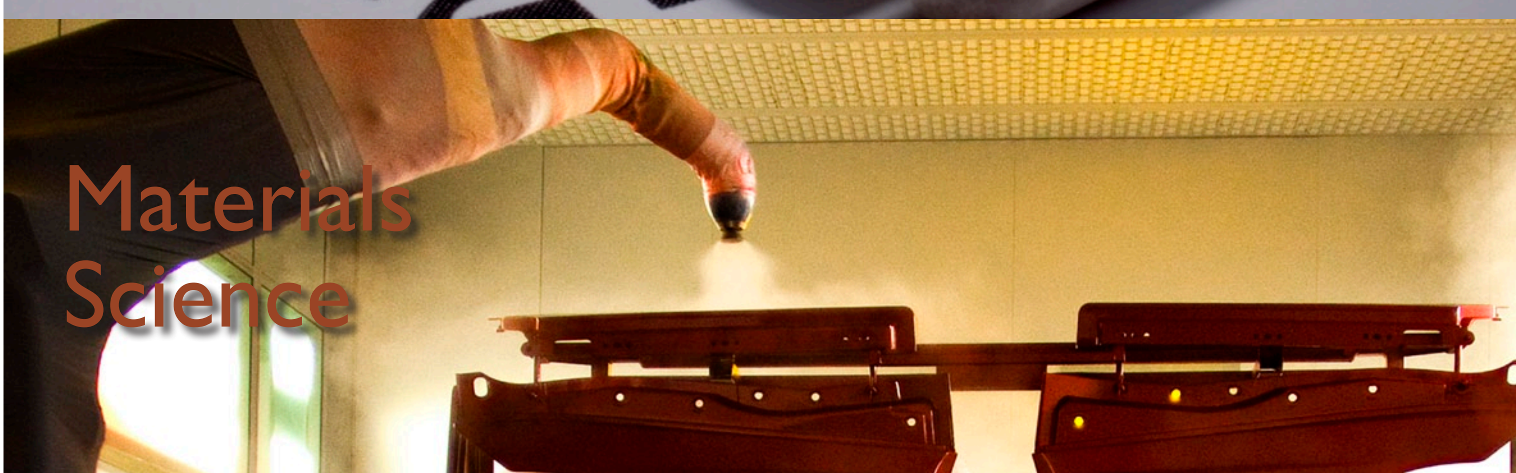
ITWM

Fraunhofer

CHALMERS
Research Centre
Industrial Mathematics

Annual Report 2012



This and other FCC reports are distributed by:
FCC
Chalmers Science Park
SE-412 88 Gothenburg
Sweden

Phone: +46 (0)31 772 40 00
Fax: +46 (0)31 772 42 60
info@fcc.chalmers.se
www.fcc.chalmers.se

© Fraunhofer-Chalmers Research Centre for Industrial Mathematics, FCC

All rights reserved.
No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from FCC.

Cover
Areas of Advance and industrial applications

Annual Report 2012
Fraunhofer-Chalmers Research Centre for Industrial Mathematics, FCC
Editors: Uno Nävert, Annika Eriksson
Layout: DekoFunk AB
Print: www.lindgren-soner.se
Published in March 2013

Contents

Preface and Profile

FCC has since start 2001 completed more than two hundred fifty industrial and public projects. We have successfully cooperated with more than hundred 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 2011 and 2012 the German Bund-Länder-Kommission and the Bundestag Haushaltsausschuss decided to give clearance for permanent institutional funding. After this, the founders have agreed on a timetable to identify and remove possible obstacles preventing widening the scope of the cooperation. The founders have expressed their conviction that this intensification of their cooperation will be to the benefit of themselves and to research and education in their countries and Europe.

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. In my opinion the year 2012 was again a successful one, in spite of a five per cent drop in total income, since the industrial income increased by thirty per cent. This brings us back to a relative industrial income close to forty per cent, which is our guideline value for a balanced financial mix. We had a small positive net result, as has been the case since start.

Together with our partners Chalmers and the Fraunhofer industrial mathematics institute ITWM we cover a wide range of applications. In 2012 our cooperation included joint actions with four ITWM departments and with several Chalmers centres and departments: Wingquist Laboratory, Systems and Synthetic Biology, Fluid Dynamics, Biomedical Engineering, Mathematical Sciences, and Chalmers e-Science Centre CheSC. We have also growing cooperations with several other Fraunhofer units.

Together with our partners we 2012 formed independent spin-offs Industrial Path Solutions AB and fleXstructures GmbH. We have signed contracts with these companies to secure focused professional marketing, maintenance, support, and adaptation of software developed by FCC and ITWM, to satisfy client demands. This structure gives exciting career and ownership opportunities to our staff members.

Our industrial clients are mainly from Sweden. We also have international clients from Europe, United States, and Japan. In 2012 we strengthened our links to the newly established Swedish – Brazilian Research and Innovation Association CISB with its Centre in São Bernardo do Campo, State of São Paulo.

The European Science Foundation has conducted a Forward Look on Mathematics and Industry. One outcome of this study is the volume "European Success Stories in Industrial Mathematics", Springer 2012, where FCC contributes with three projects in automotive, pharmaceuticals and transport.

In 2012 we were fortunate to recruit nine new co-workers. 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 a step further. Four of our currently employed MScs take PhD studies at Chalmers in this way.

Four years ago we initiated a campaign to offer an interesting option to Chalmers Master's students while boosting our base for future recruitments. We invite students from a handful of Chalmers and Gothenburg University international programmes with a mathematical profile to information meetings "Earn Money with 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 at the Centre, and to do Master's thesis projects at the Centre with joint supervision from Chalmers and FCC. In 2012 we had seventeen Master's students working on this type of contract and nine Master's students doing their thesis projects at the Centre.

In September 2012 Chalmers started the two-year licentiate programme "Advanced Engineering Mathematics" together with FCC. The programme is open to students holding an MSc degree with a strong mathematical profile. In the first announcement three students were accepted and employed by FCC for one year of courses and teaching at Chalmers Mathematical Sciences and one project year at the Centre.

I thank my co-workers 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 thirty million euros including more than ten million euros industrial income and performed four hundred full-time equivalents work. This is now my last report and I take the opportunity to thank you all for a great time and great achievements – it has been an honour and a privilege to work with you. I wish you all the best for the future and I warmly congratulate my successor Dr Johan Carlson to his new, exciting position!

Below we give a flavour of our activities through describing three profile projects. We also present our competences organized in three departments. Enjoy your reading!

Gothenburg in March 2013

Uno Nävert. Director

Photo: Jan-Olof Yxell

The department Geometry and Motion Planning, working in close cooperation with the Chalmers Wingquist Laboratory, participates in the ten-year Wingquist Laboratory VINN Excellence Centre for Virtual Product Realization 2007 – 2016. In 2012 the department continued and extended several public projects, e.g., on automatic path-planning and line-balancing, sealing, virtual paint, flexible materials, co-ordinate 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. In 2012 this cooperation generated two spin-off companies: Industrial Path Solutions AB and fleXstructures GmbH

The department Computational Engineering and Design has continued and expanded its work on novel numerical methods and simulation tools for applications in fluid dynamics, structural dynamics and electromagnetics. The department collaborates with the ITWM departments Optimization, Flow and Material Simulation, and Mathematical Methods in Dynamics and Durability, and runs several multi-physics projects involving fluid-structure and fluid-electromagnetics interaction including the six-year project on innovative simulation of paper with Swedish paper and packaging industry. The department addresses medical technology in a project on epilepsy focus localization with Chalmers S2 and Sahlgrenska University Hospital. The department is a key partner in the project on virtual paint mentioned above.

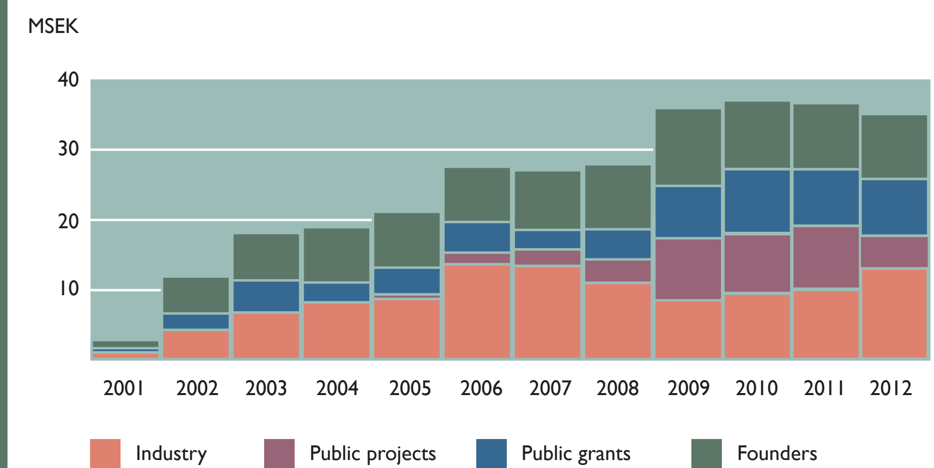
The department Systems and Data Analysis offers competence in dynamic systems, prediction and control, image and video analysis, mathematical statistics, and quality engineering. In 2012 the department has continued its activities in systems biology as partner in several EU projects and through cooperation with the ITWM department System Analysis, Prognosis and Control. Work on interactive pharmacokinetics and pharmacodynamics has resulted in the software Maxsim2 for pharmaceutical industry and the department runs a three-year industrial project on specific applications in this area. Another industrial project to be emphasised is on modelling and analysis of multi-axial stochastic loads for cultivators together with expertise from Chalmers Mathematical Sciences.

Facts and Figures

Total income

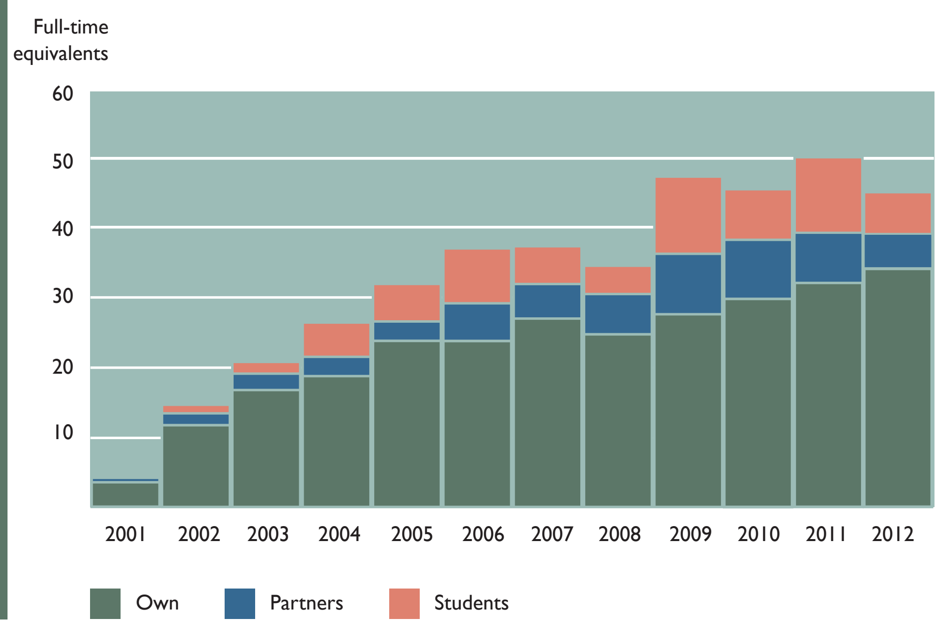
The total income 2012 was slightly more than four million euros and slightly more than thirty-five million Swedish crowns. The result was a small positive net, as has been the case every year since our start in 2001.

The profile of the Centre is controlled by its income structure, in 2012 thirty-eight per cent from each of industrial projects and public projects, and twenty-four per cent basic funding from the founders. The public funding includes fourteen per cent from public projects under industrial command and twenty-four per cent from public grants. Compared to the previous year we had a significant increase of industrial projects and a significant decrease of public projects under industrial command. The last two years show a decrease of basic funding due to the stronger Swedish crown relative to the euro.



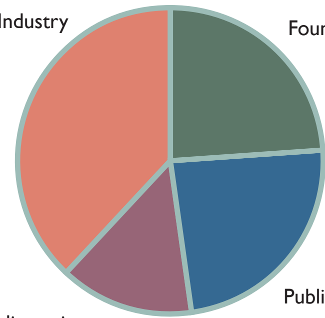
Staff – full-time equivalents

The number of staff 2012 was 45 full-time equivalents (FTE) including own staff (34 FTE), students (6 FTE), and partners (5 FTE). We were happy to recruit nine new co-workers, five of which were previously contracted students. The number of Master's students was 26 including three female students: 9 doing their Master's thesis projects (3 FTE) and 17 students in Master's programmes contracted on 10-20% for project work (2 FTE). Three own staff-members are in the Chalmers two-year licentiate programme "Advanced Engineering Mathematics" starting the 1st September 2012.



