Annual Report

2013

Fraunhofer ITWM
CHALMERS
Research Centre
Industrial Mathematics

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Cover
Illustrations from our profile projects.

Annual Report 2013
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Preface an

FCC is offering contract research, services, algorithms and software based on advanced mathematics within Modeling, Simulation and Optimization (MSO). MSO provides a significant leading edge in industrial innovation of products and production systems. In 2013, we have successfully proved this together with clients from the automotive and vehicle, pharmaceutical, wood and paper, and electronics industries. Examples include the simulation of electrostatic spray painting, the optimization of robot stations and lines, the modeling and simulation of drug compound distribution and effect, and the edge wicking of paper boards.

I am proud to say that during 2013, we have performed over fifty projects for our industrial clients and twenty public projects financed by public research agencies such as SSF, VINNOVA and the EU. The revenue shows a satisfying growth of almost 10 percent since last year, an industrial income of 41 percent and a positive net result. Our work and technologies have helped clients mainly in Sweden, but also in Germany, US, Finland, Denmark, Japan and Great Britain. However, the full potential of using advanced mathematics in industry is far from reached and new technologies together with increased efforts in marketing and sales will hopefully continue our growth in 2014 and beyond.

We have been fortunate to recruit ten new coworkers. To be attractive for our clients and employees in the long run, the scientific activities of FCC are indeed important. In 2013, we have published twenty-seven scientific papers including sixteen in journals. We can also congratulate two of our coworkers who earned their PhD degree during 2013. Also, ten students from Chalmers worked half a day a week as contracted students and five students from Chalmers did their master thesis work at FCC.

A great advantage for FCC is the possibility of long term collaborations with Fraunhofer and Chalmers. The cooperation and exchange of projects with ITWM during 2013 have involved a variety of subjects such as metrology, biomechanics, the simulation of flexibles, position tracking systems, product configuration optimization, the simulation of ultra-fast electronics, and genome analytics such as next generation sequencing. We have also grown our cooperation with several other Fraunhofer units.

The department Geometry and Motion Planning works in close cooperation with the Chalmers Wingquist Laboratory, and participates in the ten-year Wingquist Laboratory VINN Excellence Centre for Virtual Product Realization 2007 – 2016. In 2013, the department continued and extended several projects, e.g., on automatic path-planning and line-balancing, sealing, virtual paint, flexible materials, metrology, and intelligently moving manikins. The software platform IPS for rigid body path planning, robot station optimization, 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 2013, there has also been extensive cooperation with our two spin-off companies: Industrial Path Solutions Sweden AB and flexStructures GmbH.

The department Computational Engineering and Design has continued and expanded its work on novel numerical methods, fast algorithms and engineering tools to support virtual product and process development. The simulation tools are applied in projects together with Swedish and international industry, and public partners, 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 simulation of paint and surface treatment processes and the six-year project on innovative simulation of paper with Swedish paper and packaging industry.

nd Profile

The well-established collaboration with Chalmers centres and departments includes in 2013, projects, grant applications, guest lectures, PhDs and master students with Wingquist Laboratory, Product and Production Development, Systems and Synthetic Biology, Fluid Dynamics, Biomedical Engineering, Chalmers e-Science Centre CheSC, Signals and Systems, Nuclear Engineering, and Mathematical Sciences. FCC is also very active in Production and Life Science Engineering within the Areas of Advance.

I am proud and impressed by the excellent work done by my coworkers at FCC and I appreciate the fruitful collaboration with my colleagues at Chalmers and Fraunhofer ITWM. A special thanks goes to my good friend and our former director Uno Nävert. It has been a pleasure to share the hard but rewarding work we started together in 2001 to build up a successful centre in industrial mathematics following the Fraunhofer model with a high level of contracted research boosted by preparatory research funded by Fraunhofer and Chalmers. Below, some of our activities are highlighted through three profile projects.

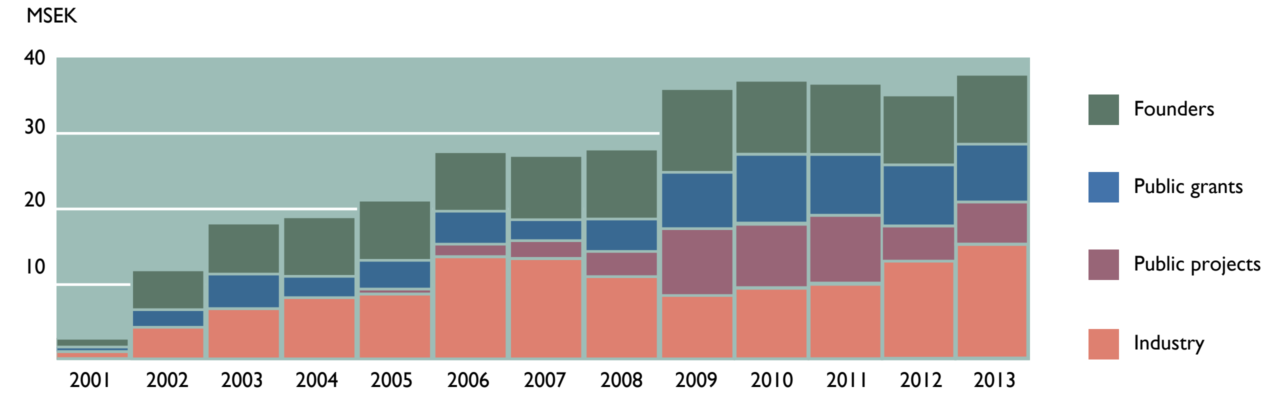
Enjoy your reading!

Photo: Anton Berce

Gothenburg in March 2014

Johan S Carlson. Director

The department Systems and Data Analysis offers competence in dynamic systems, prediction and control, image and video analysis, mathematical statistics, and quality engineering in both technical and biological/biomedical applications. In 2013, the department has continued its activities in systems biology and pharmacokinetics as partner in several EU projects and through cooperation with the ITWM department System Analysis, Prognosis and Control. Another key activity has been the successfully completed project Visual Quality Measures with Volvo Cars, with the aim to algorithmically enhance display quality of video for automotive applications based on sensor fusion. Furthermore, we have joined the Vehicle ICT Arena, which is an open environment and interest group for innovation and maintenance of competence within automotive IT. 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.



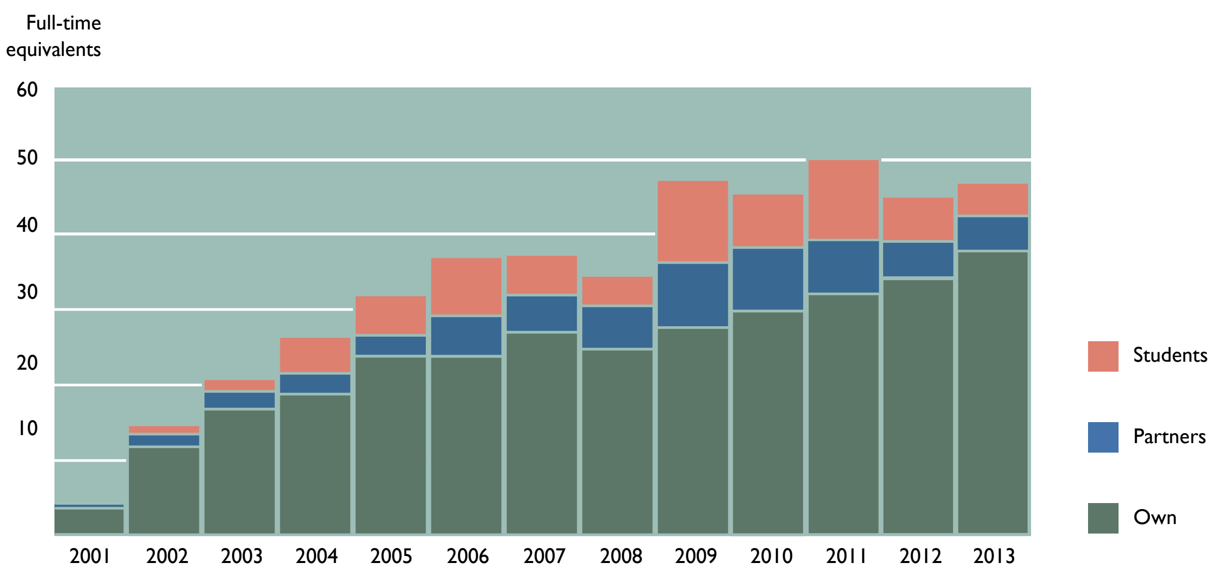
Total income

In 2013, the total income increased to thirty-eight million Swedish crowns or over four million euros which was once more all-time-high. The result was a 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 2013 forty-one percent from industrial projects, thirty-seven percent public funding, and twenty-two percent basic funding from the founders. The public funding includes sixteen percent from public projects under industrial command and twenty-one percent from public grants. Compared to the previous year we had an increase of industrial projects and public projects under industrial command, and a small decrease of public grants.

The last three years show a decrease of basic funding due to the stronger Swedish crown relative to the euro.

Facts and Figures



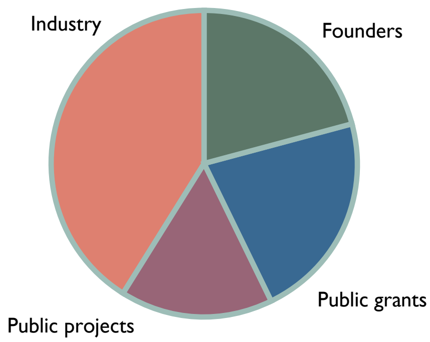
Staff – full-time equivalents

The number of staff 2013 was 47 full-time equivalents (FTE) including own staff (38 FTE), students (4 FTE), and partners (5 FTE). We were happy to recruit eight new coworkers, four of which were previously contracted students. The number of students was 16 (4 FTE) including 3 female students: 5 (2 FTE) doing their master thesis projects, 10 (1 FTE) students in Master's programs contracted on 10-20% for project work and 1 (1 FTE) industrial PhD student. The Centre has 3 (2,5 FTE) own staff-members in the Chalmers two-year licentiate programme "Advanced Engineering Mathematics" started in September 2012.

Project mix by income 2013

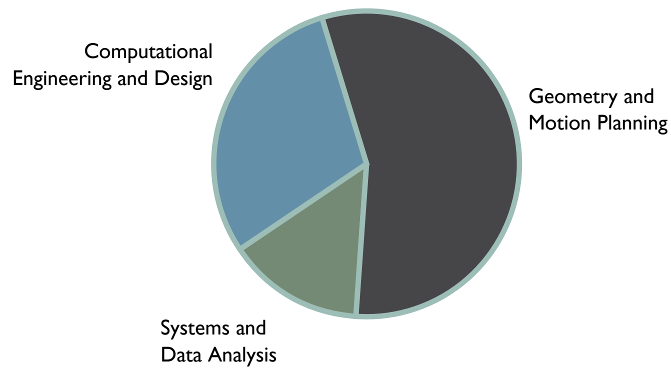
The profile of the Centre is controlled by its income structure. We distinguish between four categories: industrial projects, public projects (under industrial command), public grants, and basic funding. In 2013, these four were in good balance showing a clear industrial profile:

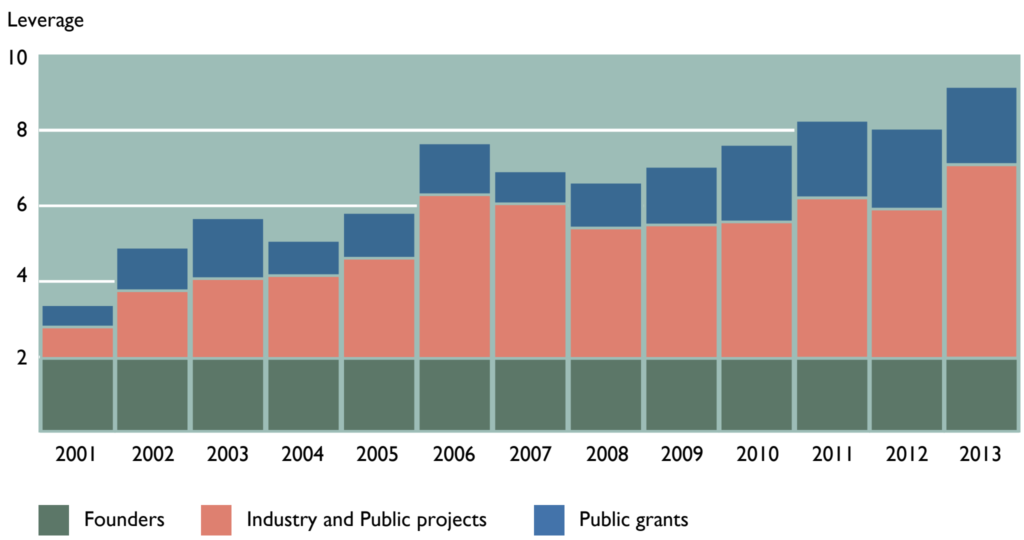
Industry (41%),
Public projects (16%),
Public grants (21%),
Fraunhofer and
Chalmers (22%).



