ITWM

Fraunhofer

CHALMERS

Research Centre
Industrial Mathematics

Annual Report
2011

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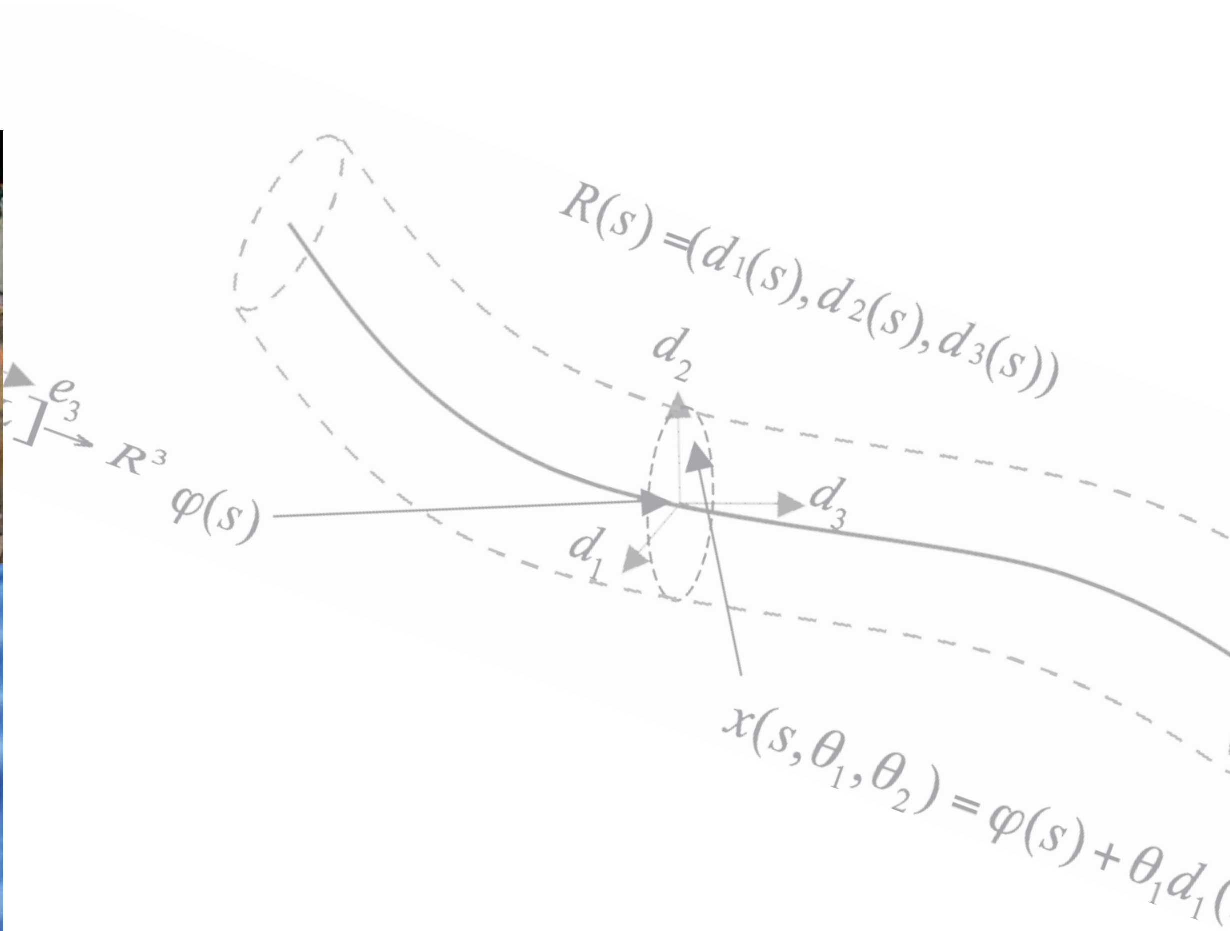

Cover
Areas of Advance and industrial applications

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Fraunhofer-Chalmers Research Centre for Industrial Mathematics, FCC
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Preface and Profile

FCC has since start 2001 completed more than two hundred 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.

Both founders have decided to continue their annual joint support of one million euros for the five-year period 2011-2015. In 2011 they further agreed to widen and intensify the scope of the cooperation. The founders 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.

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 2011 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.

The department Computational Engineering and Design has expanded its work on multi-physics applications involving fluid-structure and fluid-electromagnetics interaction, in particular through projects with Swedish and other European industrial partners together with the ITWM departments Optimization and Flow and Material Simulation. The department runs a 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.

Our mission is to undertake and promote scientific research in the field of applied mathematics to the benefits of industry, commerce, and public institutions. We do this as a business-making, non-profit, Swedish institution. The year 2011 was again a successful one, with a ten percent increase of industrial income, an annual turn-over just below the all-time high level of the previous year, and a small positive net.

Together with our partners Chalmers and the Fraunhofer industrial mathematics institute ITWM we cover a wide range of applications. In 2011 our cooperation included joint actions with four ITWM departments and with several Chalmers centres and departments: Wingquist Laboratory, Chalmers Systems Biology, Chalmers Mathematical Sciences and GMMC (Gothenburg Mathematical Modelling Centre), Chalmers Fluid Dynamics, and Chalmers Biomedical Enginering.

Our industrial clients are mainly from Sweden. We also have international clients from Europe, United States, and Japan. In 2011 we joined 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 recently conducted a Forward Look on Mathematics and Industry. One outcome of this study is the volume "European Success Stories in Industrial Mathematics", Springer 2012, launched in Dublin in October 2011, where FCC contributes with three projects in automotive and pharmaceuticals.

Last year we were fortunate to recruit six 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. Seven of our employed MScs have started PhD studies in this way: five at Chalmers and two on leave abroad.

We offer PhD students employed by our industrial partners to have an office at FCC with a supervisor from the Centre to assist the industrial and academic supervisors. In 2011 two students presented their dissertations: "Product Configuration from a Mathematical Optimization Perspective", Volvo 3P / Mathematical Sciences, and "Cost-effective Sheet Metal Assembly by Automatic Path Planning and Line Balancing, Integrated with Dimensional Variation Analysis", Volvo Cars / Product and Production Development; this work received the Volvo Cars Technology Award 2011.

Three 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 2011 we had seventeen Master's students working on this type of contract and fourteen Master's students doing their thesis projects 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 twenty-five million euros including forty percent industrial and thirty percent public income. Together we are well positioned for the challenges to come!

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

Gothenburg in March 2012

Uno Nävert. Director

The department Systems Biology and Bioimaging has continued its activities as partner in several EU projects. Our cooperation with the ITWM department System Analysis, Prognosis and Control has intensified through a strategic project on integration of systems biology, biotechnology, mathematics, and image processing in fundamental animal cell protein production. Work on interactive pharmacokinetics and pharmacodynamics has resulted in the software Maxsim2 for pharmaceutical industry and the department has started a three-year industrial project on specific applications in this area. The department has initiated a widening of its scope towards technical information-intensive systems and data analysis offering strong competence in mathematical statistics, automatic control, and quality engineering.