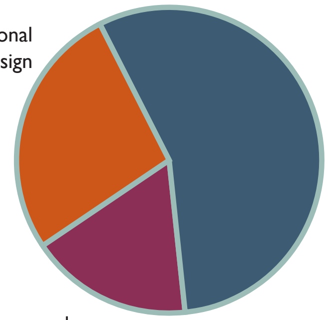
Project mix by income 2012

The profile of the Centre is controlled by its income structure. We distinguish between four categories: industrial projects, public projects (under industrial command), public grants, and basic funding. In 2012 these four were in good balance showing a clear industrial profile:
industry (38%),
public projects (14%),
public grants (24%),
and Fraunhofer and Chalmers (24%).



Departments by income 2012

The Centre has three departments. Their relative income was 56%, 27%, and 17% of the grand total including 9% transfer projects between departments.



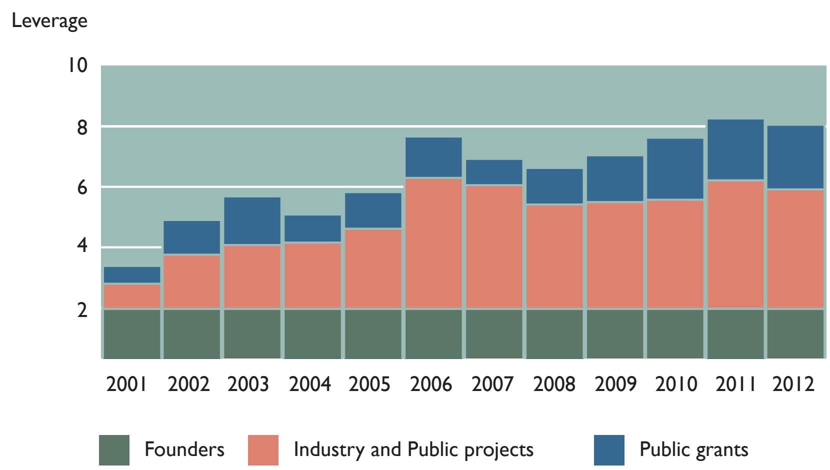
Fraunhofer ITWM and Chalmers exchange on basic funding

The basic funding to FCC is equally shared between Fraunhofer and Chalmers, in 2012 being 0.5 million euros from each founder.

The turnover is eight times the basic funding from each founder. This includes income from industrial projects and public projects under industrial command equal to four times the Fraunhofer or Chalmers basic funding.

The exchange also includes technology and joint industrial projects with ITWM and public projects and grants with Chalmers.

The Centre works to promote the brand name "Mathematics" and has substantial cooperation with the Areas of Advance "Production" and "Life Science Engineering". The Centre contributes to the Campus Johanneberg environment, where we operate with thirty-five staff members and twenty-five students in Chalmers Science Park.

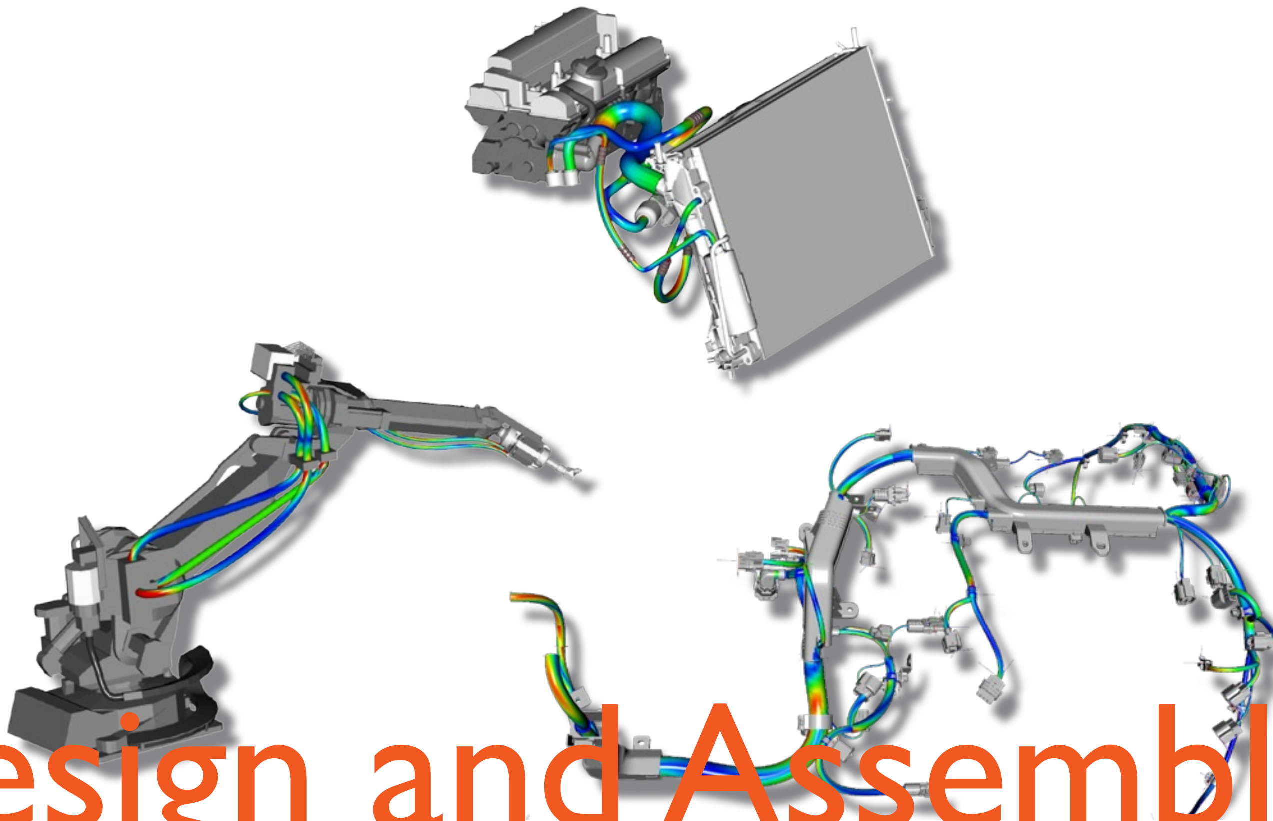


Central services

Jenny Ekenberg, MSc
Economy and IT

Annika Eriksson
Administration and Personnel

Jacqueline Rudeke
Assistant



Design and Assembly

Environmental friendly propulsion systems based on electricity and battery technology has resulted in a dramatically increased usage of complex cables and hoses in the vehicles. For virtual product realization this means new and fundamental demands on the simulation to support design, assembly and maintenance activities.

FCC has together with the dynamics and durability department at Fraunhofer-ITWM, Wingquist Laboratory at Chalmers, Saab Automobile, Volvo Cars, Opel, GM, Ford Motor Company, AB Volvo, and Delphi developed methods and algorithms packaged in the IPS software tool for accurate real time simulation of cables and hoses. More than 100 engineers are already using the software at these companies

Copyright: Volvo Car Corporation

Analysis of Flexibles

The manufacturing industry is facing considerable changes in field of engineering as a result of intensified activities to find more environmental friendly solutions. New environmental requirements, regulations and new customer demands aiming at a sustainable society have a huge impact on future products and product realization. The highly competitive automotive industry is in many aspects at the frontline when it comes to utilizing digital tools in the whole chain from design through production, maintenance and service. Vehicles of tomorrow are based on more environmental friendly propulsion systems, e.g. will use electricity and battery technology in a higher degree than before and this will result in a dramatically increased usage of complex cables and hoses. But also the challenges on low fuel consumption and CO2-levels will remain and drive development towards lighter vehicles with light weight components. For example, metal parts when possible are replaced with polymer parts. Polymers in general are used in a wide variety of industrial applications and products due to low density, relative strength and form flexibility. All together these trends create challenges during design, verification and production. For virtual product realization this means new and fundamental demands on the simulation capability of flexible structures and new materials.

Today, many assembly problems that are detected too late in the product and production realization, involve cables, hoses and wiring harnesses. Studies in the automotive industry shows approximately 25% of all quality problems are related to flexible parts and connecting tasks. For example, the assembly of high voltages cables and harnesses are tricky due to its concealed routing, connections, weight and awkward ergonomic postures. Many of the working related injuries are caused by this type of assembly tasks. Furthermore the product quality output is to a large extent dependent on the design for assembly. One major reason for these problems has been the lack of virtual manufacturing tools supporting real time simulation of flexible parts and motions.

Software and Simulation Technology

IPS Cable Simulation is a user-friendly, innovative tool for virtual assembly design as well as the verification and visualization of flexible parts. Its main capability is the real time calculation of the deformations of cables, hoses and wires of various material types and a variety of cross-section profiles. Forces and moments can be analyzed, the cable length can be optimized, clips can be attached, and motions can be evaluated.

The material properties include:

- Stretching stiffness
- Stiffness for bending around different axis
- Torsion stiffness
- Length density

The core cable simulation technology is based on 7 years of validated research at the geometry and motion planning group at FCC and the dynamics and durability group at Fraunhofer ITWM.

From the viewpoint of structural mechanics it is clear that the goal to perform realistic and physically correct simulations of the deformation behaviour of slender flexible structures could only be achieved by using so called »geometrically exact« rod models. Such models constitute a specialized topic in geometrically nonlinear structural mechanics. The numerical method proposed and used almost exclusively throughout the published literature in computational mechanics to perform simulations of such rod models are nonlinear finite elements, which are technically rather complicated and designed for higher-order simulation accuracy, not for interactive applications.

Therefore, the challenge has been to develop an alternative approach to discretizing geometrically exact rod models, which retains the necessary physical accuracy even on very coarse grids. We have shown that it is possible to resolve the conflict in between these competing requirements by innovative mathematical techniques, being non-standard in computational mechanics, in combination with numerical procedures specifically tuned to the application problem.

The discrete simulation models for 1D and 2D flexible structures developed are based on geometric finite difference type discretization of nonlinear Cosserat structural models for rods and shells and have been thoroughly validated against standard benchmark tests available from the literature and simulations using the Abaqus software package. Several companies using IPS Cable Simulation have validated the simulation results against physical measurement. Typically, such validations are done by optical 3D measurements of wiring harnesses followed by a comparison the spatial deviation with a simulated species.

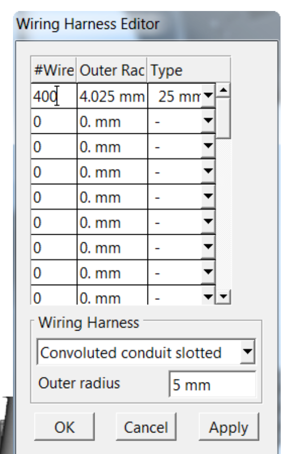
Investigations by Opel, GM, Ford and Delphi point out this technology as a global very competitive solution.

Industrial Applications and Needs

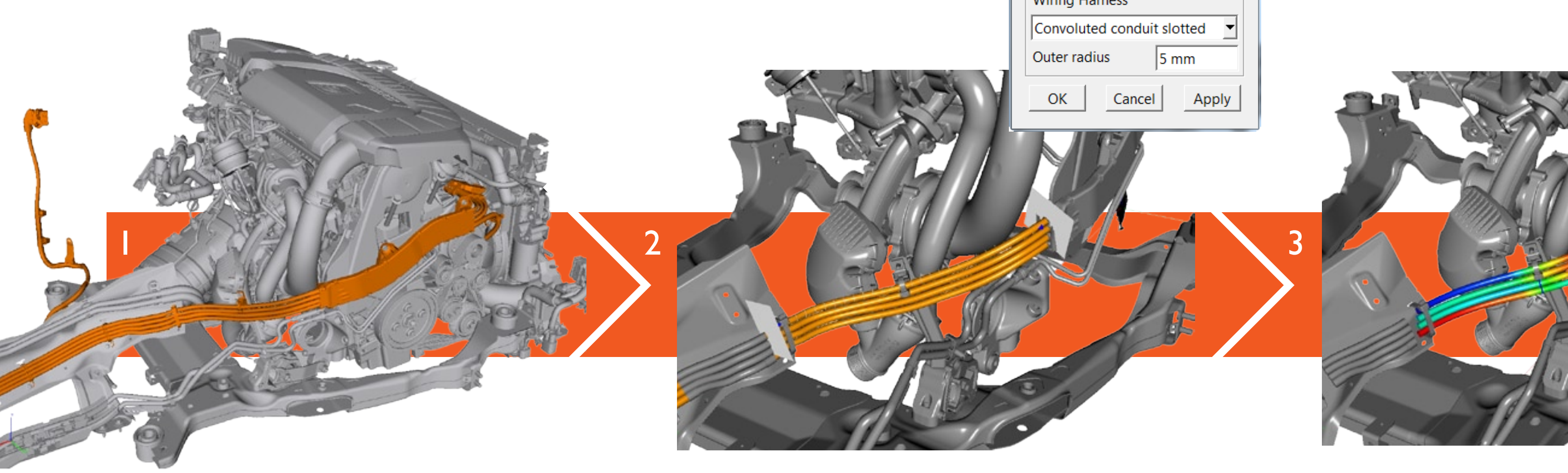
We will cover four important application areas:

- Engine packing and design
- Assembly planning
- Wiring harness design and manufacturing
- Robot cable dress packs.