Departments by income 2013

The Centre has three departments. Their relative income was 54%, 29%, and 14% of the grand total including 10% transfer projects between departments.





Central services

Jenny Ekenberg, MSc
Economy and IT

Annika Eriksson
Administration and Personnel

Julia Franzén
Assistant

Fraunhofer ITWM and Chalmers exchange on basic funding

The basic funding to FCC is equally shared between Fraunhofer and Chalmers, in 2013 being 0.5 million euros from each founder.

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

The collaboration also includes exchange of technology and joint projects with ITWM and 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 forty-six staff members and sixteen students in Chalmers Science Park.

IMMA - Intelligent

Better ergonomics in assembly plants reduce work related operator injuries, improve quality, productivity and reduce cost. Motivated by this, new methods, algorithms and software tools for fast and easy evaluation of assembly ergonomics considering human diversity have been developed in the IMMA project.
The IMMA project has successfully combined advanced mathematics, ergonomics, and virtual product realization. The project was part of the SSF ProViking Program and involved researchers from FCC, Wingquist Laboratory VINN Excellence Centre at Chalmers and Virtual Ergonomic Centre, in close collaboration with our industrial partners Volvo Car Corporation, Scania, AB Volvo, and Virtual Manufacturing.

ly Moving Manikins

The ergonomics in assembly operations are indeed an important factor to keep workers healthy and to avoid injuries and maintain productivity and production quality. A bad layout of an assembly station, a poor product design or badly chosen assembly sequences are all common sources that are known to result in awkward and uncomfortable assembly motions. To prevent these problems, it is important that the assembly operations are investigated in an early stage of the product and production system design phase. In this stage, it is less costly to change the design to improve the ergonomics. If the ergonomics are considered in a latter development stage, then the analysis may have a lower impact since most of the design parameters already have been decided. In general, the cost of making changes to product and production systems increases as the development process goes on. Thus, to ensure that the assembly ergonomics are considered early in a project, there is a need of tools that makes it easy to study feasibility and ergonomics in virtual environments.

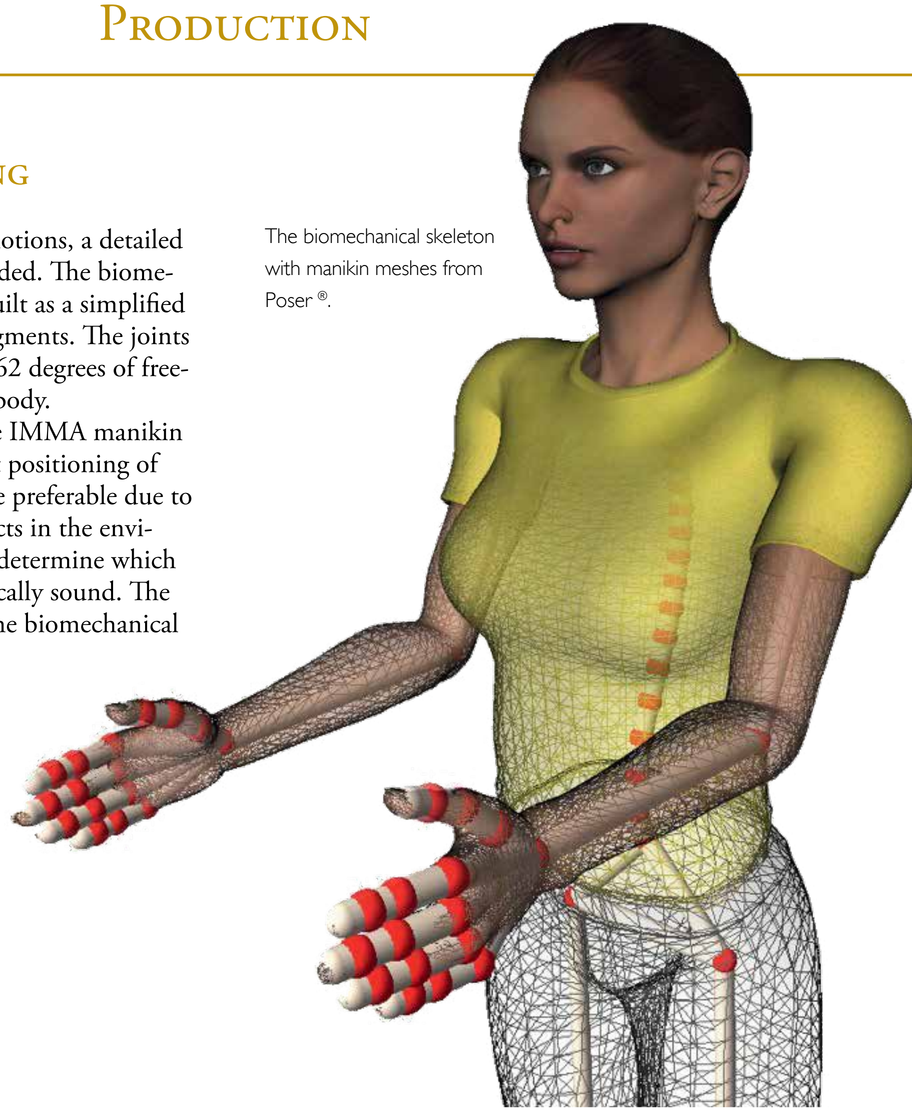
In industry today, ergonomic studies of assembly operations are conducted to some extent. The full potential, however, is far from reached due to limited software support in terms of capability for easy creation of realistic assembly motions and taking the intended population of workers into consideration. As a consequence, the ergonomic studies are time consuming and are mostly done with only a few manikins in static positions, instead of studying the full assembly motion with a set of manikins that with high confidence represent the intended work force.

To resolve these shortcomings, a digital human modeling tool, IMMA, has been developed in close collaboration with the Swedish vehicle industry. The main goal was to develop a fast and easy software tool that (i) automatically finds a collision free assembly for manual operations with as low biomechanical load as possible, and (ii) considers human diversity.

Motion planning

To automatically create manual assembly motions, a detailed modeling of human body kinematics is needed. The biomechanical model of the IMMA manikin is built as a simplified human skeleton and consists of 82 bone segments. The joints in the biomechanical model have in total 162 degrees of freedom to represent the mobility of a human body.

Similar to a human, it is possible for the IMMA manikin to perform assembly motions with different positioning of the body. However, not all positions may be preferable due to ergonomics or unwanted contact with objects in the environment. A comfort function is defined to determine which positions of the manikin that are ergonomically sound. The comfort is based on ergonomic criteria of the biomechanical model and has been formalized to fit the mathematical framework of IMMA. In this way, it is possible to automatically rule out the positions that are not seen as comfortable for the manikin when generating assembly motions.

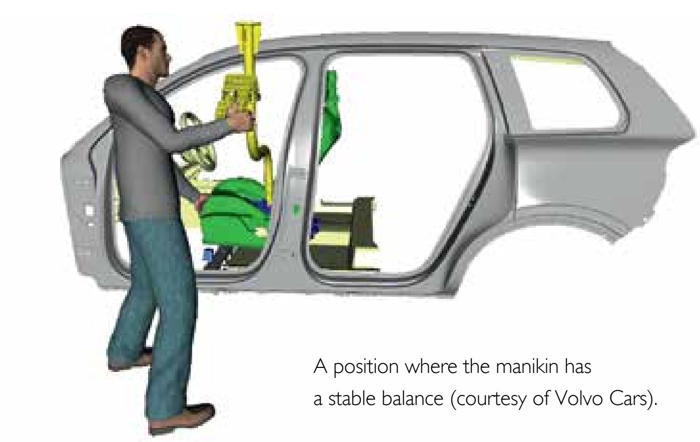


The biomechanical skeleton with manikin meshes from Poser ®.

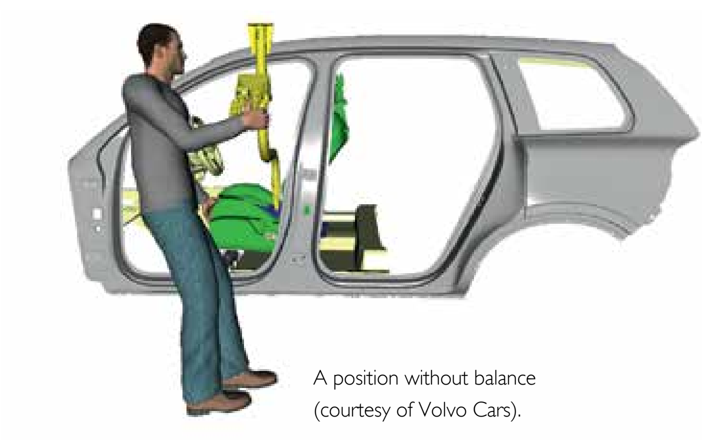
The assembling of an engine (courtesy of AB Volvo).

A generic framework creates a tight coupling between powerful algorithms for collision-free path planning and the biomechanical model. In this way, kinematic constraints, balance, contact forces, collision avoidance and comfort are taken into account in the generated assembly motions. The framework allows the manikin to work in different postures and interact with the environment.

An IMMA manikin always maintains its balance and tries to find a position that ensures that the balance is stable. To, e.g., avoid a collision, the manikin may need to perform a swift repositioning, and with a stable position, the manikin may perform such motions without losing the balance. The weight of the body and objects being carried is automatically distributed on the contact points between the manikin and the environment. Mostly, the feet of the manikin will be used as contact points. However, IMMA allows the user to define arbitrary contact points on the biomechanical skeleton. It is, e.g., possible for the manikin to support with the legs or a hand when it is leaning over objects.



A position where the manikin has a stable balance (courtesy of Volvo Cars).

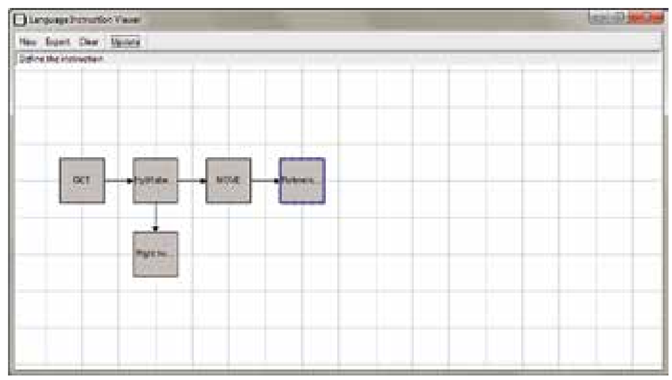


A position without balance (courtesy of Volvo Cars).

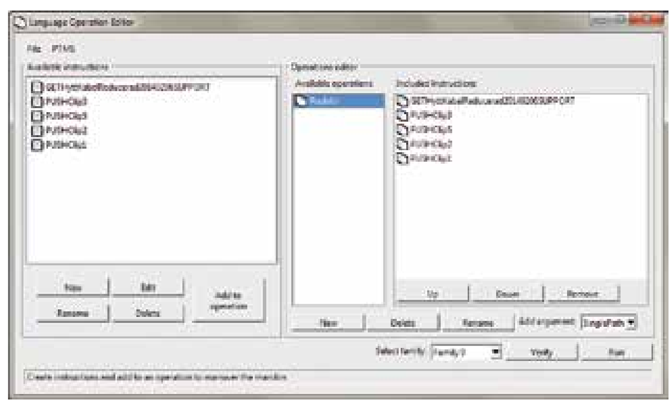
It is important that the generated assembly motions are collision free since the assembly operations are made mostly in tight and narrow regions. In the IMMA tool, the manikin automatically avoids both self collision and collision with objects in the environment.

Instruction language

In order for a user to easily perform an assembly simulation, the IMMA manikin can be instructed with a high level instruction language. Inspired by the methods used to instruct human assembly workers, the manikin is instructed with sentences similar to human assembly instructions. This is possible since the whole assembly station is modeled as a discrete event system that utilizes the automatic features of the IMMA manikin.



Construction of an assembly instruction.



A sequence of instructions may be grouped into an assembly operation.

An operation where the manikin assembles a cable into the chassis (courtesy of Scania).

The model defines the set of instructions that are available for the user to instruct the manikin. The set of available instructions that the manikin may perform during a simulation depends on the current state of the manikin and on the state of the objects in the assembly station. If, e.g., the manikin grasps an object with both hands, then it is impossible for the manikin to grasp another object unless the current object first is released.