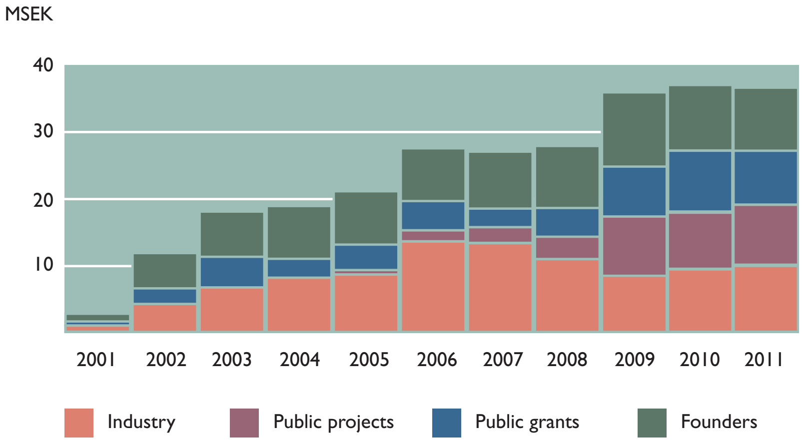
Photo: Jan-Olof Yxell

Facts and Figures

Total income

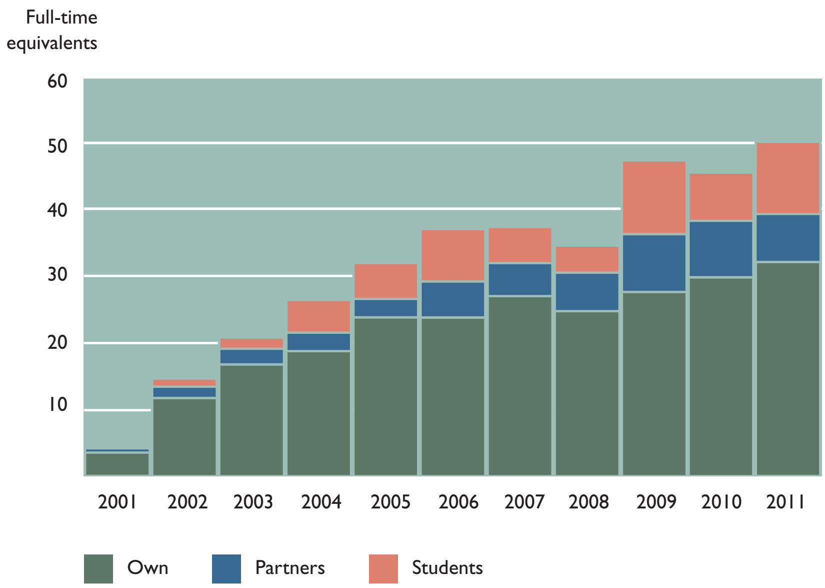
The total income 2011 was slightly more than four million euros, close to thirty-seven million Swedish crowns and just below the all-time high level of the previous year. The result was a small positive net, as has been the case every year since our start in 2001.

The profile of the Centre is controlled by its income structure. In 2011 we earned twenty-five percent from each one of the four categories industrial projects, public projects under industrial command, public grants, and basic funding from the founders. Compared to the previous year we had a ten percent increase of industrial projects (seven percent if we include the public projects under industrial command), a twelve percent decrease in public grants, and an eight percent decrease of basic funding (due to the stronger Swedish crown).



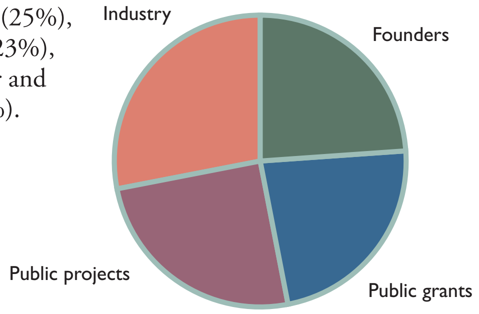
Staff – full-time equivalents

The number of staff 2011 was 50 full-time equivalents (FTE) including own staff (33 FTE), students (10 FTE), and partners (7 FTE). We were happy to recruit six new co-workers, three of which were previously contracted students. The number of Master's students was 31 including six female students: 14 doing their Master's thesis projects (6 FTE) and 17 students in Master's programmes contracted on 10-20% for project work (2 FTE). FCC assisted in supervising three PhD students including two industrial PhD students (2 FTE). We had a drop in the proportion of contracted foreign students, from fifty percent 2010 to twenty-five percent 2011, and a drop in the proportion of contracted female students, from forty percent 2010 to thirty percent 2011.



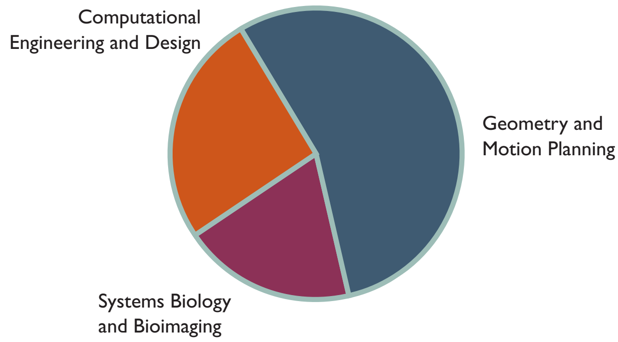
Project mix by income 2011

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 2011 these four were almost equal: industry (28%), public projects (25%), public grants (23%), and Fraunhofer and Chalmers (24%).



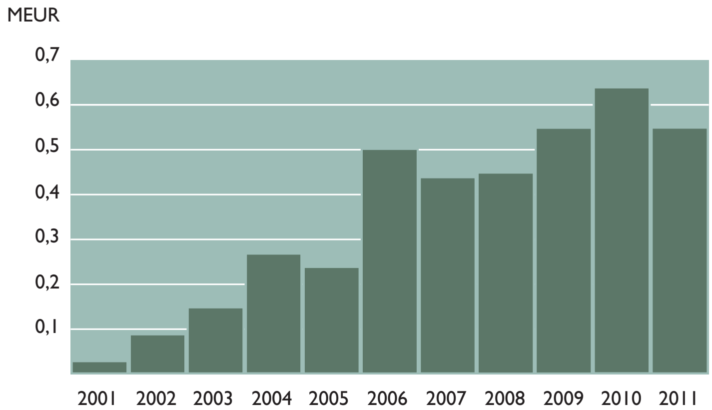
Departments by income 2011

The Centre has three departments. Their relative income were 19%, 26%, and 55% of the grand total including 7% transfer projects between departments.



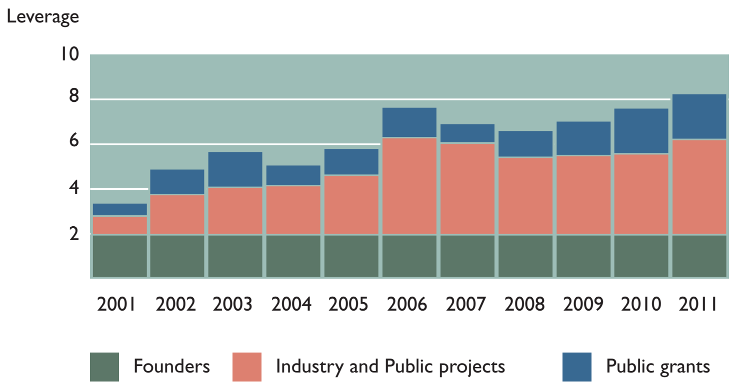
ITWM project income from FCC

The basic funding to FCC is equally shared between Fraunhofer and Chalmers, in 2011 being 0.5 million euros from each founder. The project flow from FCC to ITWM, shown in the diagram to the right, did not reach the same high level in 2011 as the previous year. The ITWM project income from German automotive industry based on the IPS software has continued to increase significantly.



