28, March 2010.

K Wärmefjord, J Carlson, R Söderberg:
An investigation of the effect of sample size on geometrical inspection point reduction using cluster analysis, CIRP Journal of Manufacturing Science and Technology, pp 227–235, No. 3, 2010.

K Wärmefjord, R Söderberg, J Carlson:
Including Assembly Fixture Repeatability in Rigid and Non-Rigid Variation Simulation, Proceedings of the ASME 2010 International Mechanical Engineering Congress & Exposition, Vancouver, British Columbia, Canada, November 12-18, 2010.

Theses

K Hahn:
Analytical Modelling of Aggregate Stiffness Parameters for Helically Bundled Cables, Master thesis, Chalmers, supervisor T Hermansson, examiner I Rychlik, June 2010.

Presentations/Posters/Conferences

B Andersson:
Modeling Surface Tension in SPH by Interface Reconstruction using Radial Basis Functions, 5th International SPHERIC Workshop, Manchester, UK, June 2010.

B Andersson:
Breakup of Droplets in Spray Painting, invited seminar at Department of Physics, University of Gothenburg, December 2010.

R Bohlin:
Path Planning Software and Advanced Simulation, Guest lecture, Robotics and Robot Systems, Department of Product and Production Development, April 2010.

S Björkenstam, R Bohlin, J Carlson, K Engström, T Hermansson, J Segeborn, D Segerdahl, D Spensieri, S Tafuri:
Wingquist Laboratory Annual Seminar on Virtual Product Realization, Chalmers, Gothenburg, December 2010.

J Carlson:
Production Engineering Research, Presentation, MERA and FFI Sustainable Manufacturing, Scania, Södertälje, April 2010.

F Edelvik:
Virtual Paint Factory – Modeling and Simulation of Spray Painting in Automotive Paint shops, BIT 50 – Trends in numerical mathematics, Lund, June 2010.

F Edelvik:
Elektromagnetiska beräkningar vid FCC, Guest Lecture for Engineering Physics Program, Chalmers, October 2010.

M Jirstrand:
Dynamic Models for Biological and Biomedical Applications, Chalmers Initiative Seminar on Scientific Models, Chalmers, September 2010.

M Jirstrand:
Physiologically Based PK/PD Simulation and Nonlinear Mixed Effects Modeling – A Personalized Medicine Perspective, Fraunhofer-ITWM Workshop on Mathematik für Personalisierte Medizin, Kaiserslautern, June 2010.

M Jirstrand:
In Silico Simulation of Fibrillation in Canine Atrial Tissue Using Detailed Ion-channel Models Including Drug Interaction Effects, International Congress of Electrocardiology, Lund, June 2010.

M Jirstrand:
Modeling and Simulation of Dynamical Systems - Biological and Biomedical Applications, Invited seminar at AstraZeneca R&D Mölndal, December 2010.

A Mark:
Comparison Between Different Immersed Boundary Conditions for Simulation of Complex Fluid Flows, 7th International Conference on Multiphase Flow (ICMF), Tampa, FL, USA, June 2010.

FCC staff on December 22, 2010

R Rundqvist:
Modeling and simulation of viscoelastic fluids using Smoothed Particle Hydrodynamics, 7th International Conference on Multiphase Flow (ICMF), Tampa, FL, USA, June 2010.

R Rundqvist:
Industriell applikation av tätmassor på bilkarosser - experiment och simulering av ett tixotropt flerfasproblem, Siamuf seminar, Stockholm, June 2010.

J Segeborn:
Load balancing of welds in multi station sheet metal assembly lines, Proceedings of the ASME 2010 International Mechanical Engineering Congress & Exposition, Vancouver, British Columbia, Canada, November 12-18, 2010.

J Segeborn:
Evaluating Genetic Algorithms that Optimize Welding Sequence with Respect to Geometrical Assembly Variation, In Proceedings of the NordDesign 2010 Conference, Gothenburg, Sweden, August 25-27, 2010.

D Spensieri:
Throughput Maximization by Balancing, Sequencing and Coordinating Motions of Operations in Multi-Robot Stations, In Proceedings of the NordDesign 2010 Conference, Gothenburg, Sweden, August 25-27, 2010.

Other assignments

J Carlson:

Member of the Governance Board of the School of Engineering at Blekinge Institute of Technology, Karlskrona, Sweden.

J Carlson:

Member of the board of Wingquist Laboratory at Chalmers University of Technology.

F Edelvik:

Reviewer for IEEE Transactions on Antennas and Propagation.

S Jakobsson:

Reviewer for Zentralblatt.

M Jirstrand:

Member of the PhD-thesis committee for Elzbieta Petelenz-Kurdziel, From cell populations to single cells – quantitative analysis of osmotic regulation in yeast, Gothenburg University, September 27, 2010.