The language uses high and low-level instructions to control the manikin. A grammar structures the different instruction levels into a hierarchical tree where the lowest level in the tree contains basic instructions for maneuvering the manikin and the higher levels contain more abstract instructions. Thus, a high-level instruction is used to define sequences of other instructions, whereas a low-level instruction corresponds to a direct instruction to the manikin.

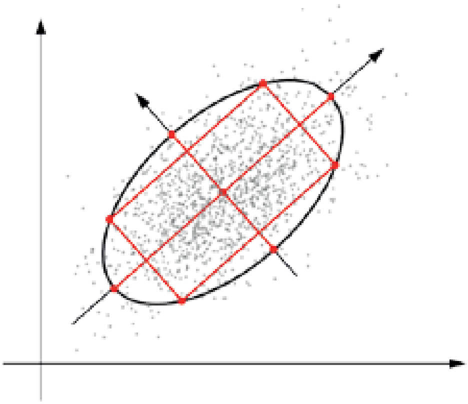
Based on the instructions from the user and on the state of the model, all the low-level instructions needed for the manikin to perform the tasks are automatically created. Since the instruction language, the manikin and the objects to be assembled are composed into the same computational model, it is verified that the instructions may be executed and thereby prohibit the user to instruct the manikin with contradictory tasks. Furthermore, this also makes it possible to apply formal methods to prove that the constructed assembly sequences do not violate any model specifications such as assembly order or physical constrains.

Anthropometric

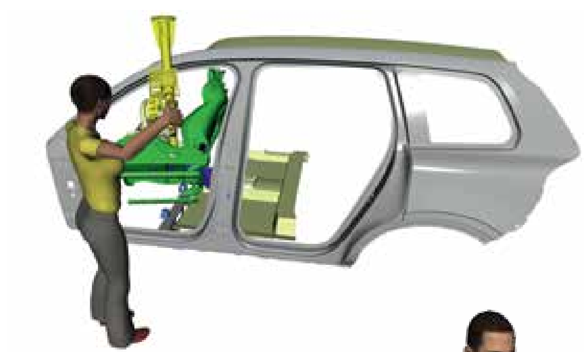
The human comes in many different sizes and to simulate this, IMMA offers the possibility to create individual manikins specified by different body measurements. An IMMA manikin is generated out of 56 anatomical variables. However, a user only has to specify the measurements of interest, and all other measurements needed are thereafter estimated based on an anthropometric data set.

It is important that the anthropometric difference of a population is considered when designing product and production systems. It is easy to simulate with several manikins in IMMA, called families. A manikin family is instructed as a single manikin and may consist of manikins of arbitrary size and gender. In this way, an assembly operation is evaluated with a broad range of different anthropometric variance. Moreover, different assembly motions may require different families to ensure that the variances with respect to the assembly specific anthropometric variables are covered.

To encourage the engineer to use manikin families without being an expert in the field of ergonomics, extensive research has been carried out to find easy to use sample methods. IMMA is a user friendly tool that aids the user in creating families that accommodates the intended population performing assembly operations.



A manikin family is constructed to accommodate the majority of the population.

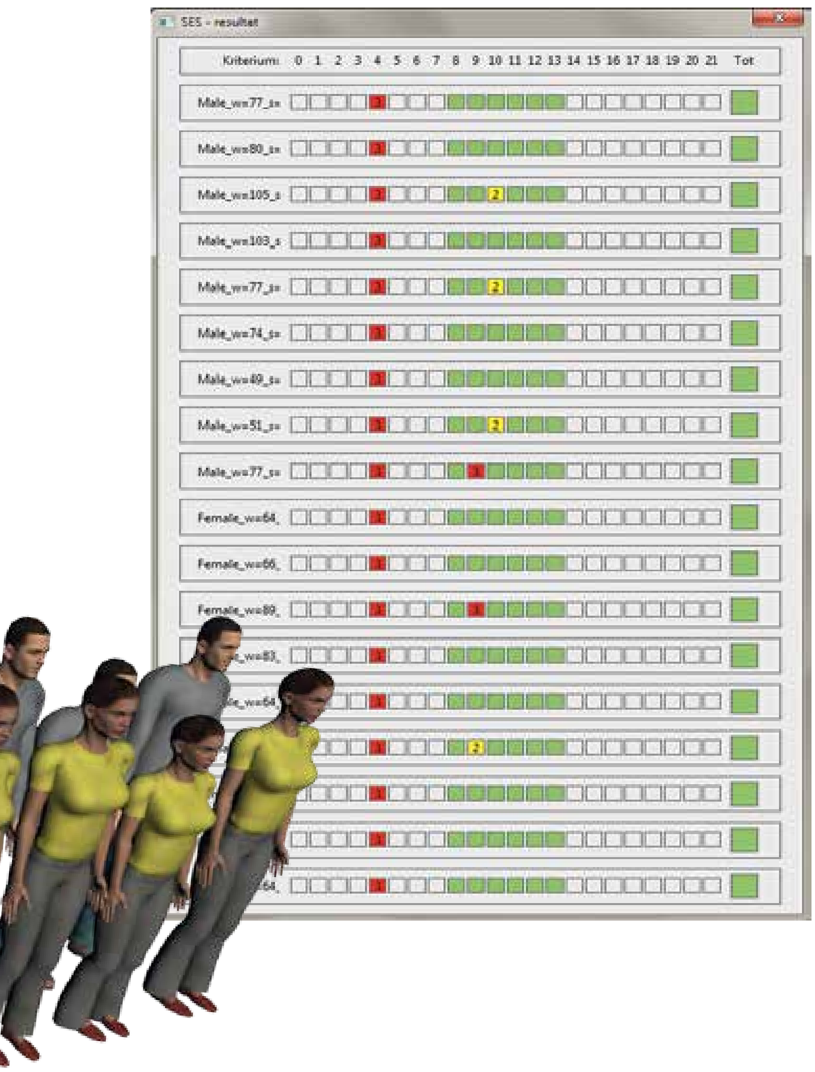


Each member of the family automatically performs the assembly instructions (courtesy of Volvo Cars).

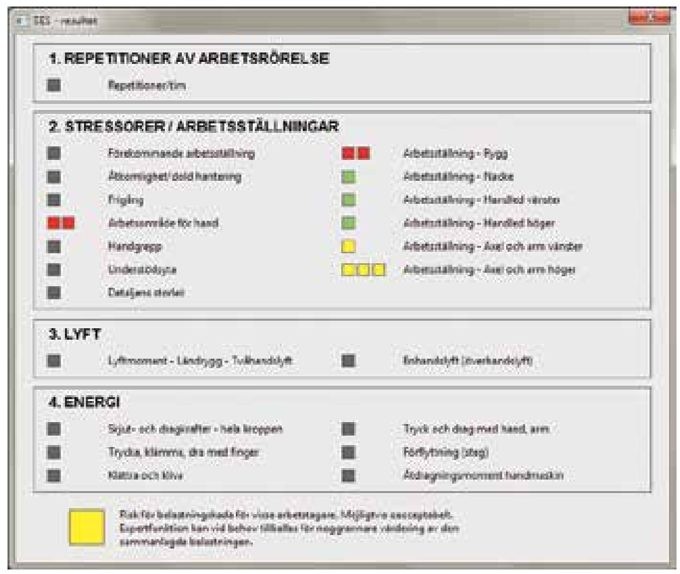
A manikin family

Ergonomic assessment

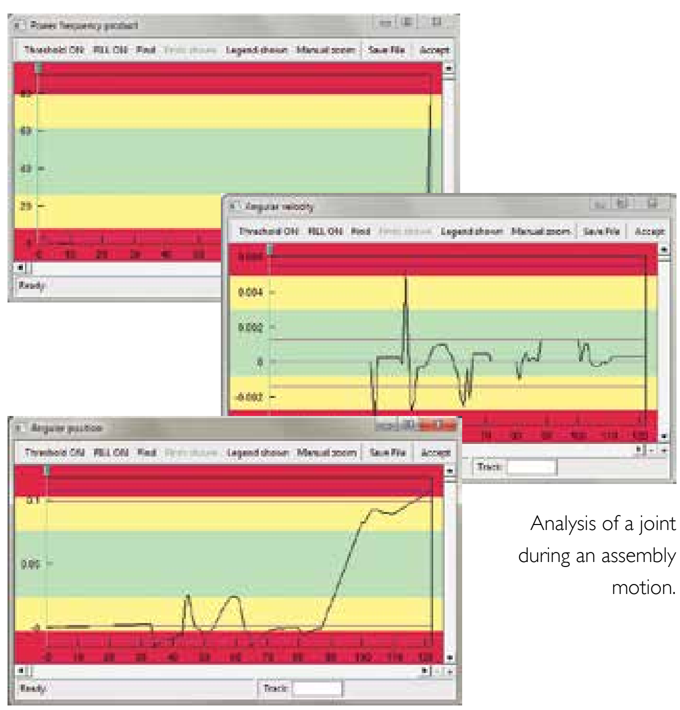
Two common ergonomic assessment methods used in industry today have been implemented in the IMMA software. The methods are integrated into the biomechanical framework of the IMMA manikin. This integration reduces the time needed for a user to analyze a simulation and allows non-experts to easily pick up and perform quick evaluation of assembly simulations. Since the users that perform the ergonomic evaluation have different background and experience, there is always a risk for non confirming classification of an assembly motion. With assessment methods integrated in the IMMA manikin, the simulations will always achieve the same classification, regardless of the user.



Moreover, since it in IMMA is possible to evaluate whole assembly motions, it is also possible to extract measurements as, e.g., joint angles, velocities, and accelerations of the biomechanical skeleton for free. Measurements, which previously only were possible to extract from human workers, are now available in an early stage of the project. Methods based on frequency analysis of simulated motions and correlation analyses with epidemiological data from different professions are developed. This brings us closer to a method for predicting the probability that the studied assembly operation will result in a future injury.



The Scania Ergonomistandard for an individual manikin.



Analysis of a joint during an assembly motion.

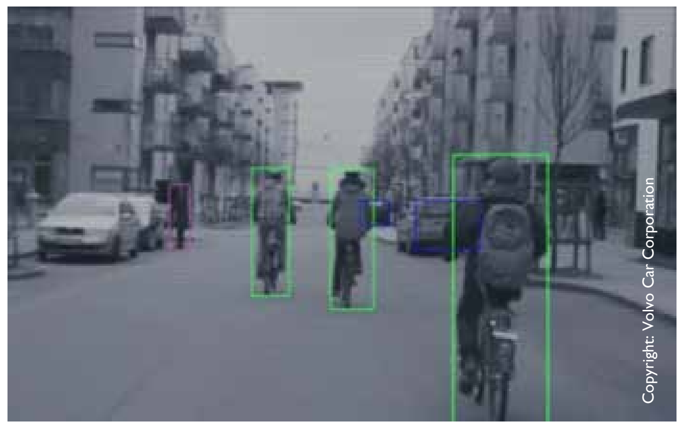
Modern automotive technology includes video cameras and automatic safety features, both autonomous systems and systems that include the driver. One critical element is to display the surrounding scene of the car as clearly as possible for the driver, with the help of cameras and advanced video processing, so that appropriate action can be taken. In a project together with Volvo Car Corporation, Chalmers, and Epsilon a video enhancement algorithm based on fusion of video signals from two different sources has been developed from initial concept to a fully functional demonstration implementation in hardware including Volvo Car Corporation's next generation driver display.

Real-Time Video for Automotiv

Enhanced video display can be combined with automatic systems for detecting dangers and automatic counter measures like auto-breaking. However, in many situations the best approach is to just issue a warning of a danger and let the driver take appropriate action. For this to be possible a clear, and sometimes artificially enhanced, view of the situation must be given.

The next generation in-car display, featuring a mode for visualization of road and surroundings using enhanced real time video processing. (Photomontage, original image courtesy of Volvo Cars.)

Automatically detected cars, cyclists and pedestrians.



In many situations where dangerous events may occur, such as during night driving, or when strong light sources are present, the direct camera output is often of limited use and advanced real time post-processing is needed before presenting the video to the driver. In this way the quality of the response action can be improved, by giving the driver better information. Infrared cameras can be used to detect people or animals at night but to get a clear view of the entire situation further video enhancement is needed.

O ENHANCEMENT
VE APPLICATIONS

In a VINNOVA FFI-project carried out in cooperation with Volvo Car Corporation, Epsilon Embedded, and Chalmers, FCC has developed an automatic algorithm for real time video enhancement based on fusion of regular and infrared video signals. The improvement is dramatic and makes it possible for the driver to get an enhanced view of both the road and its surroundings, even given very poor conditions in complex environments. The algorithm can handle changing conditions and automatically combines improved image quality in dark areas and in areas flooded with bright light.