Chalmers exchange on basic funding

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

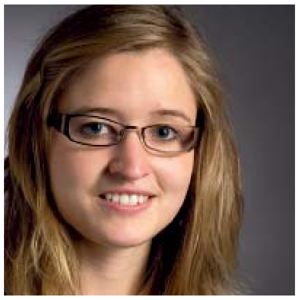


Central services

Jenny Ekenberg, MSc
Economy and IT

Annika Eriksson
Administration and Personnel

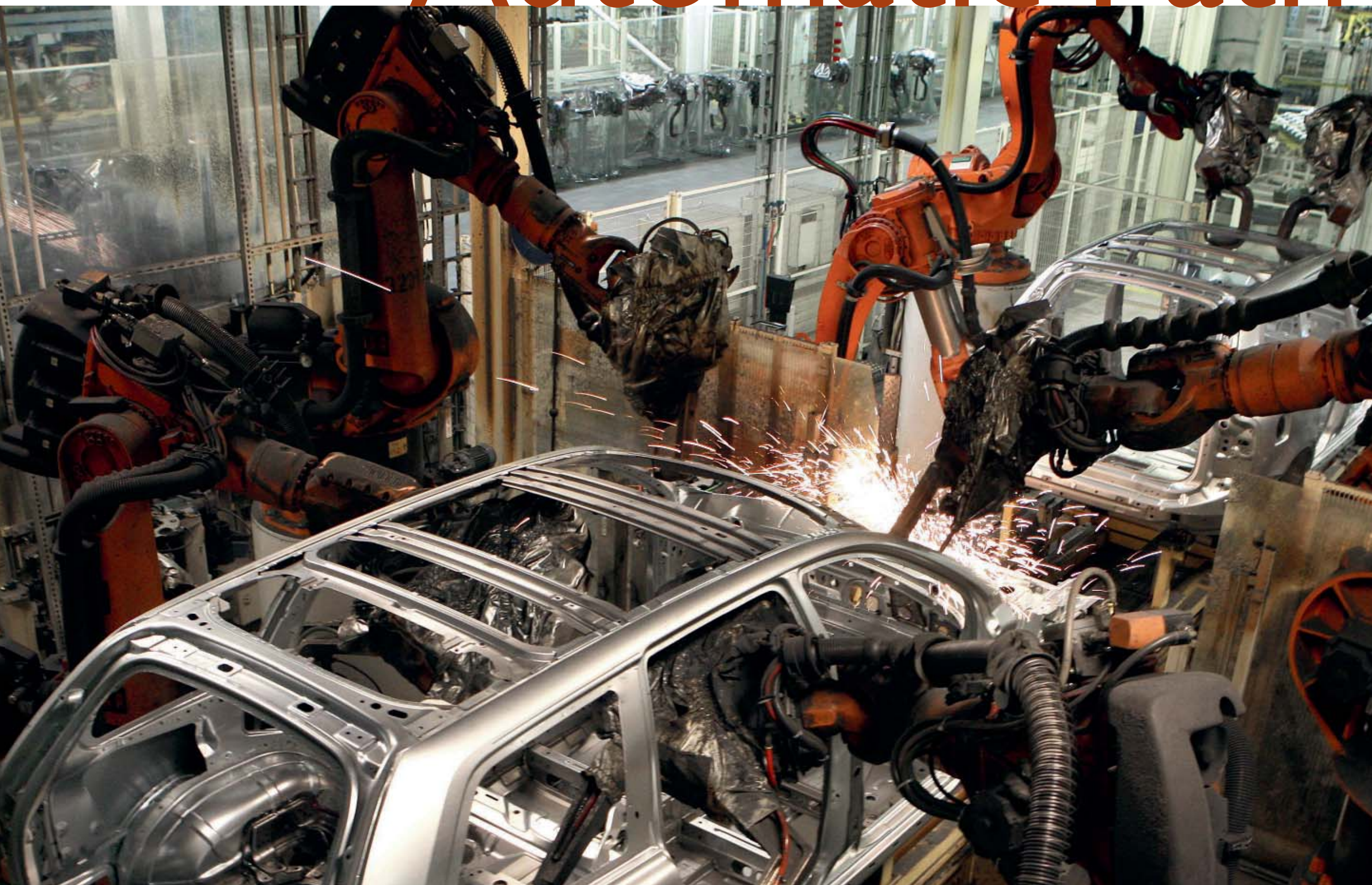
Lars Löwenadler, MSc
Technical administration



Sara Söderqvist
Assistant

In today's automotive industry, although most development is done virtually, some decisions still lack a solid mathematical basis. In order to make the manufacturing engineering process more efficient, FCC and Wingquist Laboratory at Chalmers have worked with Volvo Cars, Volvo Trucks, Saab Automobile and Scania CV in VINNOVA funded projects to develop new methods and tools for automatic load balancing of welding lines.

Automatic Path



Planning and Line Balancing

Today, the margins of automotive manufacturers are tight and competition is fierce. The industry furthermore faces paradigm shifts regarding propulsion as well as styling, with environmental requirements ever-present. Effective product realization response is thus important. By targeting the car body, which is perhaps the most defining part of any car and also has a significant influence on safety, aesthetics, handling, fuel economy and top speed, it is possible to achieve significant improvements in terms of production efficiency and production equipment utilization.

A typical automotive car body consists of about 300 sheet metal parts, joined by about 4000 welds. Typical joining methods are spot welding, arc welding, gluing and stud welding. In car body assembly plants, the welds are distributed over several hundred industrial welding robots, which are organized in up to 100 stations. Sheet metal assembly is an investment intense type of assembly. Therefore the expensive equipment needs to be utilized to its full potential. The balancing of weld work load between the executing stations and robots has a significant influence on achievable production rate and equipment utilization. Robot line balancing is a complex problem, where a number of welding robots in a number of stations are available to execute an overall weld load. Each weld is to be assigned to a specific station and robot, such that the line cycle time is minimized. Line balancing efficiency depends on station load balancing, robot welding sequencing, path planning and effectiveness of robot coordination for collision free execution within each other's working envelopes. In general, robot coordination impairs cycle time by inserting waiting positions and signals into the original paths.

So far, no automatic simulation based method for weld load balancing over entire production lines has been developed. Furthermore, in industrial practice, weld load balancing is still manually conducted, based on experience and time consuming trial-and-error analysis in CAE-tools (Computer Aided Engineering). Therefore this work has aimed at developing automatic simulation based methods for weld load balancing over entire production lines to maximize equipment utilization as well as dimensional quality. Since the criterion of dimensional quality is coupled to cycle time and thus to equipment utilization, it is added as a second criterion.

The strategy to target the load balancing problem has been (i) to treat identified station design parameters together, with respect to equipment utilization and geometrical quality, based on a chronological framework for virtual sheet metal assembly design, (ii) to utilize and further develop automatic path planning combined with discrete optimization techniques in order to automatically load balance, sequence and find collision free motions, (iii) to continuously implement the results in the FCC developed IPS software available for the project partners, since this way of working has proven to guarantee the usefulness of the project results both during and after the project, and (iv) to use real industrial case studies to quantify the level of success in reaching the objectives.

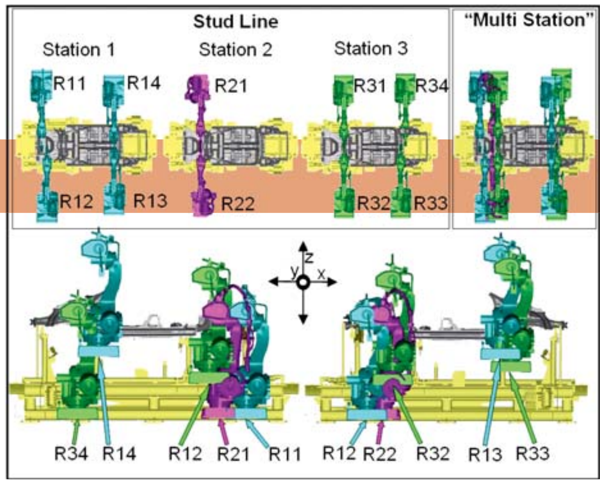
▸▸

Automatic simulation is now a reality through a world first method. The new method has been successfully applied in vehicle programs, will be rolled out to all vehicle programs and body shops at Volvo Cars, and is described in 5 principle scientific publications. The project has also resulted in a PhD thesis in product and production development at Chalmers.

Application of the automat line balancing method shows
- 25% better equipment utilization, and
- 75% reduction of offline programming- and commissioning costs.

The method also enables
- Concurrent manufacturing engineering and product development,
- Increased insensitivity to late changes,
- Backup solutions for robot break downs.

Furthermore, the project won the Volvo Cars Technology Award 2011 in the category “Research”.

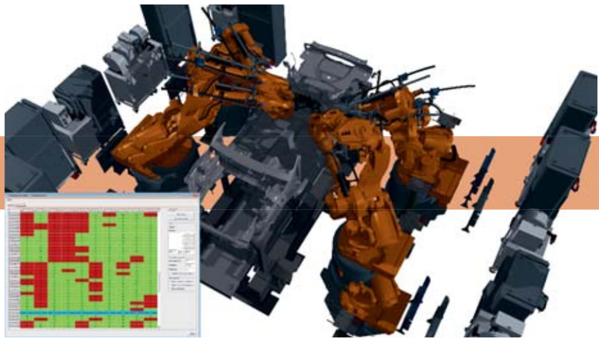


Create a multi station by super-imposition of the scenes and geometries of the line stations, with maintained robot positioning relative to the product (car body).