The benefits from real time simulation of flexible parts is highlighted and the specific need for each application are pointed out.



V60 D6 AWD Plugin-Hybrid High voltage cable simulation



Import geometry
Import the cable and engine geometries from a CAD system

Cable design
Define material parameters and extract the cable design from the geometry

- cross section profile
- initial shape / predeformation

Connect and visualize
Add or modify cable clips and connect them to other cables or rigid objects. Visualize strains and forces with color coding or add them as value measures.

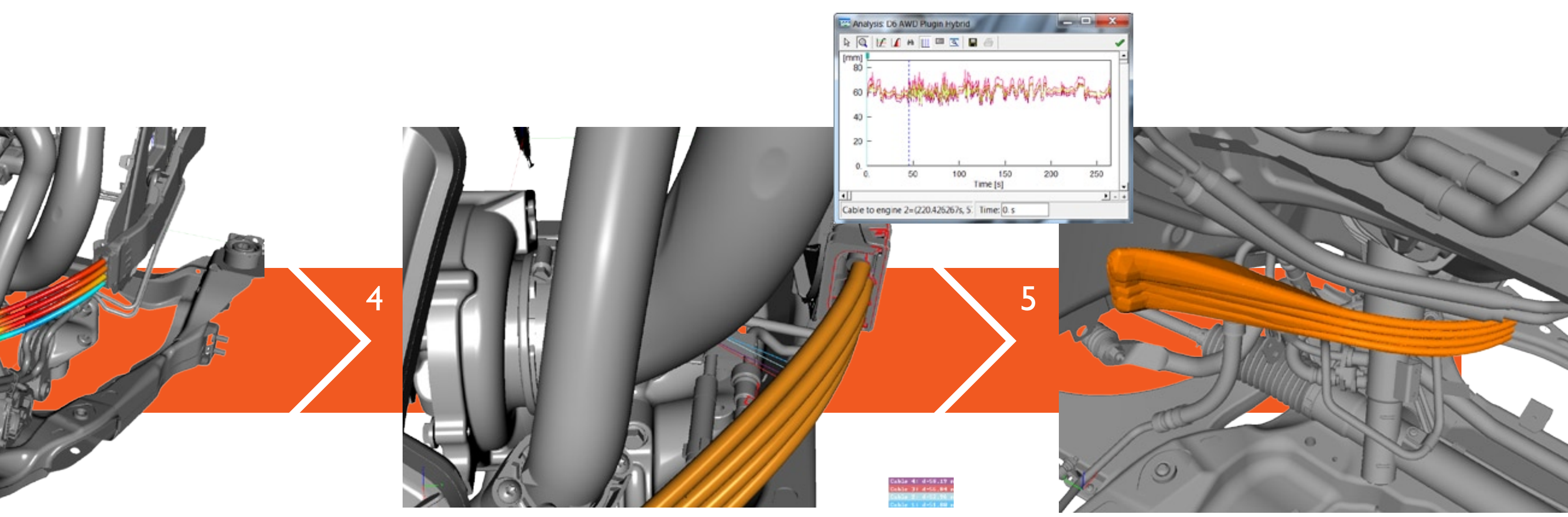
Engine packing and design

Geometrical packing and design of flexible parts such as cooling hoses and pipes, electrical cables and wiring harnesses is one of the most challenging (i.e. time consuming) and critical processes during the product realization of new propulsion systems. The connector positions, routings and dimensions of the flexible parts need to be determined with respect to space, weight, efficiency, life length, quality, and assembly solutions.

The department Platform Packaging at Volvo Cars in Göteborg has for several years used our technology to simulate flexible cables and hoses components in the engine compartment of the vehicle, see Figure 1. This is because the engine compartment of a car consists of a large amount of components relatively closely positioned to each other in order to save space. As a vehicle is moving, different components are moving relative to each other. This causes issues during the design of the components. The product development engineers must in these cases be able to predict how the components are going to move while the vehicle is moving, to ensure that collisions between the components are avoided. This problem is currently highlighted for flexible cable components since the moving pattern of these components is strongly affected by numerous parameters, which means that their behaviour before using IPS was very difficult and sometimes impossible to predict without physical testing. The purpose of the packaging department is to analyze and ensure that different components in the engine compartment are not colliding or wearing on each other, which could lead to damages and breaks. This is done by performing packaging studies where optimal positioning of the engine compartment's components is strived for and by suggesting technical solutions.

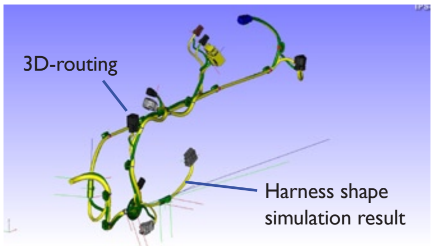
The software IPS is used to perform the kind of distance analysis (see Figure 4), in other words simulation, analysis and documentation of the critical distance, which today is considered to be the main form of analysis for the packaging department. The simulation capabilities lead to new possibilities, such as better descriptions of the flexible cable components, reduced amount of time to build up the simulation and perform the analysis, and new documentation possibilities such as movies and analysis graphs. Except for the traditional distance analysis, it is for example possible to analyze tensions, torques, forces, and deformations of length and bending radiuses, see Figure 3. Restriction volumes of the flexible cable geometries during motion can be used to position closely located geometries see Figure 5.

There is also a need to consider the effects of tolerances and manufacturing variation during design. Variation in design parameters such as material stiffness, density, clip positions can drastically affect the shape of the flexible components and hence the packing analysis. Also the ideas of robust design, to minimize the effect of variation, should be applied. Therefore, methods for representing and evaluating the effect of variation in flexible parts are highly motivated.

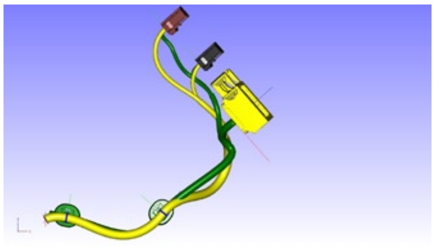


Import and analyze typical motions
Import an engine motion and monitor critical value measures.

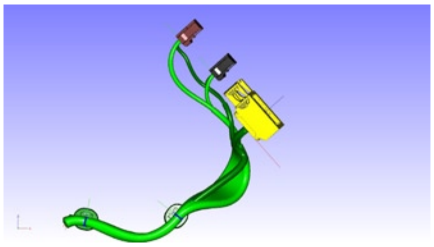
Feedback
Analysis of typical motions might suggest a different clip design or cable design to avoid extreme strains of the cable or contact with the surrounding.



Harness shape simulation and comparison with 3D-routing



Deviation between 3D-routing and physical 3D-routing



Calculated installation space with tolerances

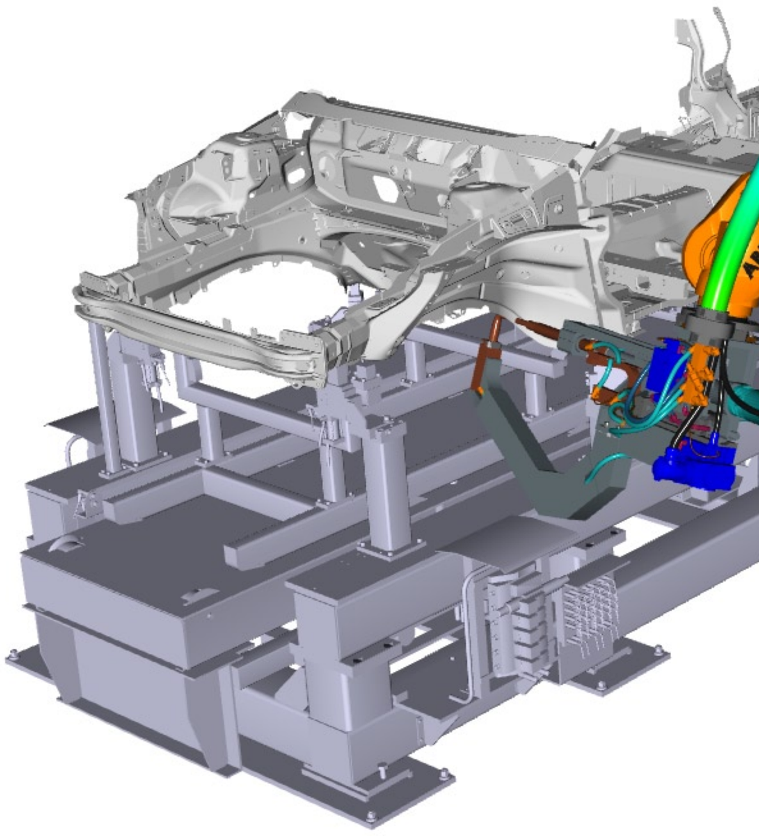
Wiring harness manufacturing and design

Wiring harnesses (w/h) connect the electrical and electronic devices of vehicles. Such devices are for example alternator, battery, electrical centers, electronic control units, electrical motors, lighting and heating units, as well as entertainment and navigation devices. Both electrical energy and electrical signals are transported by w/h. In order to ensure the reliable electrical function of w/h an according mechanical realization is necessary. Although a w/h is on the first sight not a very spectacular product it is of high technical complexity which differs in its properties significantly from rigid parts in vehicles. W/h consist of a high number of loosely connected flexible parts (wires of different cross section and structure, tapes, conduits, tubes), have a lot of flexible branches and are relatively loosely fixed in vehicles by e.g. clips, connectors, and cable channels. Manufacturing of w/h is mainly based on manual production processes which lead to higher dimensional and physical tolerances than in rigid parts of vehicles. Another effect of the manual production processes is that the design of w/h can be easily changed during the vehicle development phase. This means, that w/h are flexible in both its physical properties and its design status.

Changes in the vehicle design can technically be relatively easily considered in w/h design – but such changes require a high effort. Furthermore, the effects of such changes on the mechanical behavior of w/h can be checked only very late in the design process. Verifying w/h designs can with today means only be done very late of the design process and close to start of production. The situation becomes even more complex due to the high number of variants of w/h per car line. A full assembly test of all w/h variants is extremely time-consuming.

In today's w/h development process the 3D-routing of w/h is done using CAD- programs which allow reserving installation spaces for w/h by pure geometrical objects in 3D-CAD-models of vehicles. In addition to the geometrical 3D-routing, information which can be summarized in w/h drawings with all the structural w/h information is created. Based on this data, manufacturing planning for w/h is done requiring build of several prototypes. These prototypes are also used for checking if w/h fit into vehicles, how they can be assembled into vehicle, and how they behave during vehicle operation.

In order to do these checks in earlier design phases an according numerical simulation program is necessary which allows to do 3D-routing with consideration of physical w/h properties. This could significantly reduce the total effort in w/h design and manufacturing planning. Results from physical 3D-routing could also be used for performing investigations of w/h assembly into vehicles.