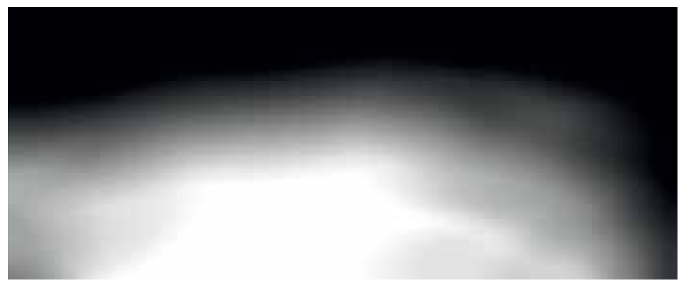
The video enhancement algorithm consists of a combination of among other things: local adaptive contrast enhancement, noise reduction, light normalization, and fusion of video streams with and without infrared flash.

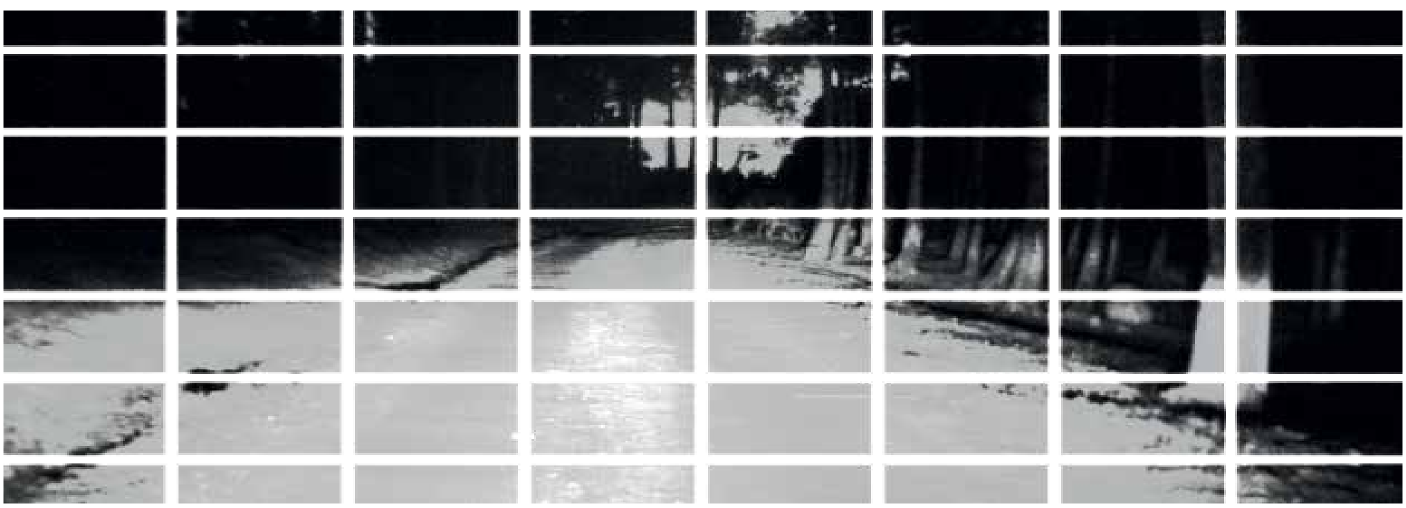
Several state of the art algorithms were initially evaluated but the resulting videos were found to be of insufficient quality. This called for a novel approach, using a combination of available methods and custom developed algorithms. Key components include Contrast Limited Adaptive Histogram Equalization (CLAHE), Video Block Matching 3D (VBM3D) and tone-mapping.

Histogram Equalization is a well established contrast enhancement technique. Contrast Limited Adaptive Histogram Equalization (CLAHE) is a version of this technique that is local in nature with less amplification of noise.

When amplifying dark video and enhancing contrast, noise is also amplified, and noise reduction is necessary. The noise reduction in this case is mainly the result of a sub-algorithm known as VBM3D (Video Block Matching 3D), which works by identifying similar small parts of an image from the current or neighboring frames of the video, building a 3D structure of those image parts and then performing a transform based noise reduction before writing processed parts back into the image.

Using an infrared flash gives better image information in dark areas but well lit areas will actually become worse. Therefore the method utilizes two video streams, one with flash and one without. The two streams are combined by using a continuously updated weight map of what parts of the image are bright and what parts are dark.

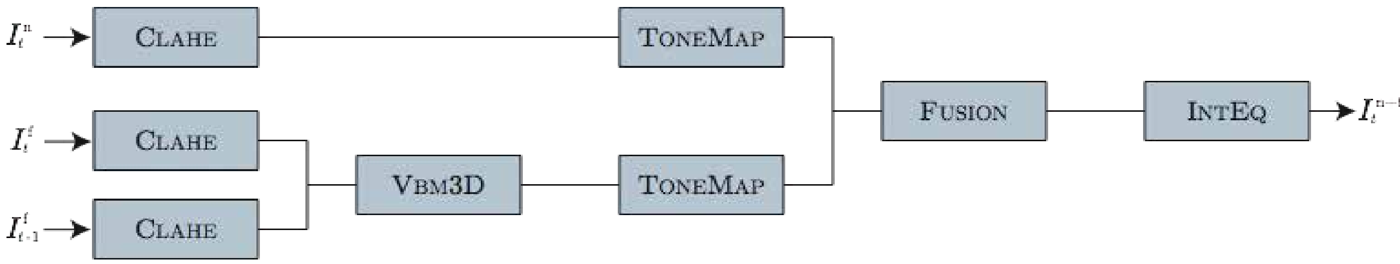




Histogram Equalization, HE
- Redistributes pixel intensities evenly among all intensity values

Adaptive HE, AHE
- Splits the image into tiles and performs HE on each tile
- A pixels intensity is then determined by interpolation

Contrast Limited AHE, CLAHE
- Clips bars of the histogram exceeding a predefined limit
- Redistributes exceeding parts equally among all bars



Finally, object contrast is enhanced, making dangers visible and artificial light-condition-objects are removed (for example the bright oval cast by the headlights). In order to do this, light patterns that are stable as the car moves are calculated and the image is then normalize based on these light patterns. This removes the oval cast by the headlights but preserves real objects.

The overall algorithm is described in the diagram above.

First, all images undergo contrast enhancement (CLAHE). Next, noise reduction (VBM3D) is performed, which focuses on the flash video stream. This is motivated by its use for the darker areas, where large noise is present. Note also that the noise reduction uses not only the current image but also the previous image. Then there is a tone mapping step, which performs an overall amplification of darker areas. After that the two video streams are fused into one and finally, stable brightness patterns like headlights are removed in an intensity equalization step.

The results were presented both internally at Volvo Car Corporation and in different forums like Innovation Bazaar, a series of local networking events at Chalmers Lindholmen arranged by Vehicle ICT Arena, and at Transportforum, the main Nordic conference for the transportation sector, and has been very well received by the automotive industry.

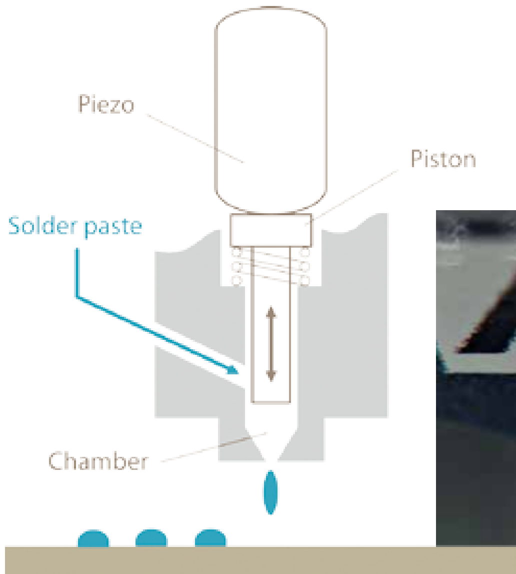
Partners: VINNOVA (FFI 2009-00071), Volvo Car Corporation, FCC, Epsilon, and Chalmers.

Image captured using the cars headlights as light source during night driving. At this point the animals are barely visible even if you know they are there and it is very difficult to take appropriate action (courtesy of Volvo Cars).

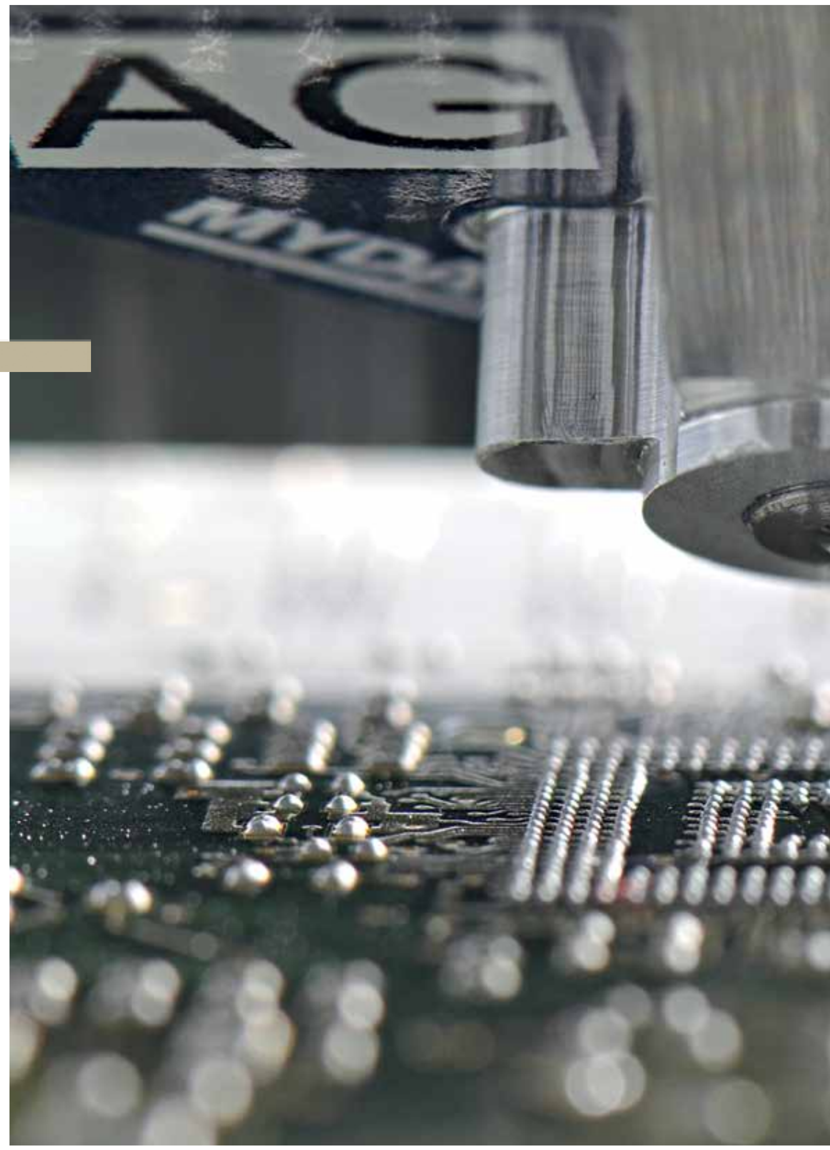
Using an infrared flash helps a little, but the situation is still not very clear. Dark areas are improved, but instead other areas are just white (courtesy of Volvo Cars).

The output from the video enhancing algorithm is dramatically better. All parts of the scene are clearly represented and it is easier to take appropriate action. Using the enhanced video output, the animals can easily be seen much earlier.