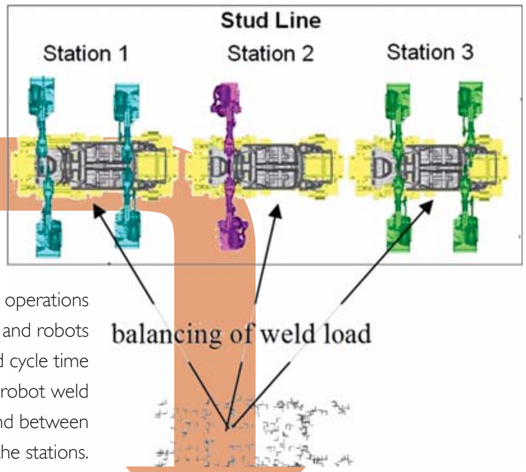
From left:
Fredrik Någård, Volvo Cars
Magnus Jivefors, Volvo Cars
Magnus Hellsten, Volvo Cars
Johan Carlson, FCC
Robert Bohlin, FCC
Johan Segeborn, Volvo Cars
Peter Martens. Volvo Cars

Industrial Reference Line							
		Running Production			Automatic Method		
station	robot	# welds	Robot CT	Station CT	# welds	Robot CT	Station CT
st1	r11	17	45.1	73.8	20	55.1	57.7
	r12	19	56.2		21	57.3	
	r13	20	73.8		20	57.7	
	r14	20	60.9		20	57.3	
st2	r21	22	53.4	55.5	21	54.3	54.3
	r22	23	55.5		20	53.5	
st3	r31	18	50.7	**80.5**	20	58.2	**61.9**
	r32	18	51.3		21	61.5	
	r33	16	48.5		19	61.9	
	r34	28	80.5		19	55.4	

The developed and implemented algorithms on path planning and line balancing have been successfully tested on a 3 station stud weld line with 10 robots and a 2 station line with 8 robots at Volvo Cars. The number of studs is about 200 in each line. A comparison between the cycle time for the running production programs optimized by an experienced robot programmer and IPS generated programs has been carried out. The comparison, including interlocking losses between robots, has been carried out in VCC's OLP software Process Simulate. The results for Stud line 1 are presented to the left showing an improvement of 23% in cycle time, while stud line 2 shows even better results.

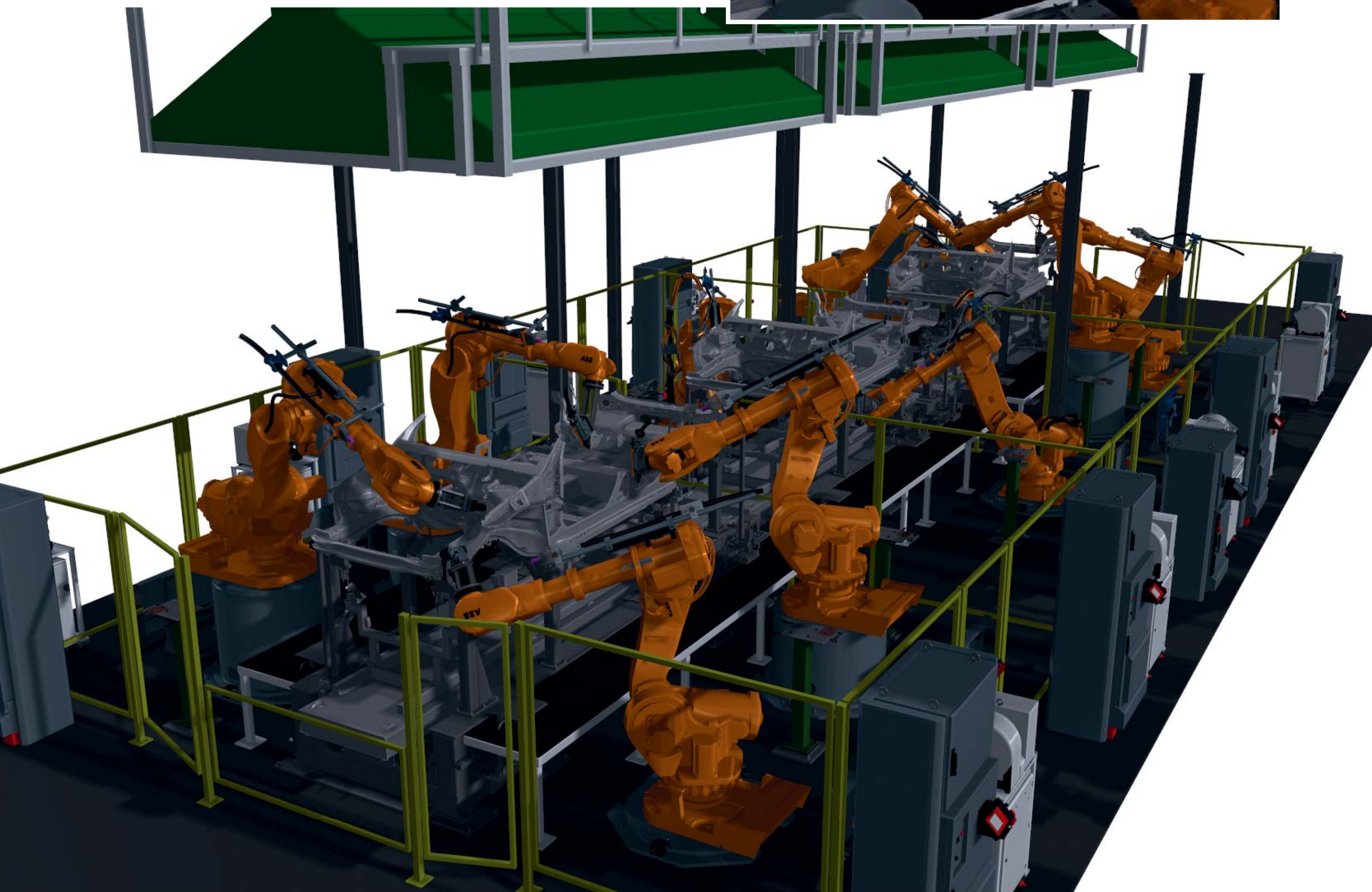


Task Plan to find collision-free alternatives to perform each welding operation in the multi station.



Distribute the welding operations between the stations and robots to minimize estimated cycle time and with preference to robot weld separation within and between the stations.

Minimize cycle time by integrating balancing, sequencing, path planning and coordinating on the welds distributed to each Station in the previous step (courtesy of Volvo Car Corporation).



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

Image Analysis Tools for Quantitativ

In microscopy studies carried out at the Bionanophotonics group at Chalmers (Prof Mikael Käll) together with the department of cell and microbiology at Gothenburg University (Prof Anders Blomberg) the objective has been to follow multiple individual cells over time to study the evolution of different phenomena and how this may vary over the cell population. An example of this is the dynamic response of individual cells to changing environmental conditions such as heat chock induced stress. In such cases the study of location (e.g. amount inside and outside of the cell nucleus) of specific proteins is a way to determine to what extent a cell is affected by the external stimuli.

By tagging the protein of interest with a fluorescent marker the nucleus will become more or less fluorescent with respect to the rest of the cell depending on the amount of protein in the nucleus. This effect may be more or less pronounced in different individuals in an image of several cells so there is a need to quantify the response of each individual cell. Manual quantification is a very time consuming process which involves marking the areas in an image corresponding to the cell membrane and cell nucleus, counting pixels for each region and their intensities, and repeat this for the same cell in consecutive images to record how the amount of protein varies over time. This has to be done for every cell in the image and it is easy to conclude that doing this manually rapidly becomes a tremendous task, which is not possible with anything but a quite limited number of involved cells. Another disadvantage of manual analysis is that the result in many respects becomes qualitative and subjective as well as non-reproducible. With an automated quantitative method of analysis the result is reproducible and objective. It also enables more resource demanding analysis – e.g. measuring the distribution of a certain protein in a whole cell population over time.

To automate the quantification of multiple single cell behaviors over time a project was conducted with FCC to develop algorithms and software tools for automated segmentation, tracking, and feature extraction on both single images and image sequences from time-lapse microscopy. The methods are implemented in a program entitled CellStat and applied in collaborative projects with external partners. CellStat is a tool equipped with graphical user-interface (GUI) for automated recognition and tracking of yeast cells from transmission microscope images, combined with quantification and localization of GFP-labeled proteins using fluorescence microscopy. The emphasis on the algorithms in CellStat lies on robust methodologies which enables long time-lapse studies of protein localization, migration, and inheritance over several cell cycles, as well as high through-put screening of protein functionality of a large number of gene-disrupted cells.