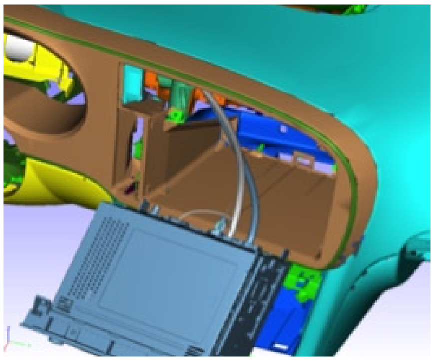


Figure 6:
Radio assembly, cable length analysis

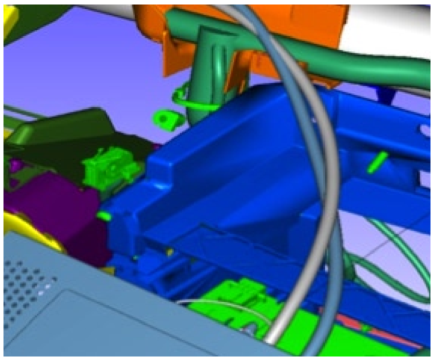


Figure 7: Collision and contact analysis. Is there any risk or obstacle? Is fixation needed (clips)

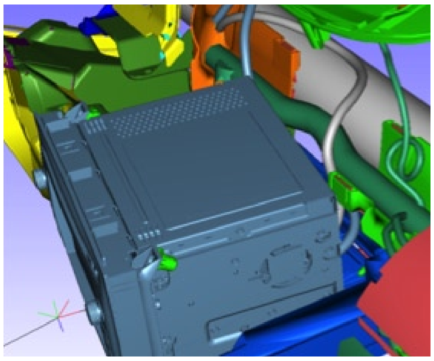
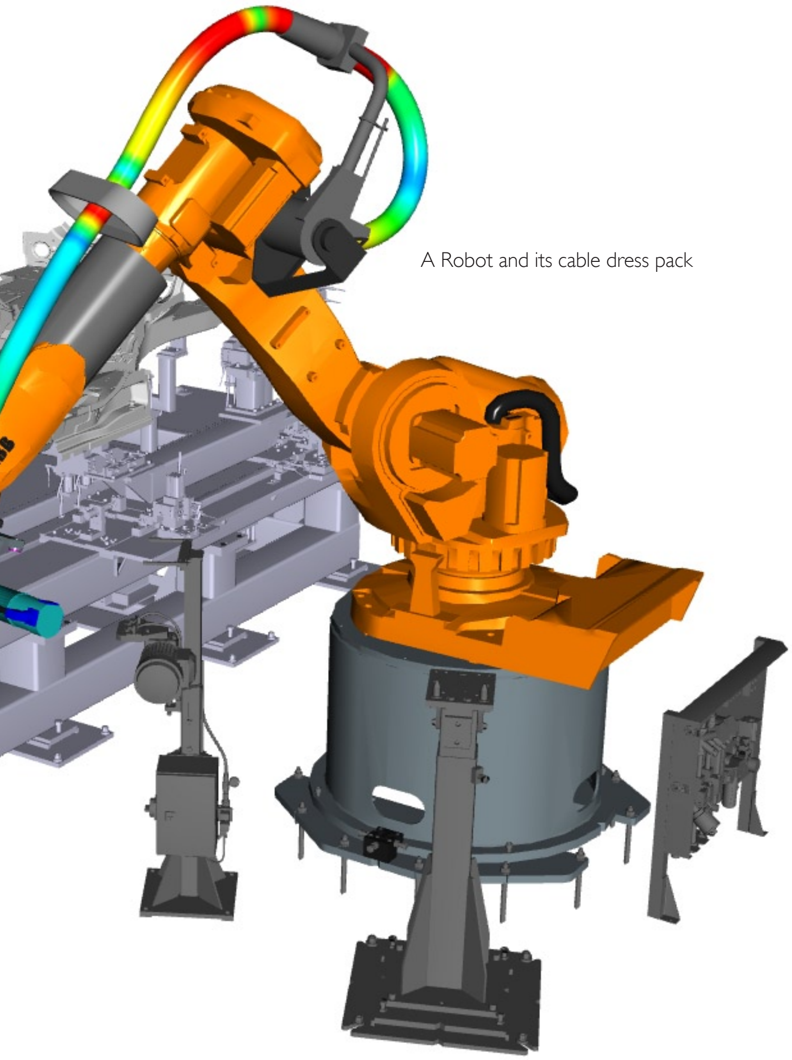


Figure 8: Assembled position. Pinch or rub risk?

Assembly Planning

To be able to simulate how cables and hoses will fulfill assembly demands already in the beginning of a project has never before IPS been possible; instead experience and assumptions have been used. This has lead to high costs for late changes which negatively have affected the production start and resulted in less qualitative solutions.

This example shows the assembly of a radio unit where it is necessary to determine whether the intended length of the cable is enough, whether it is optimal and whether there is enough space for contacting, see Figure 6. When the radio after contacting is placed in its final position, it is important to see if there is a risk for the cable to hook into something or whether there are some other obstacles. If that is the case, then fixation of the cable with help of clips could be necessary. If clips are required, then an attempt of finding the optimal positions can be performed, see Figure 7. When the radio part is in place, one wants to know if there are any risks of pinching or rubbing, see Figure 8. The software IPS have provided the possibility to simulate the assembly process in real-time, from contacting to assembled position, and to perform the analyses which earlier have been done on expensive prototypes all too late in the projects. The possibility to do it correctly from the beginning and avoid late compromising solutions is considered as a huge progress within the preparation functions and takes the virtual preparation to a whole different level.



A Robot and its cable dress pack

Robot cable dress packs

Many industrial robots are dressed with cables and hoses feeding the tool with signals, current, pressurized air, screws, paint and sealing material etc, see Figure 7. These hoses and cables have serious impact on the allowed robot configurations and motions in a robot station. The reason is the risk of breakage due to high stresses and wear. For example, a robot hose in the body shop cycles through the same motion every, say, minute. The hoses are probably affected by large deformations and strain stresses and sometimes contacts with the robot links and in worst case with the surrounding geometries see Figure 8. This type of breakdown of robot cables is a big concern in the factory creating cost and down time. A factory study showed that many robots wear out more than one cable package per year. The life length variation was shown considerable, ranging from months to years. Considering that a Body-in-White process involves something like 500 robots shows the potential of improvements in the life length of robot cables. Today, the robot manufacturers provide rules of thumbs on how to avoid high stresses, and collisions are removed by experience and on-line adjustments. However, the progress in real time simulation of cables makes it possible to determine how robot cables are deformed during the robot motions. This together with technology for automatic path planning and line balancing will in the future enable strategies for finding feasible robot configurations and motions with respect to equipment utilization/cycle time and life length of cables.

Interactive Pharr

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.

macokinetics and Pharmacodynamics

The aim of the Maxim2 project is to develop a software platform for simulation of the temporal behavior in pharmacological, pharmacodynamic, and pharmacokinetic processes. Pharmacokinetic models considered are so called compartment models as well as physiological flow models. Compartment models ranges from simple one compartment models with linear or nonlinear elimination to highly nonlinear target mediated drug disposition models whose qualitative behavior dramatically changes with dosage. This model type finds its application for example in studying biological compounds, where both target-receptor saturation and target-receptor complex elimination play important roles.

In physiological flow models or physiologically based pharmacokinetic models 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.

The resulting software, developed within the Maxsim2 project is an easy to use, intuitive, and interactive application for pharmacokinetic and pharmacodynamic simulation. A gallery of common pharmacokinetic and pharmacodynamic models is provided by which one interacts with the model and runs simulations using sliders, check boxes, and number fields. Parameters such as volumes, clearance, partition coefficients, pharmacodynamic parameters, and parameters related to absorption and dosage regimens can be changed, which in real time is mirrored by changes of concentration-time or response-time profiles. This interactivity and direct feedback of what-if scenarios give a good understanding of both the qualitative and quantitative impact of different parameters; 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.

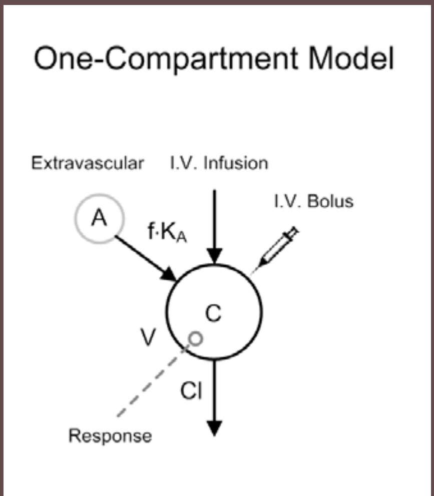
The pharmacodynamic models available in Maxsim2 are both instantaneous concentration-response models and indirect concentration-response models also known as turnover models. The indirect models include both inhibition and stimulation of build-up and loss, respectively. The instantaneous models feature 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" self-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. The targeted audience is professionals having working knowledge in pharmacokinetics and pharmacodynamics but limited or no experience in simulating such processes as well as students who want to gain experience in pharmacology from a systems perspective. For more information please visit www.maxsim2.com.

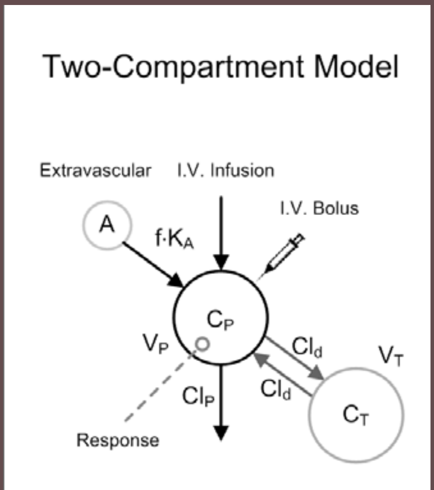
The software Maxsim2 has been developed in close collaboration with Prof. Johan Gabrielsson, the Swedish University of Agricultural Sciences, a world leading authority in the field of pharmacokinetic and pharmacodynamic data analysis.

One-compartment model with three possible types of administration and linear or nonlinear elimination.



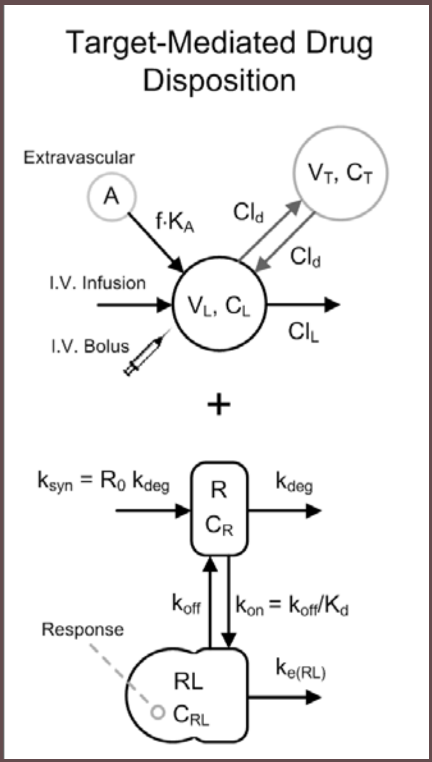
$$V\frac{dC(t)}{dt} = In(t) - Cl \cdot C(t)$$

Two-compartment model with three possible types of administration and linear or nonlinear elimination.

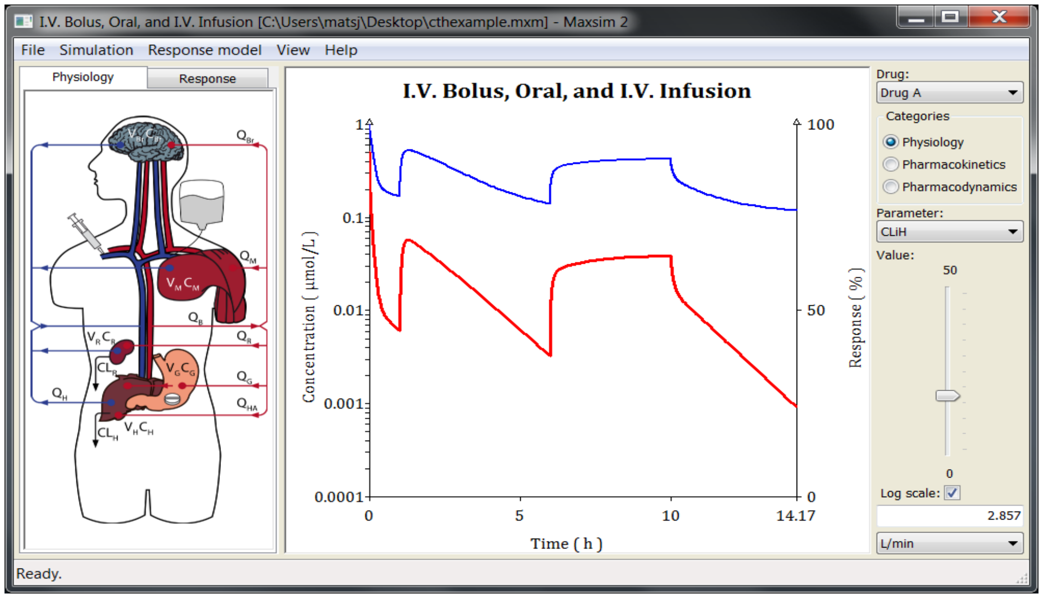


$$V_P\frac{dC_P(t)}{dt} = In(t) - Cl_P C_P(t) + Cl_d C_T(t) - Cl_d C_P(t)$$
$$V_T\frac{dC_T(t)}{dt} = Cl_P C_P(t) - Cl_d C_T(t)$$

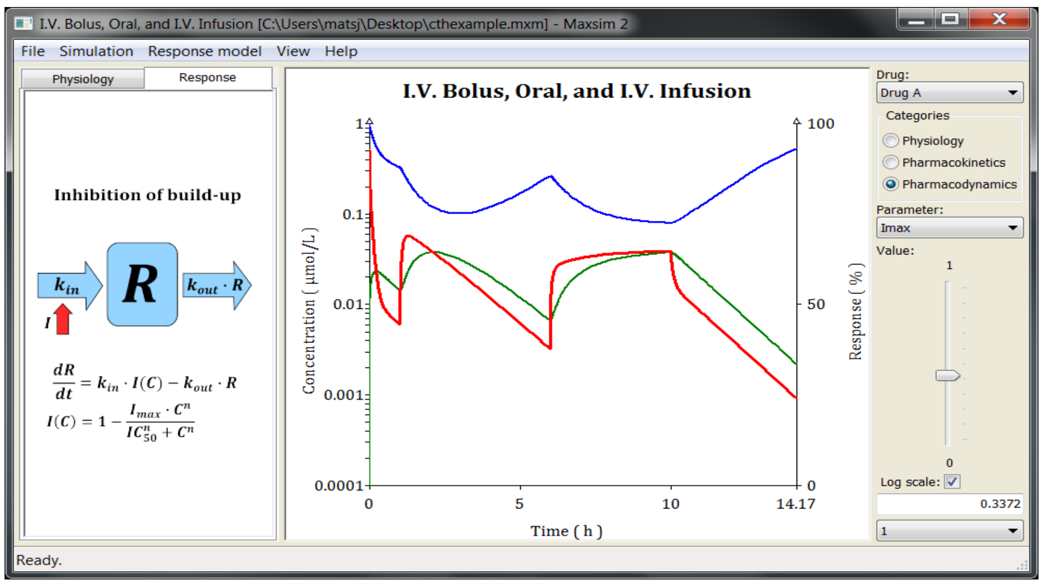
Target-mediated drug disposition with three possible types of administration and first-order elimination of drug, target, and drug-target complex.