U Nävert

Chairman of the Steering group of CheSC, Chalmers e-Science Centre, http://www.chalmers.se/rss/e-science-en/

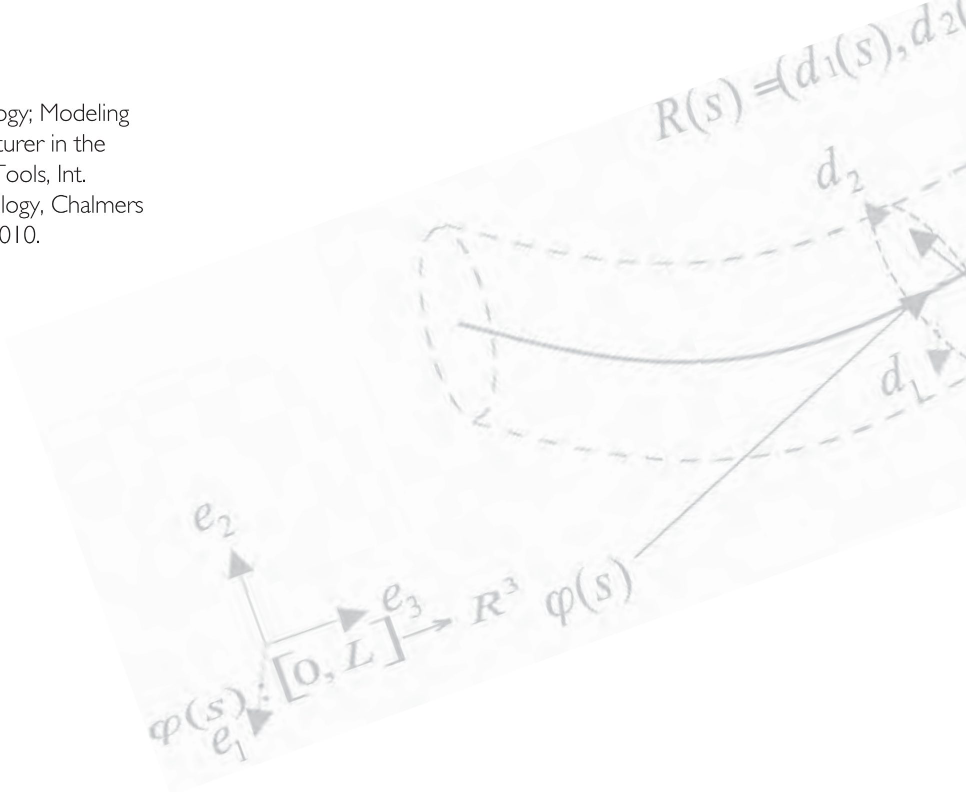
U Nävert

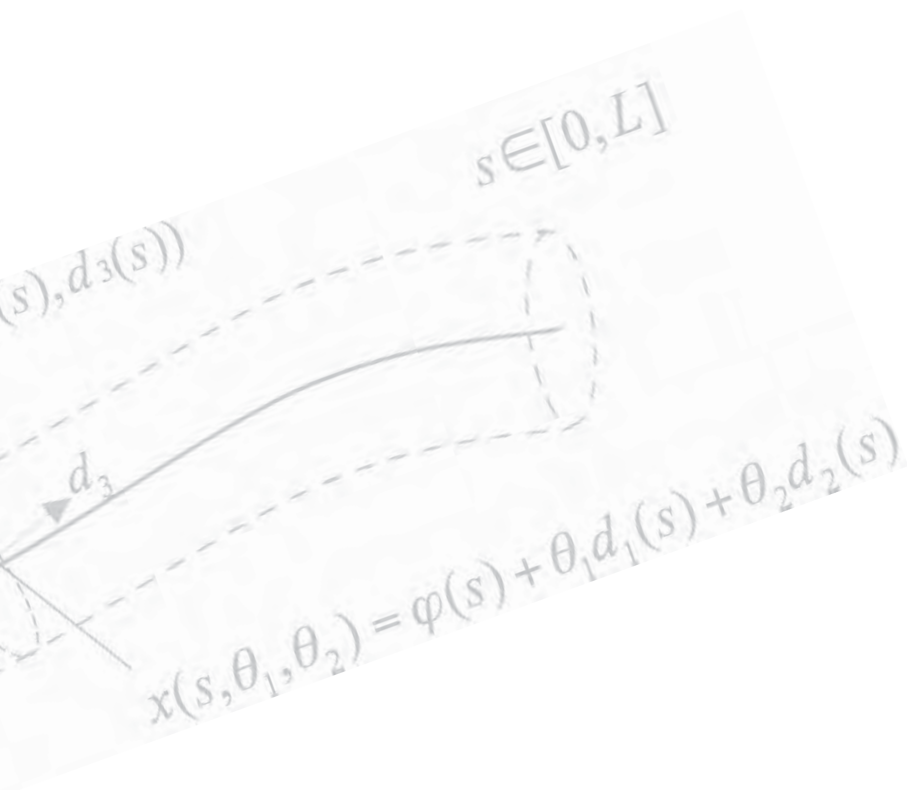
Member of the Board of SNIC, Swedish National Infrastructure for Computing, http://www.snic.vr.se/

Courses

M Jirstrand:

Systems Theory in the Toolbox for Systems Biology; Modeling Tools, PathwayLab Tutorial and Mathematica, co-lecturer in the course Mathematical Modelling and Computational Tools, Int. Master's Program for Bioinformatics and Systems Biology, Chalmers University of Technology, Gothenburg, November 2010.




s∈[0,L]
(s),d3(s))
d3
x(s,θ1,θ2) = φ(s) + θ1d1(s) + θ2d2(s)

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