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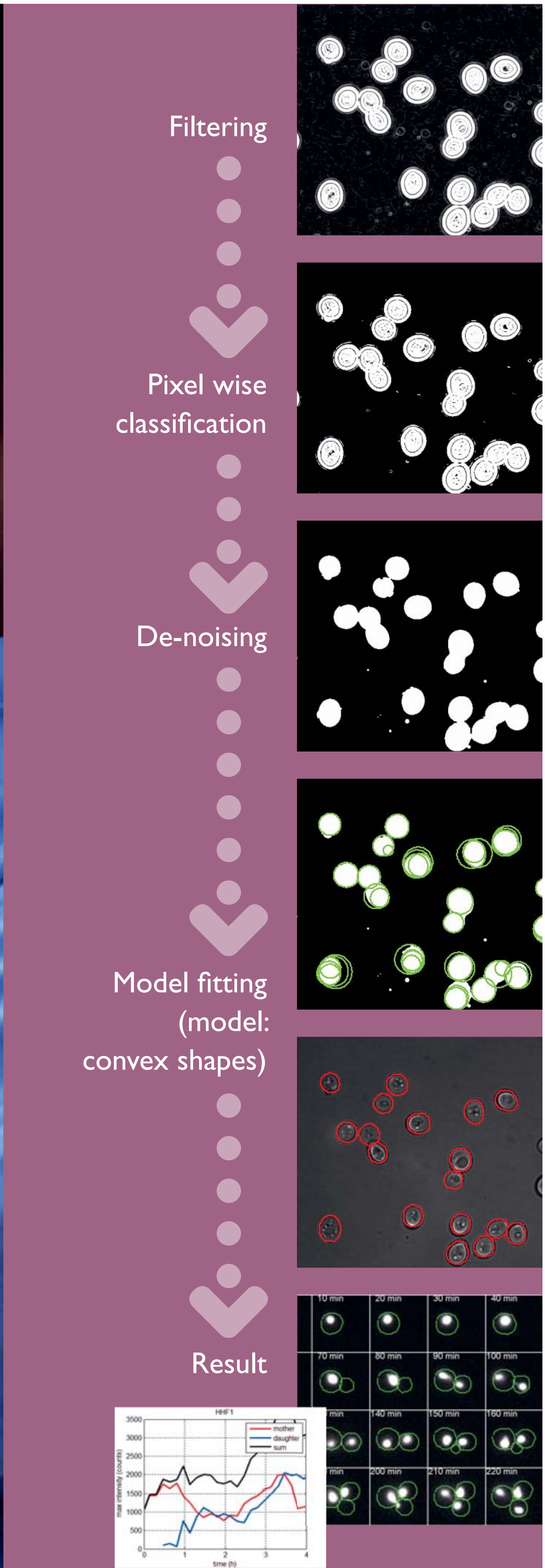
ve Yeast Cell Studies



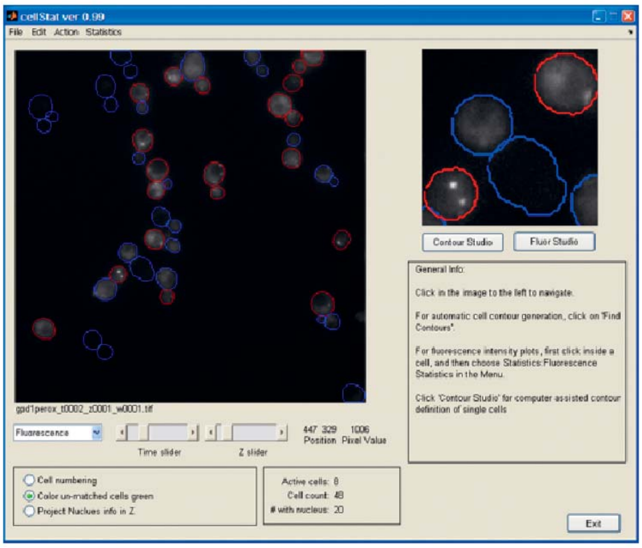
Typical work flow in image analysis where one goes from various pixelwise operations such as filtering and thresholding, to successively more complex operations which incorporates modeling of the objects of interest.

One of the most recent studies involves tracking of 50-100 cells in image sequences consisting of up to 1800 images for several different cell cultures. For each single cell, the shuttling of tagged proteins between cell nucleus and cytoplasm is measured and from this data, conclusions on cell stress levels can be drawn.

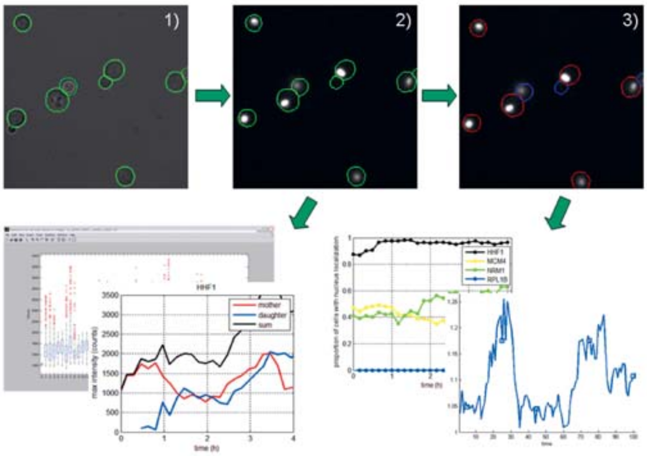
Single cell studies like these are crucial for proper understanding of cell functionality and an automated image analysis tool like CellStat is a key component in extracting data from microscopy. The development and use of the advanced image analysis algorithms in the software package CellStat has proven to be an indispensable tool in this interdisciplinary study conducted by a mixture of biologists, mathematicians, and physicists. CellStat can be used for free for non-commercial scientific purposes and currently three research laboratories use the software actively in their research.

Technical facts CellStat:

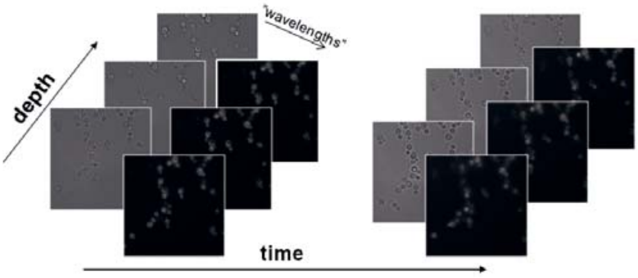
- Contour recognition and tracking of yeast cells in microscopy image sequences
- Core algorithms in C/C++
- Interface in Matlab®
- Free to use for research
- Plugins for fluorescence data extraction, designed in collaboration with end-users



Main window of CellStat for quantitative cell analysis : Here, red-colored cells are cells that contain high local concentrations (presumably the cell nucleus) of the fluorescence protein under study.



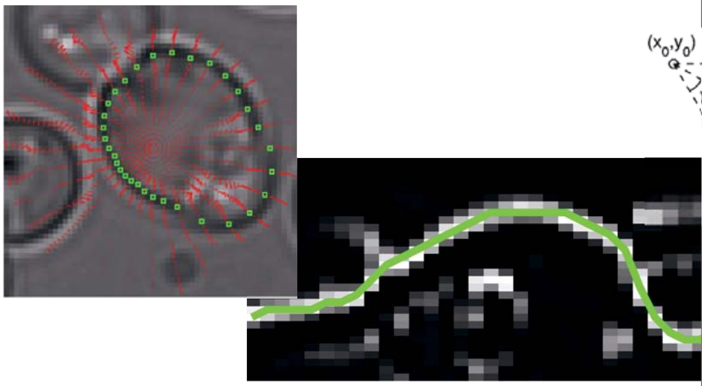
General principle of quantification in bioimaging : Top row: Contours are identified in the original bright-field image (1) using our image analysis algorithms. These are transferred to the corresponding fluorescence image (2), where labeled protein content is quantified for each cell including spatial context (3). Here, cells which have large protein expression in the cell nucleus compared to the cytoplasm are colored red. In the bottom row we illustrate ways of quantifying and display the labeled protein content, from left to right: boxplots of fluorescence in each cell; single cell expression of a daughter-mother pair over a couple of hours; proportion of cells with highly expressed protein in the cell nucleus of time for four different gene-disrupted cell types; ratio between expression level in the cell nucleus and the cytoplasm over 100 seconds after increasing the temperature.