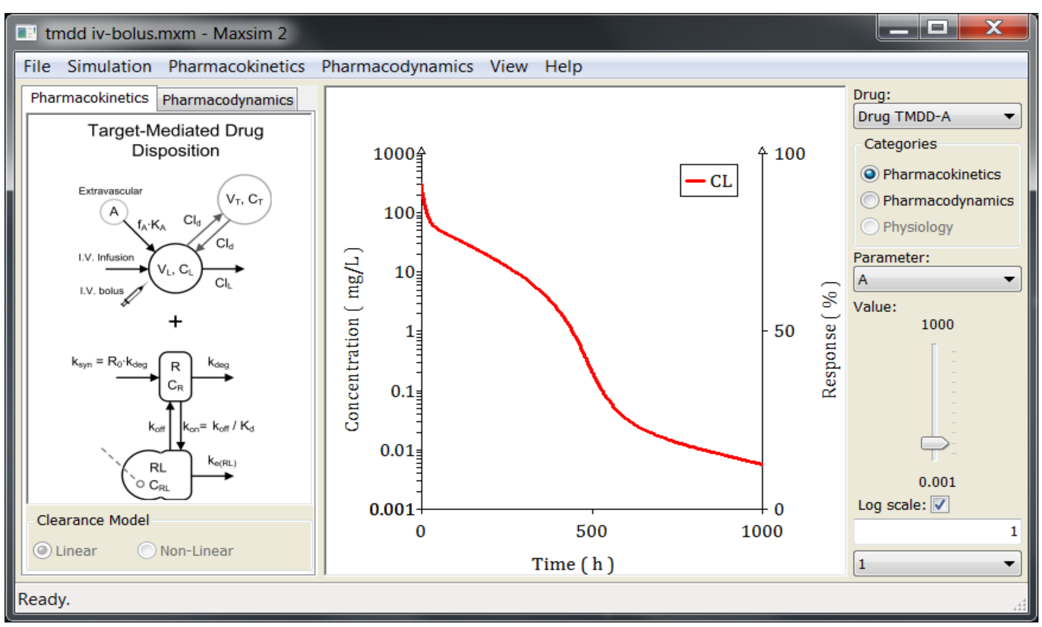
The graphical user interface of Maxsim2 showing a simulation of plasma drug concentration (red) and drug effect (blue) after three consecutive dose administrations: intravenous bolus, oral, and intravenous infusion, respectively. The slider, in this example, controls hepatic clearance, i.e., how fast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



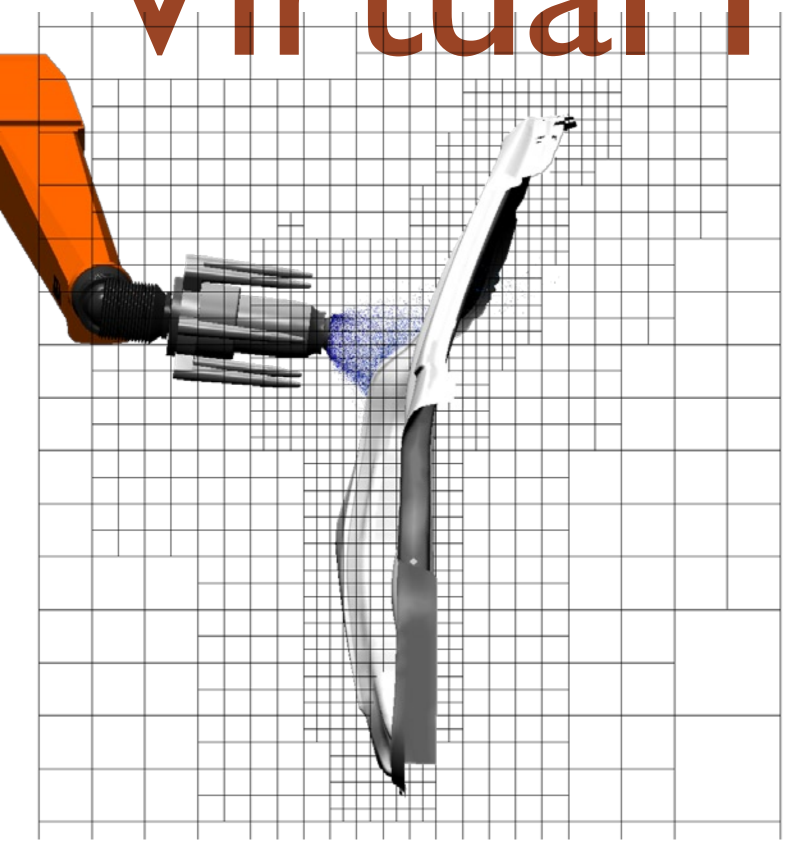
A simulation of plasma drug concentration (red) and muscle tissue drug concentration (green). The effect is modeled by a so called indirect response model with inhibition of build-up giving the drug effect (blue).



A simulation of the pharmacokinetic profile after an intravenous bolus dose for the target mediated drug disposition model. Notice the different phases of the profile: an initial rapid decline (drug and target equilibrate), followed by a slow first-order disposition (target route saturation), a mixed-order disposition phase (drug is eliminated directly as well as indirectly in the form of a drug-target complex), and finally linear target mediated disposition (drug concentration is so low that both direct and indirect elimination is linear).



Virtual Paint Shop



The goal of this ongoing project is to develop new simulation algorithms and tools for paint and surface treatment processes in automotive paint shops. The project is part of Vinnova's FFI program for Sustainable Production Technology that supports the Swedish automotive industry and our research partners are Volvo Cars, Scania CV, AB Volvo, General Motors and Swerea IVF.

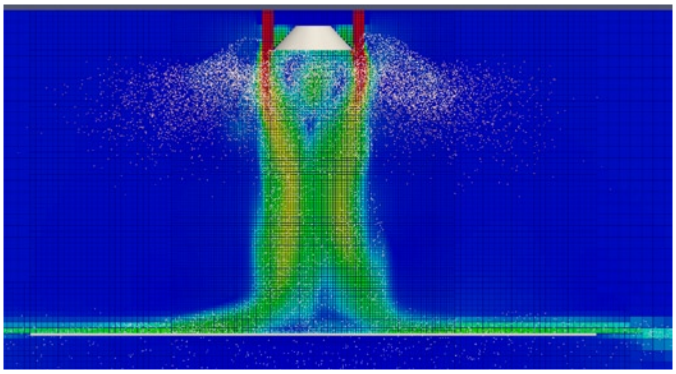
The surface treatment is the process in an automotive factory that consumes most energy, water and chemicals, and produces most waste and pollution. Approximately 36 percent of the energy for OEM operations in automotive manufacturing is consumed in the paint shops. Even though virtual tools are frequently used to support the product and production realization in other parts of the automotive factory, in the paint shop the product preparation rely to a large extent on individual experience and physical testing on a large number of prototypes. Therefore, the paint shop not only has a large environmental impact it is also a bottleneck in production.

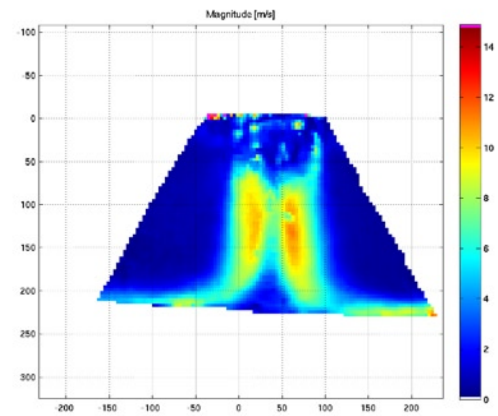
To support sustainable production and an efficient product development new virtual tools for simulation and optimization of the surface treatment processes are necessary. However, the spray painting and surface treatment processes pose great challenges for mathematical modelling and simulation, and are characterized by multi-phase and free surface flows, multi-physics, multi-scale phenomena, and large moving geometries. On the market today such software tools have therefore not been available or have had very limited performance.

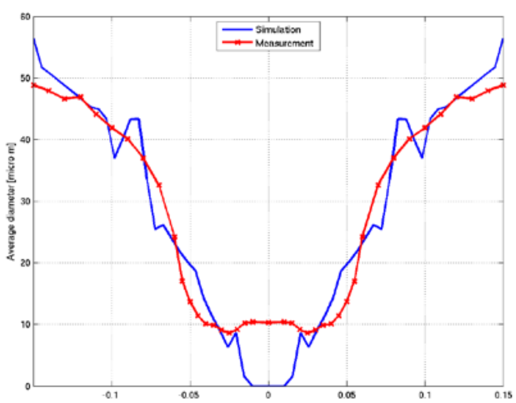
In spray painting paint primer, color layers and clear coating are commonly applied through the Electrostatic Rotary Bell Sprayer (ERBS) technique. Paint is injected at the centre of a rotating bell; the paint forms a film on the bottom side of the bell and is atomized at the edge. The droplets are charged electrostatically and driven towards the target car body both by shaping air surrounding the rotating bell and by a potential difference in the order of 50-100 kV between paint applicator and target.

- Spray Painting

Copyright: Volvo Truks







The aim of our work is to develop a new framework that can be used for accurate simulations of a complex car part in just a few hours on a standard computer. This is an extreme improvement compared to earlier approaches that require weeks of simulation time. Unique algorithms for two-way coupled simulations of air flows, electrostatic fields and charged paint droplets have made this possible. Particularly important for the computational efficiency is the in-house Navier-Stokes solver – IBOFlow (Immersed Boundary Octree Flow solver). Novel immersed boundary methods are used to model the presence of objects in the fluid and they are combined with an adaptive Cartesian octree grid. This enables modeling of moving objects at virtually no additional computational cost, and greatly simplifies preprocessing by avoiding the cumbersome generation of a body conforming mesh.

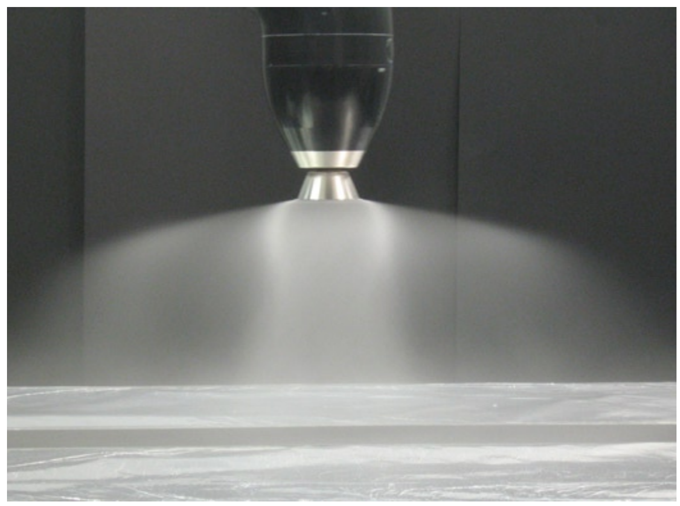
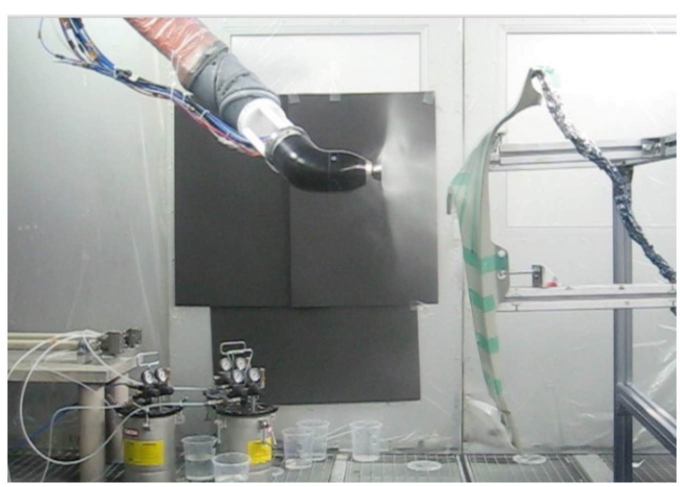


Photo of a rotary bell spraying towards a target plate.