Simulation of j
solder paste onto a p

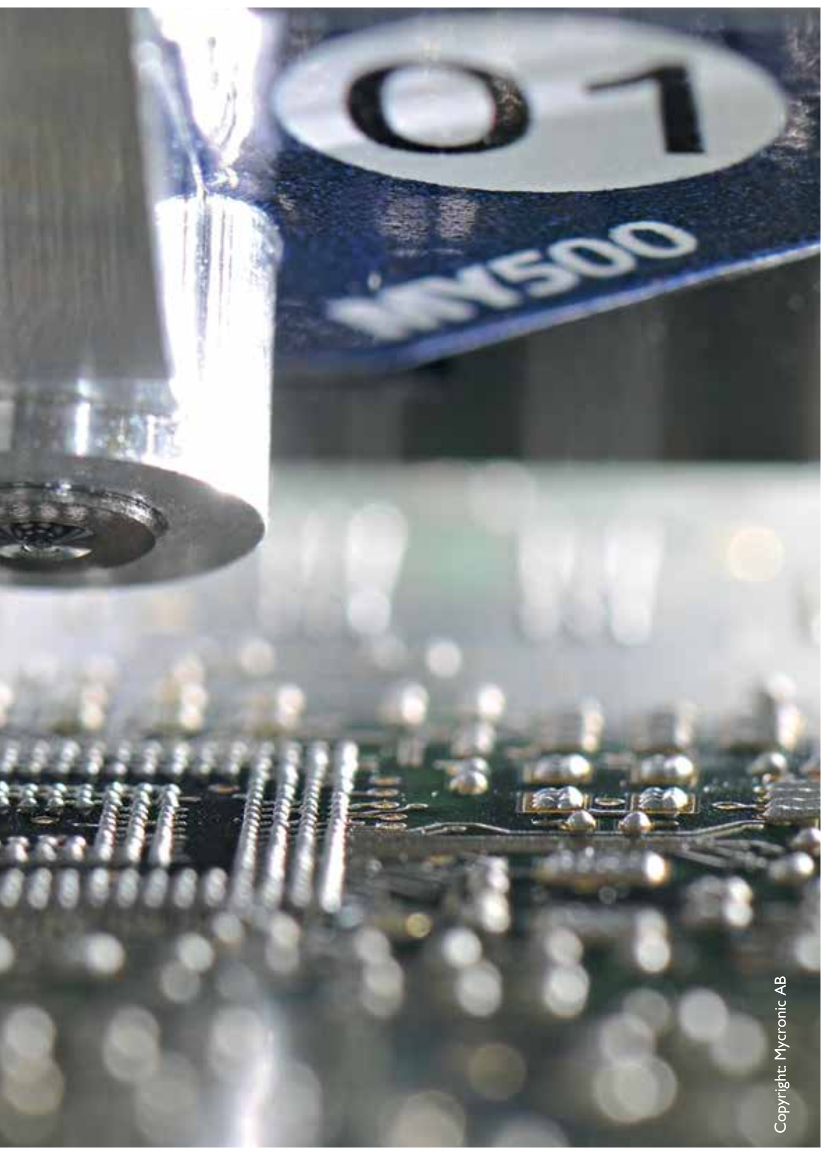


Schematic picture of a MY500 jet printer (courtesy of Mycronic AB).



In close collaboration with the company Mycronic AB, FCC is developing a novel software for simulation of the jet printing process used in the manufacturing of printed circuit boards. The software makes it possible for Mycronic to strengthen their knowledge of the complex jetting process and is supporting their product development of the next generation of jet printers.

JET PRINTING OF RINTED CIRCUIT BOARD



In 1965, Gordon E. Moore observed the trend in the electronics industry that the number of transistors per integrated circuit doubles approximately every two years and made the prediction that this would continue also in the future. His prediction has proved to be more or less valid for almost five decades now, mainly driven by the tough competition between manufacturers that continuously push the development of electronic components to be smaller and faster. This rapid development could hardly have been sustained without efficient, flexible and highly accurate manufacturing methods, which, in turn, requires a thorough understanding of the process of mounting components onto the PCB (printed circuit board).

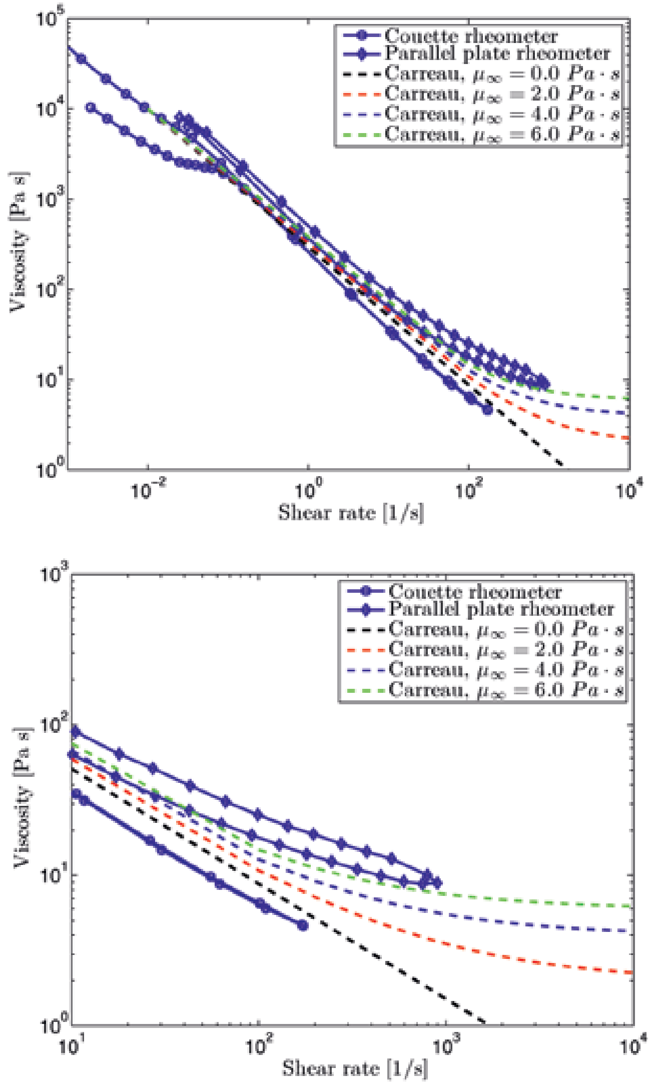
Before the components can be mounted, solder is applied onto the PCB. The components are then placed on their specific positions on the board with a placement robot and the PCB is heated such that the solder paste melts, adheres to the metallized pad and component and then finally cools to a solid joint. Mycronic has with the MY500 series the capability to perform high precision jet printing of solder paste onto the PCB while the printer head is in motion. In this way they can produce a given pattern at higher speed than what would be possible with conventional methods. The driving force in the jet printer is a piezo element that expands rapidly when subjected to an electrical signal and causes a piston to accelerate. The movement of the piston results in a sudden increase of the pressure in the chamber, containing the solder paste, forcing the fluid to squeeze through the printing head nozzle. When the signal is cut off the piezo element retracts and the pressure decreases again. At this point, the momentum of the fluid is large enough to form a droplet that will travel through the air and impact on the PCB. This technique requires knowledge of the flow conditions inside the printer head, how the material behaves under these conditions and which parameters that affect the droplet formation as the solder paste deposits from the printer head.

The solder paste consists of a mixture of solid granules and flux which makes the rheology of the fluid different from Newtonian fluids. Due to structural reorganization of the granules when subjected to deformation, the solder paste shows both visco-elastic and shear thinning behavior, meaning that the viscosity is dependent on the rate of deformation and on the time scales of the process. This non-Newtonian behavior is essential for the result of the jet printer. Due to the complexity of the solder paste and the small time and spatial scales of the process it is difficult to acquire experimental data of the jetting sequence. To perform simulations instead is an attractive alternative, but very challenging due to the large acceleration of the piston and strong fluid-structure interaction between the piston and the solder paste.

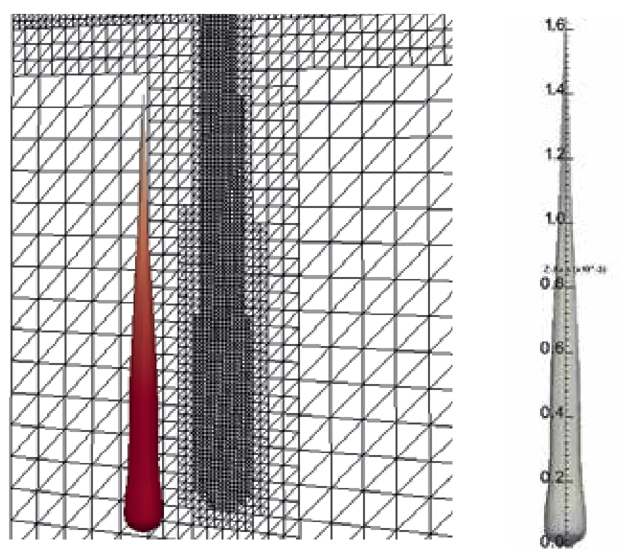
The simulations of the ejection and formation of the solder paste droplet are successfully performed with our in-house software IBOFlow (Immersed Boundary Octree Flow solver) coupled with LaStFEM (Large Strain FEM solver). The immersed boundary techniques and adaptive octree grids simplify the simulation setup and are perfectly suited for handling the complex fluid-structure interaction. The solder paste is modeled as a generalized Newtonian fluid with a time dependent Carreau model that takes both the visco-elastic and shear thinning behavior into account.

Simulations show that the jet printing process is sensitive to material parameters such as surface tension and viscosity. In particular, the viscosity at high shear rates is important in the early jetting sequence, while the surface tension is more important for the droplet formation after the actual jetting event. Different piezo signals affect not only the droplet velocity and size, but also the filament breakup and formation of satellite droplets. The software's ability to capture this is very promising since it is crucial for the quality of the solder joint. The detailed modeling and short simulation times make it possible for Mycronic to use the software to gain better knowledge of the jetting process and in their development of the next generation of jet printers.

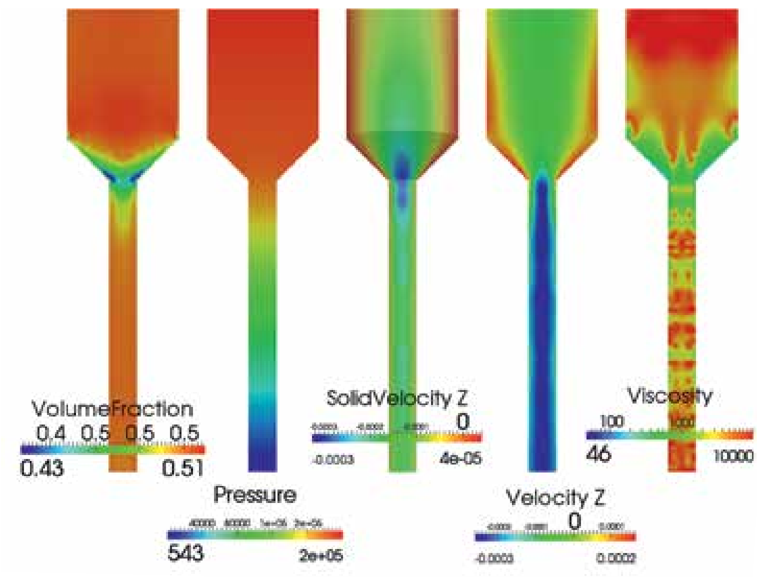
In 2014, the work will for example include what happens with the material rheology before and in between the actual jetting events and how this affects the subsequent jetting. We also believe that a thorough understanding of the material properties is essential to the jetting performance and we will therefore continue our work on the rheology of complex fluids and improve our material models. This work also contributes to our ongoing efforts on simulation of laydown of sealing and adhesive materials.



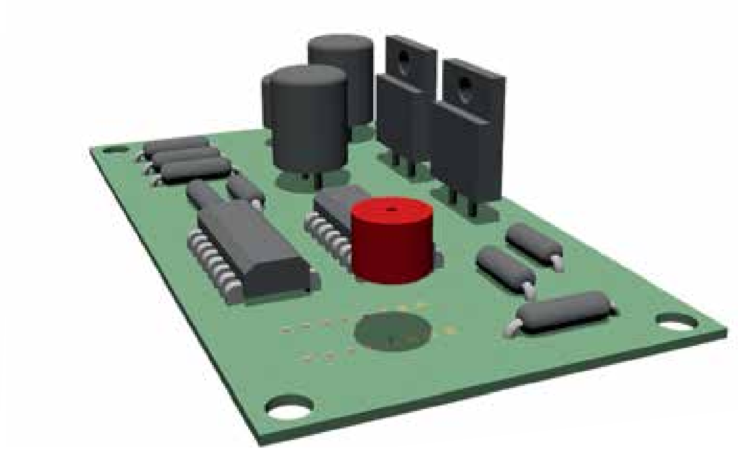
Model and experimental viscosity of a solder paste as a function of shear rate under a shear sweep rheology test. The rheological model is compared to the results from both a Couette and a parallel plate rheometer. The dashed lines represent simulation results and the solid lines experimental data. In the simulations the infinite shear rate viscosity was varied between 0.0 and 6.0 Pa s.



Jetting simulation of solder paste. In the left part of the figure, the droplet and the adaptive octree mesh are shown together with parts of the computational domain. The right part of the figure shows the droplet's size in millimeter after ejection.