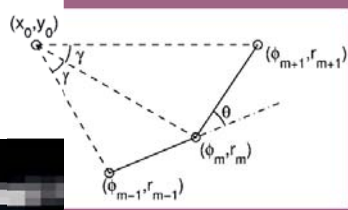


Data collection (left).
Cell culture data is collected by taking bright field and flourescence images with a microscope. For each time point, images at different depths as well as with different wave lengths are being collected.


TE2000E (Nikon)

Microscope setup (right).
Fully automated microscope with perfect focus system.



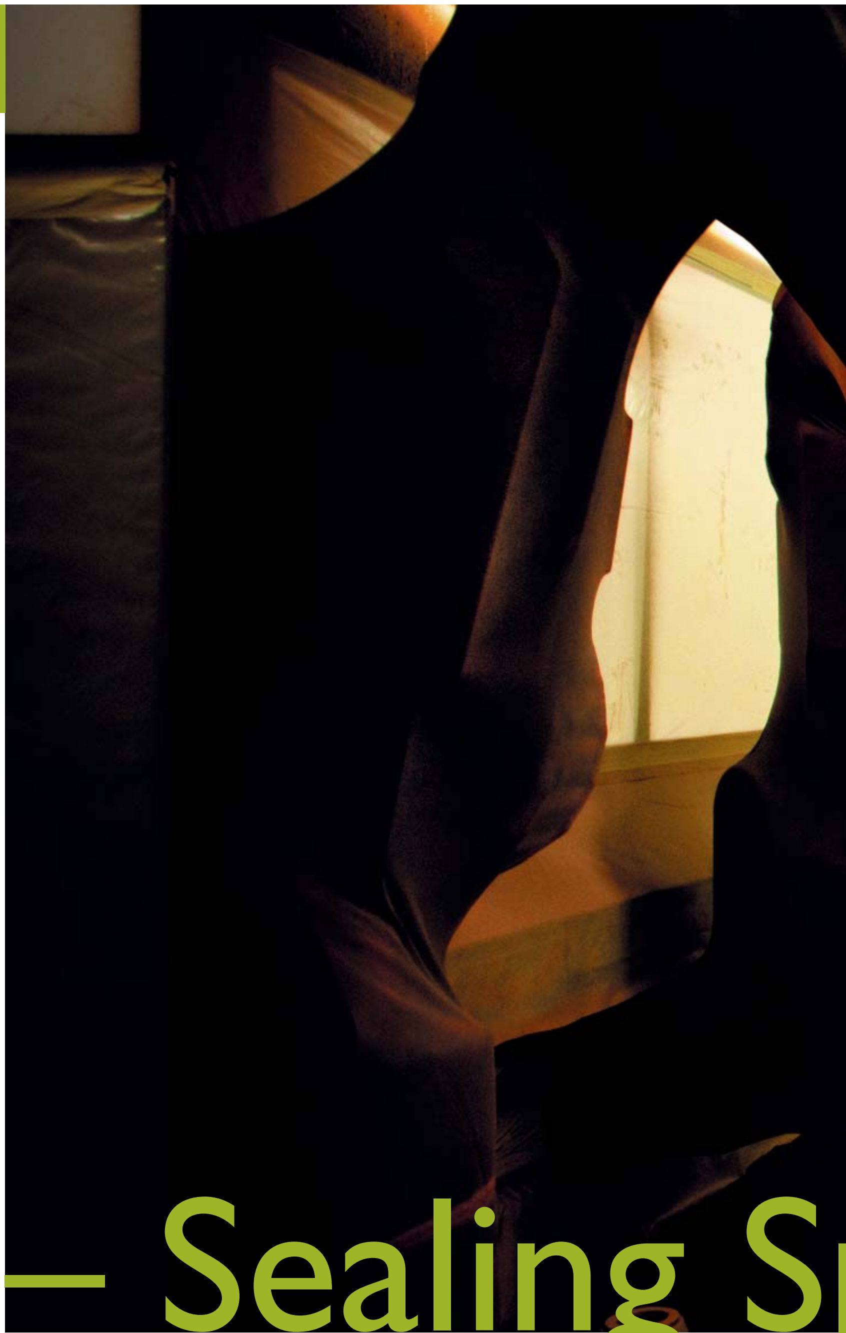


From a candidate cell center a path is found in a polar plot (right) emanating from the candidate center. Convex cell shapes are enforced by penalizing right turns as the polar plot is traversed in a counter-clockwise direction. The optimal path in the polar plot is found using a fast dynamic programming scheme.

The cost S(p) for a contour path $p = (p_1, p_2, \ldots, p_M)$ from left to right is

$$S(p) = C(p_1, 1) + \sum_{m=2}^{M} \left\{ C(p_m, m) + T(p_{m-1}, p_m) \right\}$$

where C is in the criterion function (typical image data) and T is the transition penalty (shape model). Note that we have specified that C can only depend on the present state which is the memory-less property.
A 2-D state-vector of consecutive radial positions enables us to incorporate directions penalties.



Virtual Paint Shop – Sealing Sp

The goal of this ongoing project is to develop new methods, algorithms and simulation tools for paint and surface treatment processes in automotive paint shops. The project is part of Vinnova's FFI program towards sustainable production technology and our research partners are Volvo Car Corporation, Saab Automobile AB, Scania AB, Volvo AB, Konga Bruk AB, Swerea IVF and General Motors North America.

pray

Copyright: Volvo Trucks

The main processes in automotive paint shops are electro coating, sealing and cavity waxing, spray painting and oven curing. The complexity of the processes characterized by multi-phase and free surface flows, multi-physics, multi-scale phenomena, and large moving geometries, poses great challenges for mathematical modeling and simulation. The current situation in the automotive industry is therefore to rely on individual experience and physical validation for improving the paint and surface treatment processes. In off-line programming of the robots it is a great advantage to have access to tools that combine automatic path planning with fast and efficient simulation of the processes to be able to reduce the time required for introduction of new models, reduce the environmental impact and increase quality. The development of such tools is the aim of the ongoing Virtual Paint Shop project.

Sealing material is applied to automotive bodies to cover cavities and seams, where moisture might otherwise create a corrosive environment, and also to dampen noise. In the order of 50 meters of material is used for a car. This is a complex multi-phase flow application and the material flow in air and on the target must be considered. The sealing material is a non-Newtonian fluid which is strongly shear thinning such that the viscosity depends on the shear rate. A Bingham fluid can be used to model the rheology of the material, where the yield stress and plastic viscosity parameters are determined from rotational rheometer experiments.

Seam sealing application at Volvo Cars in Torslanda (courtesy of Volvo Car Corporation).

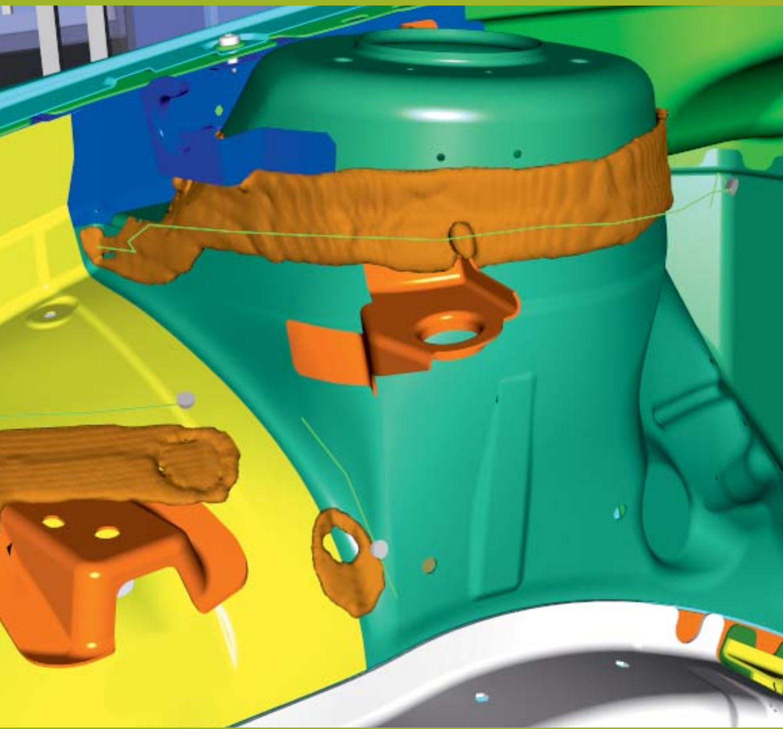
Simulation of sealing application on seams in the engine compartment using the IPS Virtual Sealing software (courtesy of SAAB Automobile AB).