A robot is painting a Volvo V60 fender in a cross-wise motion.

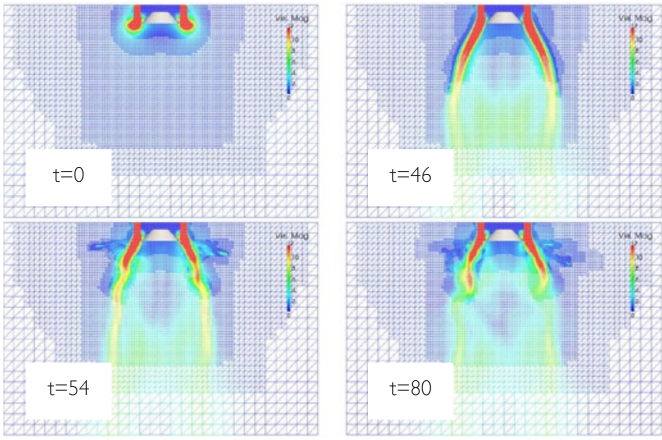


Pictures from above:

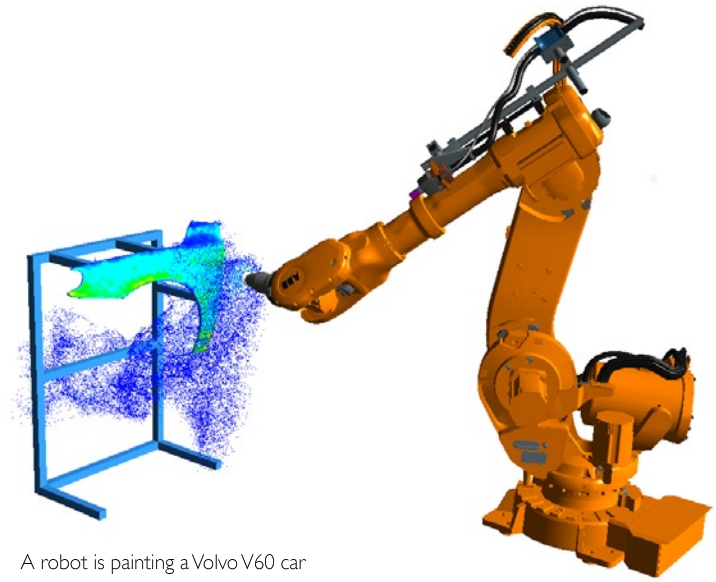
A detailed simulation of the break-up of paint liquid into droplets in the near bell region. The colors show the air velocities where blue means low and red high velocity.

A PIV measurement of the average air velocities under the bell cup with the same process parameters as in the simulation shown in the top picture.

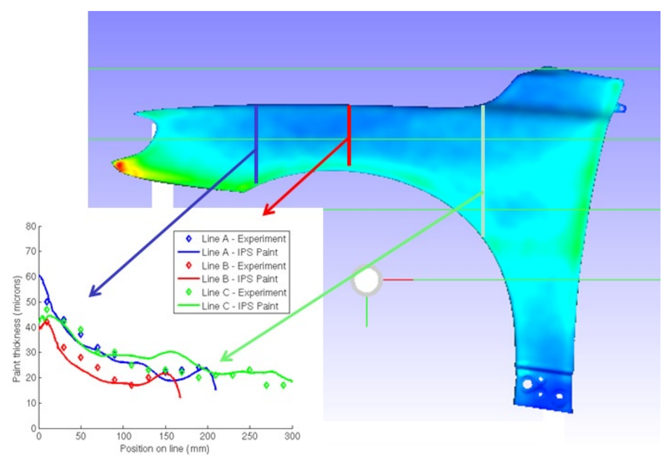
Validation of the droplet size distribution obtained by a detailed simulation of the break-up in the near bell region.



Sequence of pictures showing a near bell simulation and the adaptive grid refinement in IBOFlow. At time-step t = 50 the paint applicator begins to spray paint and it is clearly visible the effect it has on the flow: the motion of the paint droplets affect the speed of the main air current, increasing its radial velocity at the edge of the bell and decreasing its magnitude below the applicator.



A robot is painting a Volvo V60 car fender in IPS Virtual Paint.



The resulting paint thickness along three lines of the car fender is compared to measurements.

The paint simulation algorithms have been integrated in a virtual paint module in the in-house package for automatic path planning, IPS. In the software, an arbitrary geometry can be painted using a robot and the user sets the process conditions like paint flow, air flow, electrostatic droplet charge and atomizer bell rotation speed. To validate IPS Virtual Paint several measurement campaigns have been performed. At Fraunhofer IPA in Stuttgart a Volvo V60 car fender was painted with different process conditions and the resulting predicted paint thickness was compared to measurements showing a very good agreement. The first commercial release of the software IPS Virtual Paint will be available in 2013 and our industrial partners predict that positive effects will include a reduced time required for introduction of new car models, a reduced environmental impact and an increased product quality.

Currently we are working on further improvements of IPS Virtual Paint including modeling and simulation of the break-up of paint liquid into droplets in the near bell region to reduce the need for costly measurements of droplet size distributions, and droplet and air velocities, which currently are used as input for the paint thickness prediction simulations. Another challenge is the automatic generation of collision free robot paths through 3D scanning of complex components. This technology will mainly target low volume series which have until today been painted manually due to the lead time of programming a paint robot to perform the same operation. Furthermore, a large effort has been made on the sealing application and a similar break-through in simulation performance as for spray painting has been achieved.

Many products such as car and truck bodies, engines, medical prosthesis, mobile phones, and lumbering equipment depend visually and functionally on their geometry. Since variation is inherent in all production, consistent improvements 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 to effectively generate and visualize collision-free and optimized motions in the assembly plant. During 2012 the department of Geometry and Motion Planning has successfully developed methods, algorithms and tools supporting these activities within the main subjects:

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

Johan Carlson
PhD, Vice Director FCC,
Head of Department
Phone +46 31 772 42 89
johan.carlson@fcc.chalmers.se

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

Acknowledgement

In 2012, 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), and from the Sustainable Production Initiative and the Production Area of Advance at Chalmers.

Cooperation

During 2012, 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 department Dynamics and Durability has grown by working together on common projects.

Geometry and Motion Plan

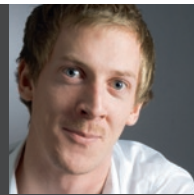
In particular, the FCC software tool Industrial Path Solutions for automatic path planning of collision-free motions has been successfully used by our partners in the automotive industry to solve geometrically complex manufacturing problems in mere minutes instead of hours or days. The strength of the 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 also part of the Master's degree program in virtual production at Chalmers.

An industrial and scientific challenge of car body manufacturing is to guarantee geometrical quality and factory throughput during spot welding. The development of new algorithms, integrating line balancing, sequencing and coordination of operations with our path planning technology has been implemented at Volvo Cars and showing a 25% better equipment utilization and improvement in commission from 3 months to 3 weeks.

Today, many assembly problems are detected too late in product and production processes, involving cables, hoses and wiring harness. The reason for this is the lack of virtual manufacturing tools supporting real time simulation of flexible parts and motions. The FCC technology developed together with ITWM has been successfully implemented as a module in the IPS software. IPS is now used in Sweden, Germany, US, and Japan.


Robert Bohlin
PhD


Fredrik Andersson
MSc


Staffan Björkenstam
MSc


Niclas Delfs
BSc


Fredrik Ekstedt
Lic


Klas Engström
PhD


Daniel Gleeson
MSc


Stefan Gustafsson
BSc


Tomas Hermansson
MSc


Peter Mårdberg
BSc


Johan Nyström
PhD

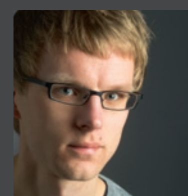

Roland Roll
Marketing and sales


Daniel Segerdahl
MSc


Evan Shellshear
PhD


Domenico Spensieri
MSc


Sebastian Tafuri
MSc


Johan Torstensson
MSc

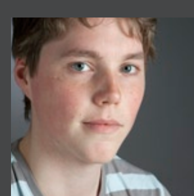
Copyright: Volvo Cars

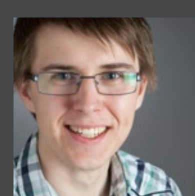
The Geometry and Motion Planning Research Group


Robert Andersson
Contracted student


Thomas Bååth Sjöblom
Contracted student

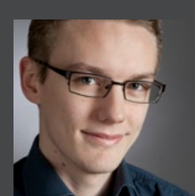

David Eriksson
Contracted student


Simon Hall
Contracted student


Nigul Ilves
Contracted student


John Isaksson
Contracted student


Niklas Karlsson
Contracted student


Jonas Kressin
Contracted student

Cooperation

During 2012, the successful collaboration with the department of Geometry and Motion Planning at FCC has been strengthened through joint projects on the Virtual Paint Shop. Also the collaboration with the departments of Flow and Material Simulation, Dynamics and Durability, and Optimization at Fraunhofer ITWM has grown by working on joint projects. Other collaborations include Swerea IVF and Chalmers divisions of Fluid Dynamics and Biomedical Engineering.

Computational Engineering...

The rapid increase in computational power has made simulations an integrated part of the development of products and processes. Virtual prototyping stimulates industrial innovation and simulations offer an alternative to measurements, when these are too expensive or even impossible to perform. Furthermore, the risk for unforeseen costs and quality problems is reduced by offering the possibility to perform analyses and optimization in the early phases of product and process development. The department of computational engineering and design supports these activities by developing novel numerical methods, fast algorithms and engineering tools, in particular for application in the areas:

- Fluid Dynamics
- Electromagnetics
- Structural dynamics
- 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 meshless 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 body-fitted 3D volume meshes. Two highlights during 2012 was the parallelization of the solver using MPI that enables us to handle tens of millions degrees of freedom, and the development of a granular flow solver that was successfully applied in two projects with Micronic Mydata for the simulation of solder paste in a microfluidic contraction. Furthermore, the efforts on simulation of paint and surface treatment processes in automotive paint shops continued and will during 2013 result in the first commercial release of the IPS Virtual Paint module. Another major activity was the project on simulation of papermaking and paperboard package quality with industrial partners Akzo Nobel, Albany International, Stora Enso and Tetra Pak, that has got a good start of its second three-year phase.

In electromagnetics research is performed on adaptive finite element methods for quasi-static applications. The in-house software has for example been used for simulation of paint processes, electrostatic precipitators and electromagnetic fields in the human brain. Furthermore, within the Fraunhofer project OptoScope we are developing methods and tools for simulation of electro-optical modulators for ultra-fast electronics.

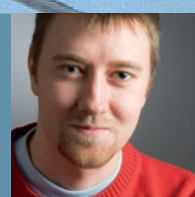
In structural dynamics we made substantial progress during 2012 on the development of the in-house software LaStFEM (Large Strain Finite Element Method) that includes a wide variety of material models and allows analysis of beams, shells and volumes subject to large deformations. Complex fluid-structure interaction applications are addressed by a combination with IBOFlow. 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 application in 2012 was EEG-based localization of epileptic foci in the human brain.

and Design

Copyright: TetraPak

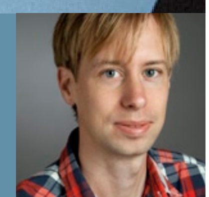
Fredrik Edelvik
PhD, Associate Professor,
Head of Department
Phone +46 31 7724246
fredrik.edelvik@fcc.chalmers.se

Andreas Mark
PhD



Björn Andersson
Lic

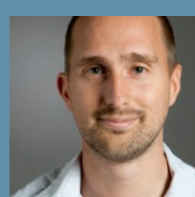
Anton Berce
MSc, Marketing and sales



Christoffer Cromvik
PhD

Stefan Jakobsson
PhD

Cornelia Jareteg
MSc, AEM Graduate Programme



Johan Nyström
PhD

Robert Sandboge
PhD

Elin Solberg
MSc, AEM Graduate Programme

Erik Svenning
MSc

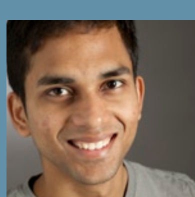
The Computational Engineering and Design Research Group

Anders Ålund
Lic

Acknowledgement

In 2012 the department received substantial funding from Vinnova through the FFI Sustainable Production Technology program, from the Sustainable Production Initiative and the Production Area of Advance at Chalmers, and from ÅForsk.