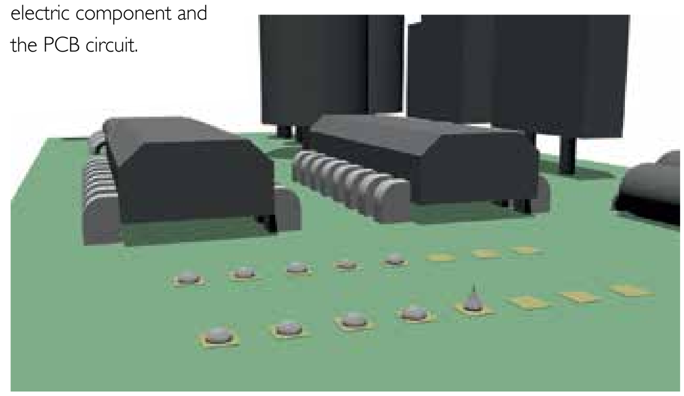


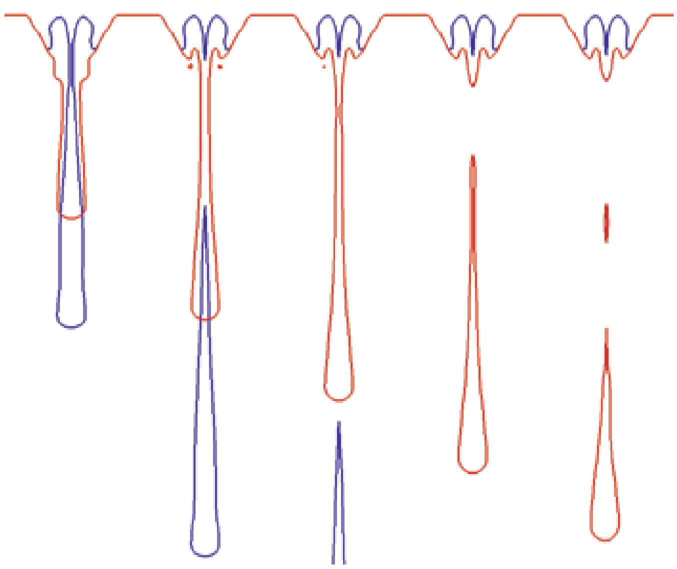
Simulation of the granular solder paste suspension with an applied pressure drop of two bars using Foscolo's pressure model.



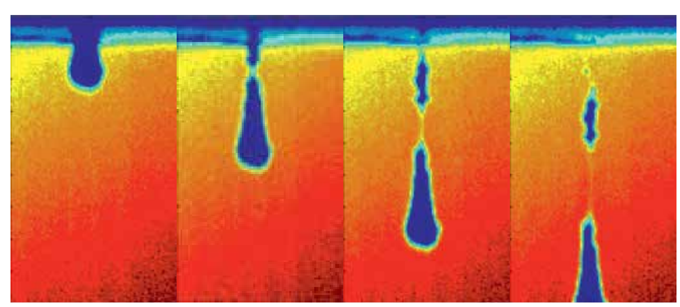
Simulation of jet printing on a PCB. The printer head is illustrated in red and the solder paste is coloured grey.

Close up of jet printing simulation on a PCB. The solder paste is ejected on the PCB in a certain pattern. In the next step of the process these droplets will form the solder joint between the electric component and the PCB circuit.





Simulated droplet shapes for two different piezo signals. For the first signal (blue), the droplet remains intact during the entire jetting sequence but for the second signal the filament breaks up into one main droplet that is followed by a satellite droplet.



The droplet formation during the jetting sequence captured by a high speed camera. The filament breaks into one main droplet that is followed by a satellite droplet (courtesy of Mycronic AB).

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 2013, 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
- Geometry Assurance and Inspection
- Computer Graphics

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

Geometry and M

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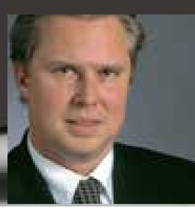

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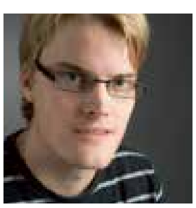

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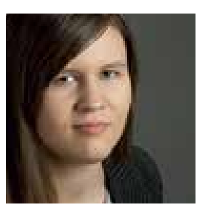

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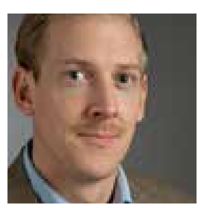

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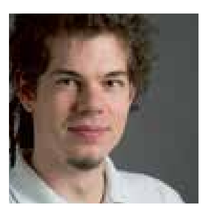

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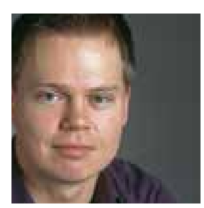

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Klas Engström
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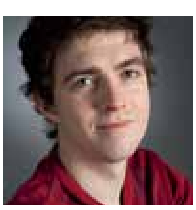

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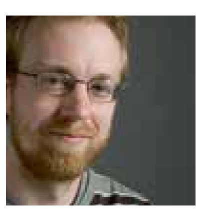

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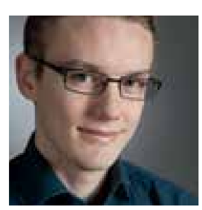

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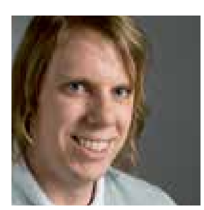

Peter Mårdberg
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to solve geometrically complex manufacturing problems in mere minutes instead of hours or days. The strength of the mathematical algorithms in combination with the easy user interface has allowed the path planning technology to be spread 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 Car Corporation and showing a 25 percent 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.

Motion Planning

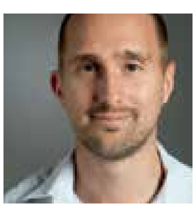
Cooperation

During 2013, 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.

Acknowledgement

In 2013, 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.

The Geometry and Motion Planning Research Group



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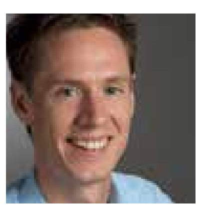
Roland Roll
Marketing and sales



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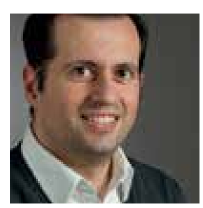

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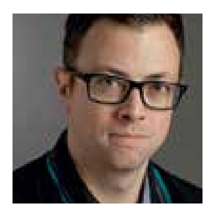

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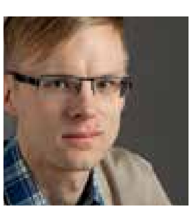

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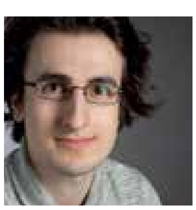

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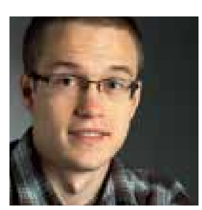

Thomas Bååth Sjöblom
Contracted student

David Eriksson
MSc student

John Isaksson
MSc student

Cooperation

During 2013, 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, Product Development, Biomedical Engineering and Nuclear Engineering.

Acknowledgement

In 2013, 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, from Åforsk, and from the Swedish Research Council (VR) for participation in a project on novel methods for safety analyses of future and existing reactors.

Computational Engineering and Design

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 2013 were the GPU parallelization of the linear algebra package using CUDA that resulted in a significant speed-up for many applications and the project with Mycronic AB where the scope was extended to multi-phase simulation of a solder jetting device with strong fluid structure interaction (see pages 16-19). Furthermore, the efforts on simulation of paint and surface treatment processes in automotive paint shops continued with successful validation campaigns and will during the spring 2014 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 is showing promising results during 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 the research platform is our finite element based 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. During 2013, the software was extended to allow for simulation of welding processes and deformation of composite materials in projects together with Chalmers PPU. Complex fluid-structure interaction applications are efficiently simulated through a coupling to 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 2013 was EEG-based localization of epileptic foci in the human brain.

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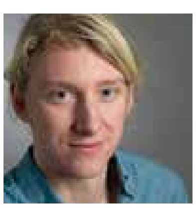

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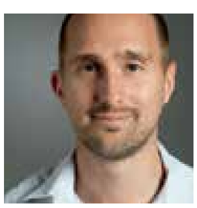

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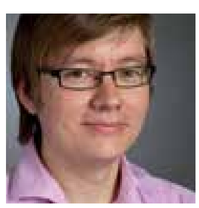

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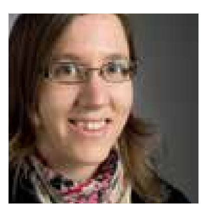

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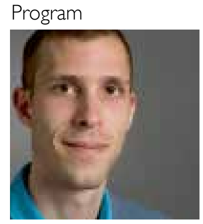

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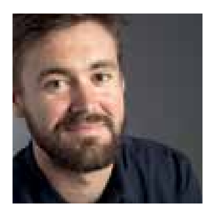

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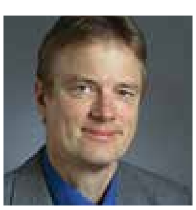

Anders Ålund
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Gustav Kettil
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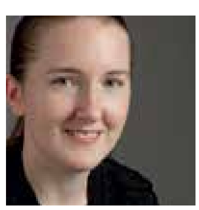

Johanna Matsfelt
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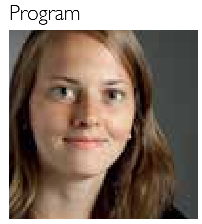

Frida Svelander
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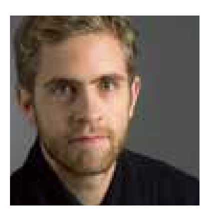

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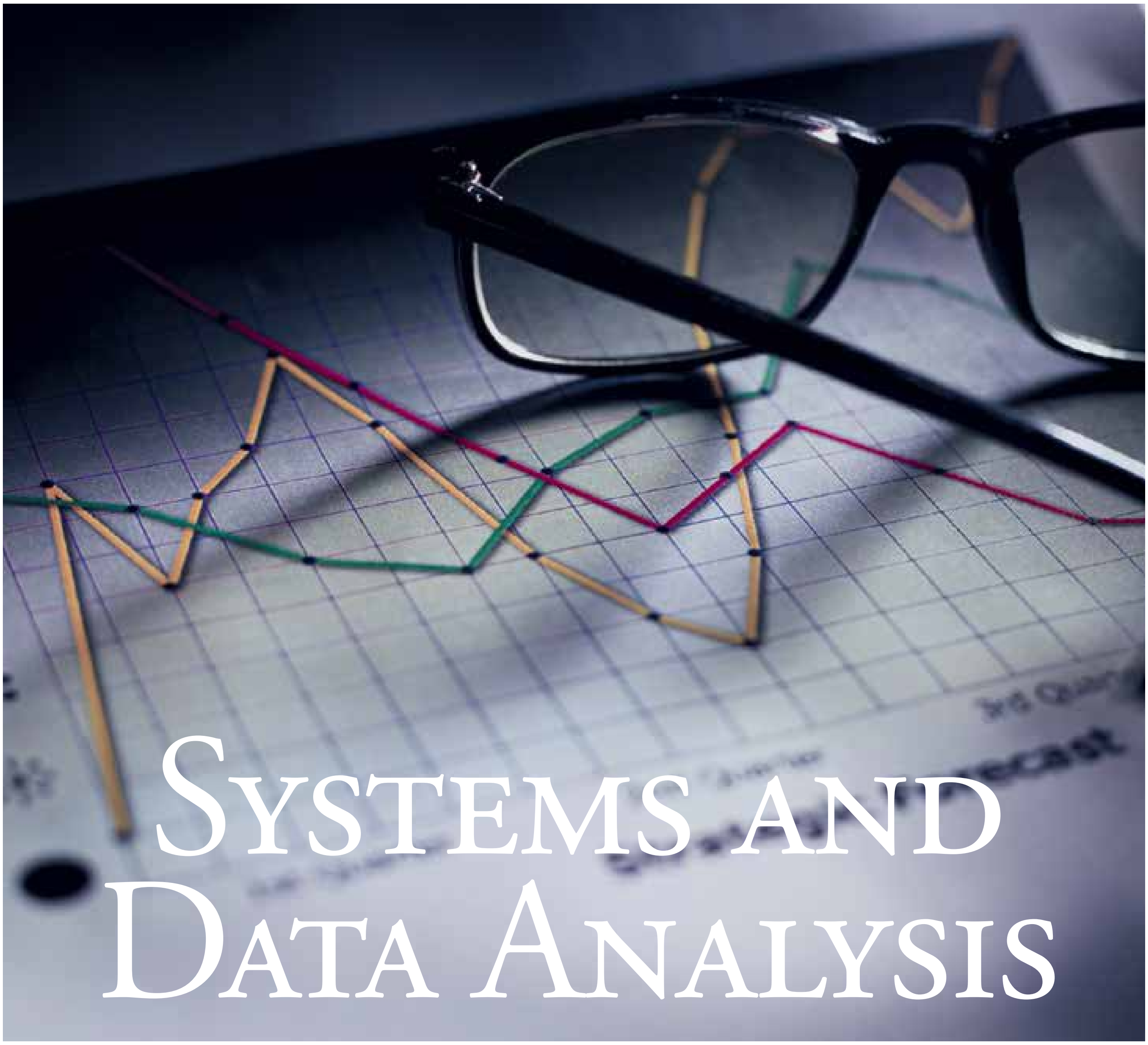

Systems and Data Analysis

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.