Application of sealing material on a flat plate using a hollow-cone nozzle. The applicator moves from right to left with constant velocity (courtesy of Volvo Car Corporation).

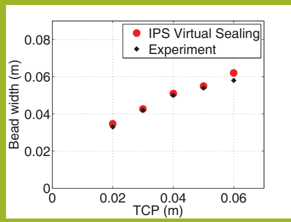
Seam sealing application at Volvo Cars in Torslanda (courtesy of Volvo Car Corporation).

There are different types of nozzles used to apply the material. Here we consider the hollow-cone, in which a curtain of sealing material is sprayed on the target. To verify the simulations the resulting width, thickness and shape of applied material on test plates as a function of time and spraying distance have been compared to experiments. The agreement is in general very good. Several more complex geometries have also been successfully simulated as shown in the figures. The efficient implementation makes it possible to simulate application of one meter of sealing material in less than an hour on a standard computer, and it is therefore feasible to include such detailed simulations in the production preparation process and off-line programming of the sealing robots.

To achieve this break-through in simulation speed compared to earlier approaches the FCC software IBOFlow has been used. IBOFlow is an incompressible Navier-Stokes solver, which is based on a finite volume discretization on a Cartesian octree grid. The octree grid can be dynamically refined and coarsened, and unique immersed boundary methods are used to model the presence of objects in the fluid. This simplifies the pre-processing and modeling of moving objects can be accomplished with virtually no additional computational cost. The multi-phase flow is handled by the novel volume of fluids (VOF) module in IBOFlow.



A robot is applying sealing material to a seam on the front damper in the IPS Virtual Sealing software (courtesy of SAAB Automobile AB).



Validation of hollow-cone application of sealing material on a flat plate. The bead width as a function of spray distance is compared to experiments.

A rotational rheometer is used for characterization of the sealing material.

Sealing station at SAAB Automobile modeled in the IPS Virtual Sealing software (courtesy of SAAB Automobile AB).

The IBOFlow software has been integrated in the in-house math-based software for virtual product and production realization, IPS. In the IPS Virtual Sealing module collision free curve following algorithms are used to automatically generate the robot paths. The automatic robot path planning includes, (i) task planning to find promising configurations and motions that can follow each sealing curve, (ii) sequence optimization and motion planning to select one solution for each seam and connect them by efficient motions and in a sequence minimizing the cycle time.

The first version of the IPS Virtual Sealing software will be delivered to our research partners during the spring 2012. Currently we are also working on simulation tools for the other automotive paint shop processes spray painting, electro dipping and oven curing. In particular, the IPS spray paint application has been successfully validated in several measurement campaigns during 2011. A commercial release is planned for the second half of 2012.

Geometry and Motion Plan

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 2011 the department of Geometry and Motion Planning has successfully developed methods, algorithms and tools supporting these activities within four main subjects:

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

In particular, the FCC software tool Industrial Path Solutions for automatic path planning of collision-free motions has been successfully used by our partners in the automotive industry to solve geometrically complex manufacturing problems in mere minutes instead of hours or days. The strength of the mathematical algorithms in combination with the easy user interface has allowed the path planning technology to be spread outside the expert teams of simulation engineers. The IPS path planning technology is 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, was rewarded with the Volvo Cars Technology Award 2011 in the category research.

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.

Cooperation

During 2011, 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.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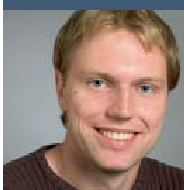
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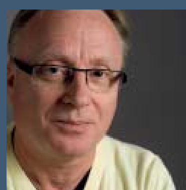
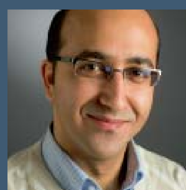

Roland Roll
Marketing and sales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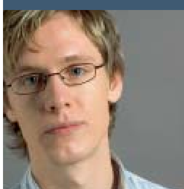
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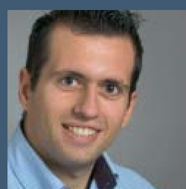
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nning

Acknowledgement

In 2011, 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.

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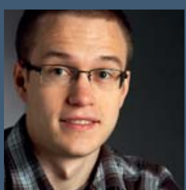

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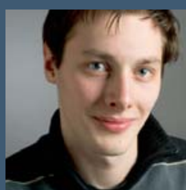

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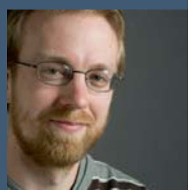

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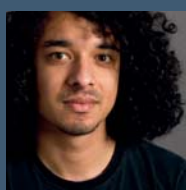

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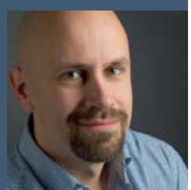

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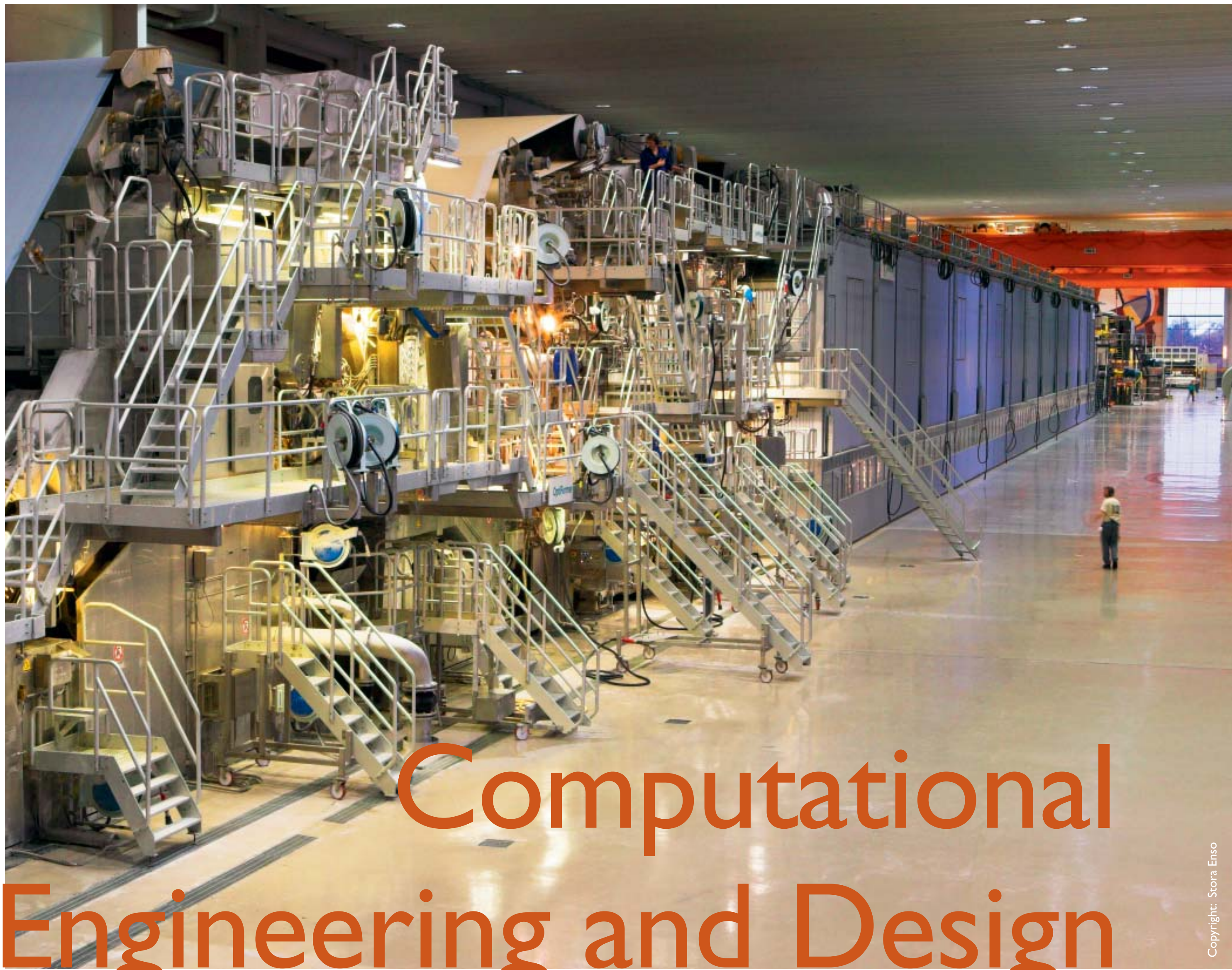
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Computational Engineering and Design