Niklas Karlsson
Contracted student

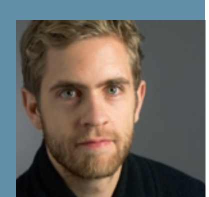


Manan Lalit
Contracted student

Frida Svelander
Contracted student

Magnus Winter
Contracted student

Lucas Ariel Martinez
MSc Student



Samuel Lorin
Lic, PPU, PhD student

Computational tools and techniques for systems and data analysis are key to gaining better understanding of processes and products as well as to optimize their performance. This holds true regardless of the applications being of technical or biological character since on a systems level they can be modeled and analyzed using general mathematical techniques. The department conducts research, application and development of computational methods, software tools, data analysis, and dynamic system modeling on different levels of abstraction utilizing time and spatially resolved measurement data. Our focus areas are:

- Systems Biology and Pharmacology
- Image and Video Analysis
- Systems, Prediction, and Control
- Industrial Statistics and Quality Engineering

Combining model based signal processing, system identification, mechanistic models, and sensitivity analysis with novel measurement platforms provides a strong competitive edge for researchers in the pharmaceutical and biotech industry. Systems biology partly addresses these things and aims at elucidating the properties and function of biochemical and biological systems on a systems level, e.g., how biomolecules interact and implement various functions which cannot be understood by studying the system components in isolation. Quantitative and Systems Pharmacology combine computational and experimental methods to elucidate, validate, and apply new pharmacological concepts to the development and use of small molecule and biologic drugs. A successful systems pharmacology approach requires efficient and reliable computational methods for model based data analysis. We successfully develop and apply mathematical methods in both systems biology and systems pharmacology.

Dynamic processes play a key role in many industrial applications such as in the automotive, aerospace, pharmaceutical, and chemical process industry. Knowledge about how to build, simulate, and analyze mathematical models of such processes is crucial to be able to optimize performance, design control systems, or make highly reliable predictions about process behavior. The department provides key competence throughout the whole chain of modeling, simulation, analysis, and control of dynamic

Systems and

The Systems and Data Analysis Research Group

Mats Jirstrand
PhD, Associate Professor,
Head of Department
Phone +46 31 7724250
mats.jirstrand@fcc.chalmers.se

Mats Kvarnström
PhD

Joachim Almquist
MSc

Kristoffer Andersson
MSc

Jonas Hagmar
MSc

Johan Karlsson
PhD

Jacob Leander, MSc
AEM Graduate Prog.

Nico Reissmann
MSc

Sofia Tapani
PhD

Mikael Wallman
MSc

Igor Rychlik
Professor, Mathematical Statistics Chalmers,
Affiliated expert, FCC

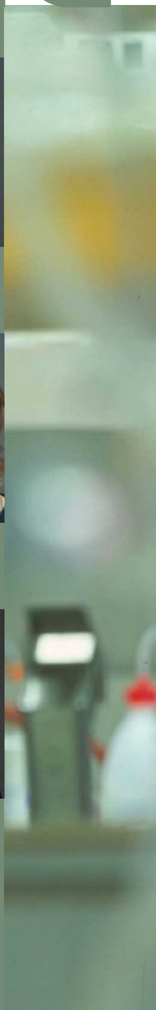
Johan Gabrielsson
Professor, Pharmacology and Toxicology, SLU
Affiliated expert FCC

Ola Martner
Contracted student

Daniel Pettersson
Contracted student

Nils Jugenfelt
MSc Student

Tobias Raski
MSc Student



processes covering a wide range of application areas. We apply and develop tools for system identification, i.e., building mathematical models using measurement data, model based signal processing, and prediction of physical quantities from indirect measurements. Example applications include statistical models of mechanical load signals.

We also develop image analysis methods for automated quantitative analysis and enhancement of images and videos. Example applications include automated segmentation and classification of cells, vesicles, or particles in individual images; cell tracking in time-lapse image sequences in fluorescence bioimaging; and enhancement and display of low light videos for the automotive industry.

An important activity for the department during 2012 has been the continued work in a long-term project from AstraZeneca on advanced mathematical pharmacokinetic/pharmacodynamic (PKPD) modeling and simulation for predictive model based drug discovery and development. Related to this area is the Maxsim2 software, which during 2012 has found a number of new customers in both industry and academia.

We have taken part in three EU funded projects during the year: 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, where the two last now has been successfully completed.

Acknowledgement

In 2012, the Systems and Data Analysis department 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; Systems and Synthetic Biology, Biological Physics, and Mathematical Sciences at Chalmers University of Technology; 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; and partners in the UNICELLSYS, CANCERSYS, and SYSINBIO EU-projects.

Data Analysis

Copyright: Astra Zeneca

Styrelsen för Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik, FCC, får härmed avge följande redovisning över verksamheten under tiden 1 januari 2012 – 31 december 2012, stiftelsens elfte 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 har till ändamål att främja och genomföra vetenskaplig forskning, utveckling och utbildning inom området tillämpad matematik i nära samarbete med universitet och andra vetenskapliga och industriella organ samt verka för användning av matematiska modeller, metoder och resultat i industriell verksamhet. Stiftelsens verksamhet skall bedrivas utan vinstsyfte.

Stiftelsen bedriver huvuddelen av sin verksamhet i Chalmers Teknikpark och har 2010 tecknat fortsatt hyresavtal med Chalmersfastigheter AB omfattande 1 096 kvm i Teknikparken till och med den 31 mars 2014.

Chalmers och Fraunhofersällskapet har under året fortsatt finansiera Stiftelsen med vardera 500 000 EUR per år enligt beslut fattat 2010 för fem år 2011 - 2015.

Stiftelsen gav i februari klarsignal för ett spin-off bolag med Chalmers och anställda vid Stiftelsen som delägare. Stiftelsen har sedan tecknat avtal med bolaget om mjukvaran IPS Industrial Path Solutions utvecklad av Stiftelsen.

Chalmers och Fraunhofersällskapet har ambition att strukturellt permanenta sitt samarbete kring Stiftelsen och att undanröja eventuella hinder för en utvidgning. Under året har tyska förbundsdagens Haushaltsausschuss fattat erforderliga beslut efter tidigare positiva beslut av Bund-Länder-Kommission. Chalmers och Fraunhofersällskapet har sedan i november enats om fortsatt tidtabell för att vidga Stiftelsens ramar.

Årets omsättning har varit drygt trettiofem miljoner kronor. Antalet anställda och studenter har motsvarat 40 heltidsekvivalenter (FTE) varav 6 kvinnor. Antalet studenter utgörs av 9 examensarbetare i mastersprogram knappt 3 FTE, 17 studenter i mastersprogram anställda på 10-20% för arbete i projekt knappt 2 FTE och industridoktorander 1 FTE, totalt ca 6 FTE. Härutöver har arbete motsvarande cirka 5 FTE lagts ut på partners.

Rörelsens intäkter har uppgått till 35 257 kSEK (36 775 kSEK föregående år). Av detta utgör 38% (28%) industriprojekt, 14% (25%) offentliga projekt, 24% (23%) offentliga anslag och 25% (24%) finansiering från stiftarna. Årets resultat efter skatt är 182 kSEK (114 kSEK). Eget kapital uppgick den 31 december 2012 till 4 029 kSEK (3 974 kSEK) inkluderat kapitalandelen i obeskattade reserver.

Stiftelsens styrelse har under verksamhetsåret sammanträtt tre gånger (varav en gång per telefon). Ersättning har utgått till ordföranden med 17 365 kronor och till övriga ledamöter med 17 365 kronor per person och år.

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

Göteborg den 21 mars 2013

Bo Johansson
Helmut Neunzert
Dieter Prätzel-Wolters
Rikard Söderberg

Räkenskaperna har granskats av Deloitte

Årsredovisning

Resultaträkning
120101 – 121231, (kSEK)

Intäkter

Nettoomsättning	35 257
Summa intäkter	35 257

Kostnader

Externa kostnader	-9 323
Personalkostnader	-25 721
Avskrivningar av materiella anläggningstillgångar	-140
Summa kostnader	-35 184

Rörelseresultat	**72**

Resultat från finansiella investeringar

Ränteintäkter och liknande resultatposter	177
Räntekostnader och liknande resultatposter	-74

Resultat efter finansiella poster	**175**

Bokslutsdispositioner	171
Årets skatt	-164

Årets resultat	**182**

Balansräkning
121231, (kSEK)

Anläggningstillgångar

Maskiner och inventarier	237
Summa anläggningstillgångar	237

Omsättningstillgångar

Kundfordringar	5 246
Förutbetalda kostnader och upplupna intäkter	3 847
Övriga kortfristiga fordringar	184
Kassa och bank	5 200
Summa omsättningstillgångar	14 477

Summa tillgångar	**14 714**

Eget kapital

Eget kapital vid årets ingång	3 281
Årets resultat	182
Summa eget kapital	3 463

Obeskattade reserver	768

Kortfristiga skulder

Leverantörsskulder	3 420
Övriga kortfristiga skulder	986
Skatteskulder	250
Upplupna kostnader och förutbetalda intäkter	5 827
Summa kortfristiga skulder	10 483

Summa skulder och eget kapital	**14 714**

Styrelse och ledning den 22 november 2012

Från vänster:
Rikard Söderberg, Chalmers
Johan Carlson, biträdande föreståndare FCC
Dieter Prätzel-Wolters, ITWM
Helmut Neunzert, ITWM
Bo Johansson, Chalmers
Uno Nävert, föreståndare FCC

Appendix

Publications

B Andersson, V Golovitchev, S Jakobsson, A Mark, F Edelvik, L Davidson, J S Carlson:
Modified TAB Model for Viscous Fluids applied to Breakup in Rotary Bell Spray Painting, Proceedings of 12th International Conference on Liquid Atomization and Spray Systems, 2012.

B Andersson, V Golovitchev, S Jakobsson, A Mark, F Edelvik, L Davidson, J S Carlson:
Modified TAB Model for Viscous Fluids applied to Breakup in Rotary Bell Spray Painting, Proceedings 12th Triennial International Conference on Liquid Atomization and Spray Systems, Heidelberg, Germany, 2012.

M Anguelova, J Karlsson, M Jirstrand:
Minimal Output Sets for Identifiability, Mathematical Biosciences, 239(1):139-153, September 2012.

M Berglund, M Sunnåker, M Adiels, M Jirstrand, B Wennberg:
Investigations of a compartmental model for leucine kinetics using non-linear mixed effects models with ordinary and stochastic differential equations. Mathematical Medicine and Biology, 29(4):361-384, 2012.

S Björkenstam, J Segeborn, J S Carlson, R Bohlin:
Assembly Verification and Geometry Design by Distance Field based Shrinking, 4th CIRP Conference on Assembly Technology and Systems - CATS 2012, University of Michigan, Ann Arbor, USA on May 21-23, 2012.

R Bohlin, N Delfs, L Hanson, D Högberg, J S Carlson:
Automatic Creation of Virtual Manikin Motions Maximizing Comfort in Manual Assembly Processes, 4th CIRP Conference on Assembly Technology and Systems - CATS 2012, University of Michigan, Ann Arbor, USA on May 21-23, 2012.

J S Carlson, R Bohlin, L Lindkvist, D Spensieri, R Söderberg:
Non-nominal path planning for increased robustness of robotized assembling processes, 4th CIRP Conference on Assembly Technology and Systems - CATS 2012, University of Michigan, Ann Arbor, USA on May 21-23, 2012.

N Delfs, R Bohlin, P Mårdberg, S Gustafsson, J S Carlson:
Comparison of Algorithms for Automatic Creation of Virtual Manikin Motions, 2nd International Conference on Applied Digital Human Modeling, July 21-25 2012, San Francisco.

S Gustafsson, S Tafuri, N Delfs, P Mårdberg, J S Carlson:
Automatic Fitting of a 3D Character to a Computer Manikin, 2nd International Conference on Applied Digital Human Modeling, July 21-25, 2012, San Francisco.

T Hermansson, R Bohlin, J S Carlson, R Söderberg:
Automatic path planning for wiring harness installations (wt), 4th CIRP Conference on Assembly Technology and Systems - CATS 2012, University of Michigan, Ann Arbor, USA on May 21-23, 2012.

T Hermansson, J S Carlson, S Björkenstam, R Söderberg:
Geometric Variation Simulation and Robust Design for Flexible Cables and Hoses, CIRP International Conference on Computer Aided tolerancing, Huddersfield, UK, 2012.