The Systems and Data Analysis Research Group

Acknowledgement

In 2013, the Systems and Data Analysis department has received funding for the UNICELLSYS, project from the European Commission. We have also participated in projects funded by Västra Götalandsregionen (Acosense, FoU kort) and VINNOVA (Acosense, Forska&Väx).

Cooperation

We have very close collaboration with the Swedish company InNetics. Other collaborations include joint work with 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; General Zoology at Kaiserslautern University; the Department of System Analysis, Prognosis and Control at Fraunhofer ITWM; and partners in the UNICELLSYS EU-project.

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 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 with Väderstad-Verken and robust regression on acoustic transmission spectra for fluid property estimation with Acosense.

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 2013 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 2013 has found a number of new customers in both industry and academia. Another key activity has been the successfully completed project Visual Quality Measures with Volvo Car Corporation. We have also joined the Vehicle ICT Arena, which is an open environment for innovation and maintenance of competence within automotive IT.

We have also successfully completed our so far largest EU funded project during the year: UNICELLSYS – Eukaryotic unicellular organism biology – systems biology of the control of cell growth and proliferation.

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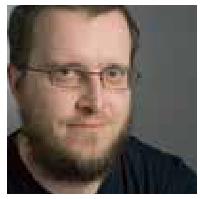

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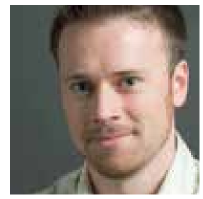
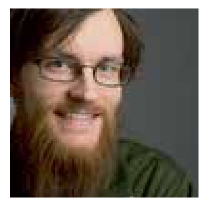


Joachim Almquist
MSc

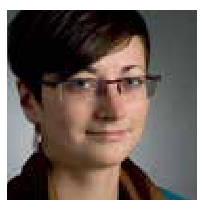
Jacob Leander, MSc
AEM Graduate Program

Mikael Wallman
PhD

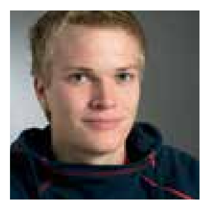


Kristoffer Andersson
MSc

Mats Kvarnström
PhD

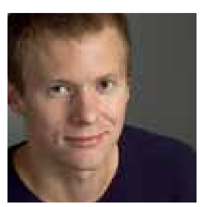


Sofia Tapani
PhD

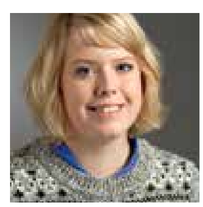


Robert Andersson
MSc, Marie Curie,
PhD student

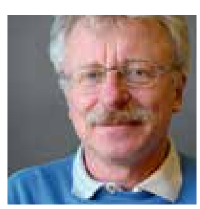
David Janzén
MSc, Marie Curie,
PhD student



Måns Larsson
Contracted student



Annie Westerlund
Contracted student



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

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

Årsredovisning

Styrelsen för Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik, FCC, får härmed avge följande redovisning över verksamheten under tiden 1 januari 2013 – 31 december 2013, stiftelsens tolfte verksamhetsår, med ny Föreståndare Johan S Carlson från 1 april 2013.

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 2013 tecknat fortsatt hyresavtal med Chalmersfastigheter AB omfattande 1 096 kvm i Teknikparken till och med den 31 mars 2017.

Chalmers och Fraunhofersällskapet har under året finansierat Stiftelsen med vardera 500 000 EUR.

Årets omsättning har varit drygt trettioåtta miljoner kronor. Antalet anställda och studenter har motsvarat 42 heltidsekvivalenter (FTE) varav 6 kvinnor. Antalet studenter utgörs av 5 (2 FTE) examensarbetare, 10 (1 FTE) studenter anställda på 10-20% för arbete i projekt och 1 (1 FTE) industridoktorand, totalt ca 4 FTE. Härutöver har arbete motsvarande cirka 5 FTE lagts ut på partners.

Resultaträkning

130101 – 131231, (kSEK)

Intäkter	
Nettoomsättning	38 550
Summa intäkter	38 550
Kostnader	
Externa kostnader	-9 418
Personalkostnader	-27 039
Avskrivningar av materiella anläggningstillgångar	-128
Summa kostnader	-36 585
Rörelseresultat	**1 965**
Resultat från finansiella investeringar	
Ränteintäkter och liknande resultatposter	268
Räntekostnader och liknande resultatposter	-103
Resultat efter finansiella poster	**2 130**
Bokslutsdispositioner	-578
Årets skatt	-415
Årets resultat	**1 137**

Balansräkning

131231, (kSEK)

Anläggningstillgångar	
Maskiner och inventarier	308
Summa anläggningstillgångar	308
Omsättningstillgångar	
Kundfordringar	6 174
Förutbetalda kostnader och upplupna intäkter	6 768
Övriga kortfristiga fordringar	1
Kassa och bank	3 377
Summa omsättningstillgångar	16 320
Summa tillgångar	**16 628**
Eget kapital	
Eget kapital vid årets ingång	3 463
Årets resultat	1 137
Summa eget kapital	4 600
Obeskattade reserver	1 346
Kortfristiga skulder	
Leverantörsskulder	2 918
Övriga kortfristiga skulder	1 023
Skatteskulder	288
Upplupna kostnader och förutbetalda intäkter	6 453
Summa kortfristiga skulder	10 682
Summa skulder och eget kapital	**16 628**

Rörelsens intäkter har uppgått till 38 550 kSEK (35 257 kSEK föregående år). Av detta utgör 41% (38%) industriprojekt, 16% (14%) offentliga projekt, 21% (24%) offentliga anslag och 22% (25%) finansiering från stiftarna. Årets resultat efter skatt är 1 137 kSEK (182 kSEK). Eget kapital uppgick den 31 december 2013 till 5 650 kSEK (4 029 kSEK) inkluderat kapitalandelen i obeskattade reserver.

Stiftelsens styrelse har under verksamhetsåret sammanträtt två gånger. Ersättning har utgått till ordföranden med 26 250 kronor och till övriga ledamöter med 17 500 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 26 mars 2014

Bo Johansson †
Helmut Neunzert
Dieter Prätzel-Wolters
Rikard Söderberg

Räkenskaperna har granskats av Deloitte

† *Till minne och saknaden av vår käre vän och styrelseledamot Bo Johansson. Vårt mångåriga samarbete och hans stora och tydliga engagemang för tillämpad och industriell matematik betyder mycket för oss.*

Fraunhofer-Chalmers Centre

Appendix

Journals

B Andersson, V Golovitchev, S Jakobsson, A Mark, F Edelvik, L Davidson, J S Carlson:
A Modified TAB Model for Simulation of Atomization in Rotary Bell Spray Painting, Journal of Mechanical Engineering and Automation, 3(2):54-61, 2013.

J S Carlson, D Spensieri, R Söderberg, R Bohlin, L Lindkvist:
Non-nominal path planning for robust robotic assembly, Journal of Manufacturing Systems, 10.1016/j.jmsy.2013.04.013.

J Gabrielsson, K Andersson, G Tobin, C Ingvast-Larsson, M Jirstrand:
Maxsim2 Real-time interactive simulations for computer-assisted teaching of pharmacokinetics and pharmacodynamics, Computer Methods and Programs in Biomedicine, Volume 113, Issue 3, pages 815-829, December 2013.

T Hermansson, J S Carlson, S Björkenstam, R Söderberg:
Geometric variation simulation and robust design for flexible cables and hoses, Journal of Engineering Manufacture, Volume 227, Issue 5, May 2013.

T Hermansson, R Bohlin, J S Carlson, R Söderberg:
Automatic assembly path planning for wiring harness installations, Journal of Manufacturing Systems, Available online, May 2013.

A Jansson, A Pernestig, P Nilsson, M Jirstrand, E Hultgren Hörnquist:
Toward quantifying the thymic dysfunctional state in mouse models of inflammatory bowel disease, Inflamm Bowel Dis. 2013 Mar-Apr;19(4):881-8.

A Krengel, J Hauth, M-R Taskinen, M Adiels, M Jirstrand:
A continuous-time adaptive particle filter for estimations under measurement time uncertainties with an application to a plasma-leucine mixed effects model, BMC Systems Biology, 2013, 7:8.

S Lorin, L Lindkvist, R Söderberg, R Sandboge:
Combining Variation Simulation With Thermal Expansion Simulation for Geometry Assurance, Journal of Computing and Information Science in Engineering, 13(3):031007, 2013.

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, Atomization and Sprays, 23(1): 25-45, 2013.

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.

J Segeborn, D Segerdahl, F Ekstedt, J S Carlson, M Andersson, R Söderberg:
An Industrially Validated Method for Weld Load Balancing in Multi Station Sheet Metal Assembly Lines, ASME Journal of Manufacturing Science and Engineering, 2013.

E Shellshear, F Bitar, U Assarsson:
PDQ: Parallel Distance Queries for Deformable Meshes, Graphical Models (2013), doi: 10.1016/j.gmod.2012.12.002.

E Shellshear, S Tafuri, J S Carlson:
A multi-threaded algorithm for computing the largest non-colliding moving geometry, Computer-Aided Design, Volume 49, pages 1–7, April 2014.

E Shellshear:
1D sweep-and-prune self-collision detection for deforming cables, The Visual Computer, 2013.

Y Shirvany, T Rubaek, F Edelvik, S Jakobsson, O Talcoth, M Persson:
Evaluation of a Finite-Element Reciprocity Method for Epileptic EEG Source Localization: Accuracy, Computational Complexity and Noise Robustness, Biomedical Engineering Letters, 3:8-16, 2013.

Y Shirvany, F Edelvik, S Jakobsson, A Hedström, M Persson:
Application of Particle Swarm Optimization in Epileptic Spike EEG Source Localization, Applied Soft Computing,13(5):2515-2525, 2013.

Conference Proceedings

S Björkenstam, D Gleeson, R Bohlin, J S Carlson, B Lennartsson:
Energy Efficient and Collision Free Motion of Industrial Robots using Optimal Control, IEEE Conference on Automation Science and Engineering, , Madison, WI, USA, August 17-21, 2013.

N Delfs, R Bohlin, L Hansson, D Högberg, J S Carlson:
Introducing Stability of Forces to the Automatic Creation of Digital Human Postures, 2nd International Digital Human Modeling, University of Michigan in Ann Arbor, June 11-13, 2013.

S Lorin, C Cromvik, F Edelvik, L Lindkvist, R Söderberg:
Variation Simulation of Welded Assemblies Using a Thermo-Elastic Finite Element Model, In proceedings from the ASME 2013 International Mechanical Engineering Congress & Exposition, IMECE2013, San Diego, USA, November 2013.

Q Mahmood, Y Shirvany, A Mehnert, A Chodorowski, J Gellermann, F Edelvik, M Persson:
On the Fully Automatic Construction of a Realistic Head Model for EEG Source Localization, Proceedings from IEEE Engineering in Medicine and Biology Society (EMBC'13), 3331-3334, Osaka, Japan, July 2013.

A Mark, G Mårtensson, T Kurian, F Edelvik:
Simulation of a non-Newtonian dense granular suspension in a microfluidic contraction, Proceedings from International Conference on Multiphase Flow (ICMF) 2013, Jeju, Korea, May 2013.

P Mårdberg, J S Carlson, R Bohlin, N Delfs, S Gustafsson, A Keyvani, L Hansson:
Introducing a Formal High-Level Language for Instructing Automated Manikins, 2nd International Digital Human Modeling, University of Michigan in Ann Arbor, June 11-13, 2013.

G Mårtensson, A Mark, T Kurian:
Simulation of a non-Newtonian dense granular suspension in a microfluidic contraction, Proceedings from The Society of Rheology 84th Annual Meeting, Pasadena, California, February 2013.

Y Shirvany, X Chen, P Sharad Dhanpalwar, F Edelvik, M Persson:
Influence of Different Sources of Noise on Epileptic Spike EEG Source Localization, Proceedings from SPIE Medical Imaging conference, vol. 8672, Florida, USA, 2013.