J Karlsson, M Anguelova, M Jirstrand:
An Efficient Method for Structural Identifiability Analysis of Large Dynamic Systems, In Proceedings of the 16th IFAC Symposium on System Identification (SYSID 2012), Brussels, Belgium, July 11-13, 2012.

S Lorin, R Sandboge:
Stabilized Finite Element Method for Solids with Large Gradient Mechanical Properties, Proceedings ASME International Mechanical Engineering Congress & Exposition, 2012.

S Lorin, R Söderberg, L Lindkvist, R Sandboge:
Combining Variation Simulation With Thermal Expansion For Geometry Assurance, Proceedings ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE, 2012.

A Mark, B Andersson, S Tafuri, K Engström, H Söröd, F Edelvik, J S Carlson:
Simulation of Electrostatic Rotary Bell Spray Painting in Automotive Paint Shops, Proceedings of the 12th Triennial International Conference on Liquid Atomization and Spray Systems, Heidelberg, Germany, 2012.

A Mark, E Svenning, F Edelvik:
An Immersed Boundary Method for Simulation of Flow with Heat Transfer, International Journal of Heat and Mass Transfer, 56:424-435, 2013.

A Mark, R Sandboge, A Berce, F Edelvik, . Glatt, S Rief, A Wiegmann, M Fredlund, J Amini, R Lai, L Martinsson, U Nyman, J Tryding:
Multi-scale simulation of paperboard edge wicking using a fiber-resolving virtual paper model, Tappi Journal, 11(6):7-14, 2012.

A Mark, J Tryding, J Amini, F Edelvik, M Fredlund, E Glatt, R Lai, L Martinsson, U Nyman, M Rentzhog, S Rief, A Wiegmann:
Modeling and Simulation of Paperboard Edge Wicking, Nordic Pulp & Paper Research Journal, 27(2):397-402, 2012.

A Mark, B Andersson, S Tafuri, K Engström, H Söröd, F Edelvik, J S Carlson:
Simulation of Electrostatic Rotary Bell Spray Painting in Automotive Paint Shops, I: Proceedings of 12th International Conference on Liquid Atomization and Spray Systems, 2012

A Mark, R Bohlin, D Segerdahl, F Edelvik, J S Carlson:
Optimization of Robotized Sealing Stations in Paint Shops by Process Simulation and Automatic Path Planning, Proceedings from the 5th International Swedish Production Symposium SPS12, Linköping, pp 487-496, November 2012.

R Meyer, L D`Alessandro, S Kar, B Kramer, B She, D Kaschek, B Hahn, D Wrangborg, J Karlsson, M Kvarnstrom, M Jirstrand, W-D Lehmann, J Timmer, T Höfer, U Klingmüller:
Heterogeneous kinetics of AKT signaling in individual cells are accounted for by variable protein concentration, Frontiers in Physiology/Systems Biology, 3:451, November 2012.

M R Morelande, L Svensson, J Hagmar, M Jirstrand:
Optimal Posterior Density Approximation for Bearings-Only Tracking, In Proceedings of the 37th International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Kyoto, Japan, March 25-30, 2012.

P Mårdberg, J S Carlson, R Bohlin, N Delfs, S Gustafsson:
Using Ergonomic Criteria to Adaptively Define Test Manikins for Design Problems, 2nd International Conference on Applied Digital Human Modeling, July 21-25 2012, San Francisco.

E Shellshear, J S Carlson, R Bohlin:
A Combinatorial Packing Algorithm and Standard Trunk Geometry for ISO Luggage Packing, ASME IDETC/CIE 2012, Chicago Illinois, DETC2012-70778.

Y Shirvany, F Edelvik, S Jakobsson, A Hedström, M Persson:
Application of Particle Swarm Optimization in Epileptic Spike EEG Source Localization, Applied Soft Computing, in press, 2012.

Y Shirvany, F Edelvik, S Jakobsson, A Hedström, Q Mahmood, A Chodorowski, M Persson:
Non-Invasive EEG Source Localization Using Particle Swarm Optimization: A Clinical Experiment, Proceedings from 34th International Conference of the IEEE Engineering in Medicine & Biology Society, San Diego, USA, 2012.

E Svenning, A Mark, F Edelvik, E Glatt, S Rief, A Wiegmann, L Martinsson, R Lai, M Fredlund, U Nyman:
Multiphase Simulation of Fiber Suspension Flows Using Immersed Boundary Methods, Nordic Pulp & Paper Research Journal, 27(2):184-191, 2012.

E Svenning, A Mark, L Martinsson, R Lai, M Fredlund, U Nyman, F Edelvik:
Microstructure simulation of paper forming, Proceedings from the 17th European Conference on Mathematics for Industry, Lund, Sweden, 2012.

E Svenning, A Mark, F Edelvik:
Simulation of a highly elastic structure interacting with a two-phase flow, Proceedings from the 17th European Conference on Mathematics for Industry, Lund, Sweden, 2012.

H Söröd, R Ingemarsson, A Mark, R Bohlin, D Segerdahl, F Edelvik, J S Carlson:
3D Scanning and Automatic Path Planning of Paint Process in General Coating Industry, Proceedings from the 5th International Swedish Production Symposium SPS12, Linköping, pp 21-25, November 2012.

S Tafuri, E Shellshear, R Bohlin, J S Carlson:
Automatic Collision Free Path Planning in Hybrid Triangle and Point Models: A Case Study, Winter Simulation Conference, Berlin, December 2012.

S Tafuri, F Ekstedt, J S Carlson, A Mark, F Edelvik:
Improved Spray Paint Thickness Calculation From Simulated Droplets Using Density Estimation, Proceedings of the ASME 2012 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2012, Chicago, IL, USA

Theses

B Andersson:
Droplet Breakup in Automotive Spray Painting, Licentiate thesis, Chalmers, supervisor L Davidson, January 2012.

C Jareteg:
Solving inverse problems in EEG-based source localization by combining parametric and non-parametric methods, Master thesis, University of Gothenburg, supervisor S Jakobsson, examiner S Larsson, June 2012.

N Jungenfelt and Tobias Raski:
Contrast Enhancement, Denoising and Fusion in Dark Video for Applications in Automobile Safety, Master thesis, Chalmers, supervisors J Karlsson and M Kvarnström. examiner Thomas McKelvy, June 2012.

Y Shirvany:
Non-invasive Functional Neuroimaging for Localizing Epileptic Brain Activity, Licentiate thesis, Chalmers, supervisor M Persson, co-supervisors F Edelvik and A Hedström, March 2012.

E Solberg:
A Wave Propagation Solver For Computational Aero-Acoustics, Master thesis, University of Gothenburg, supervisor R Sandboge, examiner S Larsson, February 2012.

Presentations/Posters/Conferences

B Andersson:
Simulation of Electrostatic Rotary Bell Spray Painting in Automotive Paint Shops, 12th Triennial International Conference on Liquid Atomization and Spray Systems, Heidelberg, Germany, September 2012.

B Andersson:
Modified TAB Model for Viscous Fluids applied to Breakup in Rotary Bell Spray Painting, 12th Triennial International Conference on Liquid Atomization and Spray Systems, Heidelberg, Germany, September 2012.

A Berce:
Multi-Phase Flow Research at FCC, Siamuf seminar, Sundsvall, May 2012.

F Edelvik:
Industrial Mathematics at FCC, Guest Lecture for Engineering Physics Program, Uppsala University, January 2012.

F Edelvik:
Virtual Paint, Manufacturing R&D Clusters, Katrineholm, May 2012.

F Edelvik:
Industrial Mathematics at FCC, Guest Lecture for Engineering Physics Program, Uppsala University, September 2012.

F Edelvik:
Modeling and Simulation of Coating Processes in Automotive Industry, Seminar at Department of Information Technology, Uppsala University, September 2012.

S Jakobsson:
Optimal control of focused ultrasound surgery, Seminar at University of São Paulo, São Carlos, Brazil, October 2012.

S Jakobsson:
Optimal control of focused ultrasound surgery, Seminar at Unicamp, Campinas, Brazil, October 2012.

S Jakobsson:
Industrial mathematics at Fraunhofer Chalmers Center", Open Innovation Seminar, São Paulo, São Carlos, Brazil, November 2012.

C Jareteg:
Kan man bota epilepsi med matematik?, My-dagen, October 2012.

M Jirstrand:
Modeling and Simulation – Design, Analysis, and Interpretation Strategies of PK and PKPD Experiments, 12th International Congress of the European Association for Veterinary Pharmacology and Toxicology, Noordwijk, Netherlands, July 2012.

M Jirstrand:
Advanced Parameter Estimation Methods for Simultaneously Collected Multiple Single Cell Data, The 5th UNICELLSYS General Meeting, Milano, March 2012.

M Jirstrand:
An Efficient Method for Structural Identifiability Analysis of Large Dynamic Systems, 16th IFAC Symposium on System Identification, Brussels, Belgium, July 2012.

M Jirstrand:
Interactive Simulation for Future Improved Personalized Dosage, invited seminar at Beyond the Pill - Future of Health Care, Göteborg, November 2012.

A Mark:
Modeling and Simulation of Paperboard Edge Wicking, 2012 International Paper Physics Conference, Stockholm, June 2012.

A Mark:
Optimization of Robotized Sealing Stations in Paint Shops by Process Simulation and Automatic Path Planning, 5th International Swedish Production Symposium SPS12, Linköping, November 2012.

A Mark:
Multi-scale simulation of edge wicking in a filling machine, Siamuf seminar, Varberg, November 2012.

A Mark:
Simulation of solder paste in a microfluidic contraction, Complex Fluids Symposium, Micronic Mydata AB, December 2012.

E Svenning:
Simulation of fiber suspensions using immersed boundary methods, EU cost action on Fibre Suspension Flow Modelling, Brussels, Belgium, March 2012.

E Svenning:
Multiphase Simulation of Fiber Suspension Flows Using Immersed Boundary Methods, 2012 International Paper Physics Conference, Stockholm, June 2012.

E Svenning:
Microstructure simulation of paper forming, 17th European Conference on Mathematics for Industry, Lund, Sweden, 2012.

E Svenning:
Simulation of a highly elastic structure interacting with a two-phase flow, 17th European Conference on Mathematics for Industry, Lund, Sweden, 2012.

S Tapani and M Jirstrand:
Mathematical modeling tools for dynamical systems in pharmacokinetic and pharmacodynamic applications, invited seminar at AstraZeneca R&D, Mölndal, February 2012.

Other assignments

F Edelvik:
Reviewer for Nordic Pulp & Paper Research Journal.

Reviewer for IEEE Antennas and Wireless Propagation Letters.

Reviewer for IEEE Transactions on Antennas & Propagation.

M Jirstrand:
Member of Chalmers Area of Advance Life Science Management Group.

Member of the PhD-thesis committee for Roberto Olivares Hernandez, Systems Biology in *Saccharomyces cerevisiae*. Statistical data analysis and mathematical methods, Chalmers University of Technology, February 1, 2012.

A Mark:
Reviewer for Nordic Pulp & Paper Research Journal.

E Svenning:
Reviewer for Nordic Pulp & Paper Research Journal.

Reviewer for Journal of Composite Materials.

J S Carlson:
Member of the Wingquist Laboratory board, Chalmers.

Member of the Governance Board Blekinge Schools of Engineering.

Member of the management group of Wingquist Laboratory Vinn Excellence Centre.

Member of the reference board of Teknisk Matematik, Chalmers.

Reviewer for ASME.

Reviewer for CIRP.

Courses

M Jirstrand:
PK/PD Concepts & Maxsim2 workshop, EAVPT2012, Noordwijk, Netherlands, July 2012.

FCC staff on December 21, 2012,
in front of Chalmers Science Park.

$s \in [0, L]$
$d_1(s), d_2(s), d_3(s))$
d_2
d_3
d_1
$x(s, \theta_1, \theta_2) = \varphi(s) + \theta_1 d_1(s) + \theta_2 d_2$
$\varphi(s)$
e_3
$[0, L] \to R^3$
e_1

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

The purpose of FCC is to promote and undertake scientific research, development, and education in the field of applied mathematics, in close cooperation with universities and other scientific and industrial agencies, and promote the use of mathematical models, methods, and results in industrial activities.

The Centre, in close cooperation with Chalmers in Gothenburg and Fraunhofer ITWM in Kaiserslautern, shall be a leading partner for international industry and academia to mathematically model, analyse, simulate, optimize, 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.

Our vision is
"Mathematics as Technology".

ITWM

Fraunhofer **CHALMERS**
Research Centre
Industrial Mathematics

Fraunhofer-Chalmers Centre
Chalmers Science Park
SE-412 88 Gothenburg
Sweden

Visiting address:
Sven Hultins gata 9D

Phone: +46 (0)31 772 40 00
Fax: +46 (0)31 772 42 60
info@fcc.chalmers.se
www. fcc.chalmers.se