Y Shirvany, F Edelvik, M Persson:
Multi-dipole EEG Source Localization Using Particle Swarm Optimization, Proc. from IEEE Engineering in Medicine and Biology Society (EMBC'13), 6357-6360, Osaka, Japan, July 2013.

D Spensieri, R Bohlin, J S Carlson:
Coordination of robot paths for cycle time minimization, IEEE Conference on Automation Science and Engineering, Madison, WI, USA, 17-21 August 2013.

M Wallman, A Bueno-Orovio, B Rodriguez:
Computational Probabilistic Quantification of Pro-arrhythmic Risk from Scar and Left-to-right Heterogeneity in the Human Ventricles. In Proceedings of Computing in Cardiology, 40:711-714, 2013.

Other Magazines and Books

F Edelvik:
Den virtuella målerifabriken, Ytforum, 2:21-22, March 2013.

P Johannesson, M Speckert, K Dressler, J de Maré, S Lorén, N Ruf, I Rychlik, A Streit, T Svensson:
Guide to Load Analysis for Durability in Vehicle Engineering, Wiley, November 2013.

Presentations/Posters/Conferences

R Andersson, M Chappell, N Evans, J Gabrielsson, M Jirstrand, J Yates:
Dose-response-time analysis – pharmacodynamic modelling without plasma concentration, Pharmacokinetics UK, Harrogate, November 2013.

E Boger, P Ewing, B-M Fihn, U Eriksson, M Chappell, M Jirstrand, M Hammarlund-Udenaes, M Fridén:
Development a novel pulmonary in vivo target occupancy methodology for the glucocorticoid receptor, Pharmacokinetics UK, Harrogate, November 2013.

M Dietrich, J Almquist, J Hauth, M Jirstrand, P Lang, J W Deitmer:
Cellular Proton Buffer Capacity Revisited: A Study in Xenopus Oocytes, 92nd Annual Meeting of the German Physiological Society, Heidelberg, Germany, 2013.

F Edelvik:
The Virtual Paint Factory, Manufacturing R&D Clusters, Katrineholm, May 2013.

F Edelvik:
A New Simulation Software for Spray Painting and Bodywork Seam Sealing, Scandinavian Coating fair, May 2013.

F Edelvik:
A New Simulation Software for Spray Painting and Bodywork Seam Sealing, European Automotive Coating, Deutsche Forschungsgesellschaft für Oberflächenbehandlung, Potsdam, Germany, May 2013.

S Jakobsson:
Optimal control of focused ultrasound surgery, Seminar at Federal University of Pelotas, UFPel, Pelotas, Brazil, October 2013.

S Jakobsson:
Rational radial basis functions with applications to antenna design, Seminar at University of São Paulo, USP, Campus São Carlos, October 2013.

S Jakobsson:
Mathematics as a technology, Seminar at University of FEI, São Bernardo do Campo, Brazil, November 2013.

C Jareteg:
Kan man böja en bit komposit med matematik som redskap?, My-dagen, October 2013.

D Janzén, J Yates, J Gabrielsson, M Jirstrand, N Evans, M Chappell:
Structural Identifiability and Indistinguishability in Systems Pharmacology, Pharmacokinetics UK, Harrogate, November 2013.

M Jirstrand:
Quantifying cell-to-cell variability using nonlinear mixed effects modelling, SILS Systems Biology Conference, Örsundsbro, November 2013.

A Mark:
Simulation of a solder paste jetting device in IBOFlow, Complex Fluids Symposium, Micronic Mydata AB, Täby, Stockholm, December 2013.

M Trägårdh, M Chappell, N Evans, M Jirstrand, J Gabrielsson, P Gennemark:
Input Estimation in Nonlinear Ordinary Differential Equations for Quantitative and Systems Pharmacology, Pharmacokinetics UK, Harrogate, November 2013.

M Wallman:
Computational Probabilistic Quantification of Pro-arrhythmic Risk from Scar and Left-to-right Heterogeneity in the human Ventricles. Computing in Cardiology 2013, Zaragoza, Spain, September 22-25, 2013.

Theses

B Andersson:
Modeling and Simulation of Rotary Bell Spray Atomizers in Automotive Paint Shops, PhD thesis, Chalmers University of Technology, supervisor L Davidson, December 2013.

J Isaksson:
Statistical Methods for Estimating Variance of Paint Thickness on Curved Surfaces, Master thesis, Chalmers University of Technology, supervisor F Ekstedt, examiner B Johansson, June 2013.

N Karlsson:
An Incompressible Navier-Stokes Equations Solver on the GPU Using CUDA, Master thesis, Chalmers University of Technology, supervisor A Mark, examiner U Assarsson, August 2013.

J Kressin:
Path Optimization for Multi-Robot Station Minimizing Dresspack Wear, Master thesis, Chalmers University of Technology, supervisor T Hermansson and D Segerdahl, examiner B Lennartsson, May 2013.

P Mårdberg:
Using Ergonomic Criteria to Adaptively Define Test Manikins for Assembly Operations, Master thesis, Chalmers University of Technology, supervisor J S Carlson, examiner P Damaschke, December 2013.

Y Shirvany:
Non-invasive EEG Functional Neuroimaging for Localizing Epileptic Brain Activity, PhD thesis, Chalmers University of Technology, supervisor M Persson, co-supervisors F Edelvik and A Hedström, March 2013.

M Wallman:
Computational Methods for the Estimation of Cardiac Electrophysiological Conduction Parameters in a Patient Specific Setting, PhD thesis, University of Oxford, supervisor B Rodriguez, September 2013.

R Ytterlid:
SIMD Optimized Bounding Volume Hierarchies for Fast Proximity Queries, Master thesis, Chalmers University of Technology, supervisor E Shellshear, August 2013.

Other assignments

F Edelvik:
Reviewer for International Journal of Manufacturing Research.

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

Member of Steering group for the Gothenburg Centre for Systems Biology.

FCC Representative in Vehicle ICT Arena.

Member of the PhD-thesis committee for Torbjörn Nordling, Robust Inference of Gene Regulatory Networks, KTH Royal Institute of Technology, May 28, 2013.

Member of the PhD-thesis committee for Rasmus Ågren, On Metabolic Networks and Multi-Omics Integration, Chalmers University of Technology, May 29, 2013.

Reviewer for the European Control Conference.

Reviewer for Netherlands Organization for Scientific Research (NWO)-Vidi proposals.

Courses

R Bohlin:
Virtual Process Planning, Automatic Path Planning and Optimization, Production Engineering Program,Chalmers University of Technology, Guest lecturer, February 28, 2013.

R Bohlin:
Robotics and Robot Systems, Path Planning Software and Advanced Simulation, Production Engineering Systems and Control and Mechatronics Programs, Chalmers University of Technology, Guest lecturer, April 25, 2013.

F Edelvik:
Multi-Physics Methods and Process Development, presentation during internal evaluation of Area of Advance Production, Chalmers University of Technology, April 2014.

F Edelvik:
Industrial Mathematics at FCC, Engineering Physics Program, Uppsala University, Guest lecturer, September 2013.

D Gleeson:
Industriautomation, Introduktionsföreläsning om IPS, Automation och Mekatronik, Chalmers University of Technology, Guest lecturer, December 2013.

C Jareteg:
Programmering med Matlab, Matematikprogrammet, University of Gothenburg, lab supervisor, January - March 2013.

C Jareteg:
Numerisk Analys, Matematikprogrammet, University of Gothenburg, lab supervisor, March - May 2013.

C Jareteg:
Analys och linjär algebra, del A, Bioteknik, Chemical Engineering and Chemical Engineering with Physics Programs, Chalmers University of Technology lab supervisor, September-October 2013.

C Jareteg:
Analys och linjär algebra, del B, Bioteknik, Chemical Engineering and Chemical Engineering with Physics Programs, Chalmers University of Technology, lab supervisor, October - December 2013.

J Karlsson:
Linjär algebra, Väg och vatten, Chalmers University of Technology, Lecturer, January - March 2013.

J Leander:
System identification in drug development models, estimation and analysis, My-dagen Chalmers University of Technology Guest lecturer, October 2013.

J Leander:
Calculus and linear algebra (part C), Exercises for Chemical Engineering with Engineering Physics Program, Chalmers University of Technology, January - March 2013.

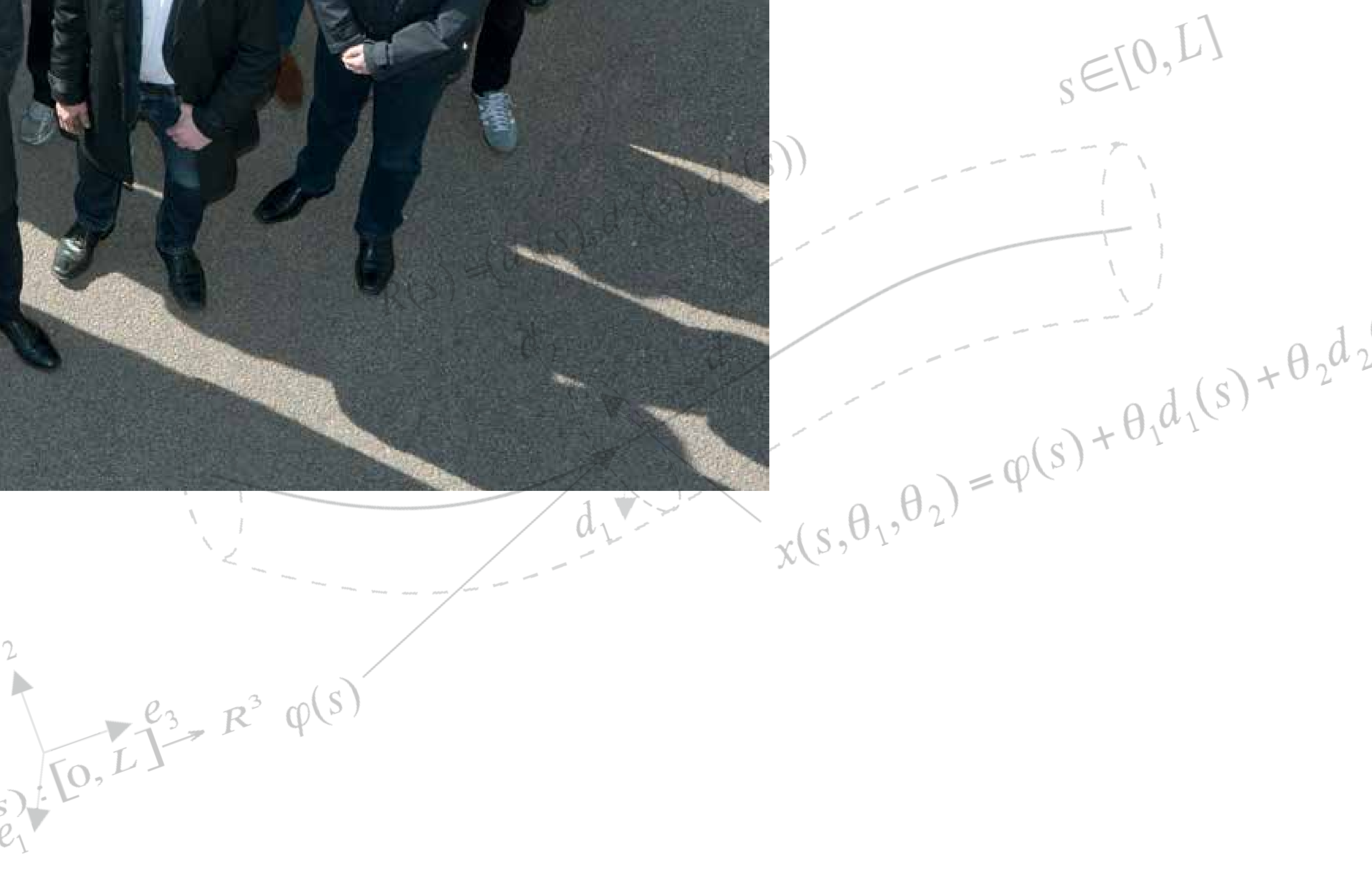
J Leander:
Calculus and linear algebra (part A), Matlab exercises for Chemical and Biotechnology Engineering Program, Chalmers University of Technology, September - October 2013.

J Leander:
Calculus and linear algebra (part B), Matlab exercises for Chemical and Biotechnology Engineering Program, Chalmers University of Technology, November - December 2013.

E Solberg:
Calculus and linear algebra (part C), Matlab exercises for Chemical Engineering with Engineering Physics Program, Chalmers University of Technology, January - March 2013

E Solberg:
Multidimensional Calculus, Exercises for Mechanical Engineering Program, Chalmers University of Technology, March - May 2013.

FCC personnel


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

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Industrial Mathematics

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