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

The work is organized in three areas:

- Fluid Dynamics
- Electromagnetics
- Optimization

The research in fluid dynamics is focused on the development of methods and algorithms for multi-phase flows, free surface flows, and fluid-structure interaction. The department strives to provide an innovative software that integrates state-of-the-art research on grid-free techniques and offers unique possibilities for efficient simulation of complex industrial flow applications. The IBOFlow (Immersed Boundary Octree Flow Solver) software is tailored for applications involving moving objects interacting with the flow and sets a new standard for CFD software by avoiding the cumbersome generation of 3D volume meshes. A highlight during 2011 was the development of a novel volume of fluids (VOF) module that was successfully used for several applications. In addition, a structural dynamics module was developed for simulation of large deformation of beams, shells and solids. Furthermore, the efforts on simulation of paint and surface treatment processes in automotive paint shops continued (cf. pp. 14 - 17). Several measurement campaigns were successfully performed and the agreement between experimental and simulation results was overall remarkably good. Another major activity was the

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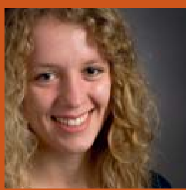

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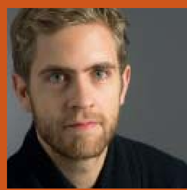

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Cooperation

During 2011, the successful collaboration with the department Geometry and Motion Planning at FCC has been strengthened through joint projects on Virtual Paint Shop. Also the collaboration with the departments Optimization, and Flow and Material Simulation, at Fraunhofer-ITWM has grown by working on joint projects. Other collaborations include the Chalmers divisions of Fluid Dynamics and Biomedical Engineering.

Acknowledgement

In 2011, the department received substantial funding from Vinnova through the FFI Sustainable Production Technology program, from the Swedish Foundation for Strategic Research (SSF) through the Gothenburg Mathematical Modelling Centre (GMMC), and from the Sustainable Production Initiative and the Production Area of Advance at Chalmers.

project on simulation of papermaking and paperboard package quality with industrial partners Albany International, Eka Chemicals, Stora Enso and Tetra Pak, that had an excellent progress during the year and first versions of the paper forming and edge wicking modules were delivered to the companies. The industrial consortium decided to continue the project with another three-year phase 2012 - 2014 with a significantly larger project volume.

In electromagnetics research is performed for electrostatic applications for which an in-house adaptive finite element software package is being developed and for high frequencies based on the platform developed in the GEMS project. Activities during 2011 included continued work on the joint project with Lund University and Efield AB, within the framework of the Swedish National Aerospace Research Program (NFFP), on improved simulation software for analysis of sensors and antennas integrated on platforms.

In optimization the research is focused on simulation-based optimal design and multiple criteria optimization. This includes novel optimization algorithms, coupling of simulation and optimization software and development of decision support systems that integrate multiple criteria optimization and simulation. The main applications in 2011 were multi-objective optimization of oven curing and EEG-based localization of epileptic foci in the human brain.

The main applications in 2011 were: multi-objective optimization of oven curing together with Fraunhofer ITWM; EEG-based localization of epileptic foci in the human brain together with Chalmers Biomedical Engineering and Clinical Neurophysiology at Sahlgrenska University Hospital; and reduction of variants in truck chassis packaging together with Volvo 3P and Fraunhofer ITWM.

Systems Biology and Bioimaging

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

The work at the department includes both biological/biomedical modeling applications as well as development of computational tools and algorithms. The department is organized in two areas:

- Systems Biology
- Bioimaging

An important accomplishment for the department during 2011 has been the acquisition of 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 also the Maxsim2 software, which during the year has found a number of new customers in both industry and academia.

We are currently involved in modeling projects where yeast *(Saccharomyces cerevisiae)* and Chinese hamster ovary (CHO) cells are used as model organisms. Other areas of interest include modeling of ion-channels and action potential propagation related to atrial fibrillation, signaling pathways involved in liver cancer, and kinetic modeling of the secretion pathway for improved protein production. The computational tools and algorithms developed at the department can be divided in four main areas: system identification, model reduction, image analysis, and software tools.

We take part in three EU funded projects: UNICELLSYS – Eukaryotic unicellular organism biology – systems biology of the control of cell growth and proliferation, CANCERSYS – Mathematical modeling of beta-catenin and ras signaling in liver and its impact on proliferation, tissue organization and formation of hepatocellular carcinomas, and SYSINBIO – Systems biology as a driver for industrial biotechnology. The department has also hosted activities to widen its scope and address challenges under the notion of Information-intensive Systems and Data Analysis. Here we have had successful industrial collaborations, e.g., to enhance the visual appearance of media on displays, and to develop statistical models of mechanical load signals.

The Systems Biology and Bioimaging Research Group

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Cooperation

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

Acknowledgement

In 2011, the Systems Biology and Bioimaging department has received funding from the Swedish Foundation for Strategic Research via Gothenburg Mathematical Modelling Centre, GMMC. Furthermore, the group has received funding for the UNICELLSYS, CANCERSYS, and SYSINBIO projects from the European Commission.

Styrelse och ledning den 14 november 2011

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

Årsredovisning

Styrelsen för Stiftelsen Fraunhofer-Chalmers centrum för industrimatematik, FCC, får härmed avge följande redovisning över verksamheten under tiden 1 januari 2011 – 31 december 2011, stiftelsens tionde verksamhetsår.

Stiftelsen bildades av Chalmers och Fraunhofersällskapet i juni 2001 och registrerades av Länsstyrelsen i Västra Götalands län i oktober 2001 som en svensk näringsdrivande stiftelse. Stiftelsen skall utveckla och anpassa matematiska metoder för industrin. Stiftelsen bedriver konkurrensneutral forskning och marknadsföring med finansiering från stiftarna och offentliga finansiärer. Stiftelsen genomför projekt med företag på kommersiell grund.

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.

Chalmers och Fraunhofersällskapet har efter samtal på ledningsnivå i juni 2011 förklarat sin avsikt att permanenta samarbetet inom ramen för en utvidgning till en paraply Fraunhofer Chalmers Sverige (FCS) för alla Fraunhofers aktiviteter i Sverige med Chalmers som Premium Partner.

Årets omsättning har varit knappt trettiosju miljoner kronor. Antalet anställda och studenter har motsvarat 43 heltidsekvivalenter (FTE) varav 6 kvinnor. Antalet studenter utgörs av 14 examensarbetare i mastersprogram drygt 6 FTE, 17 studenter i mastersprogram anställda på 10-20% för arbete i projekt drygt 2 FTE och industridoktorander drygt 2 FTE, totalt drygt 10 FTE. Härutöver har arbete motsvarande cirka 7 FTE lagts ut på partners.

Rörelsens intäkter har uppgått till 36 775 kSEK (37 336 kSEK föregående år). Av detta utgör 28% (25%) industriprojekt, 25% (23%) offentliga projekt, 23% (26%) offentliga anslag och 24% (26%) finansiering från stiftarna. Årets resultat efter skatt är 114 kSEK (86 kSEK). Eget kapital uppgick den 31 december 2011 till 3 974 kSEK (3 957 kSEK) inkluderat kapitalandelen i obeskattade reserver.

Stiftelsens styrelse har under verksamhetsåret sammanträtt fyra gånger (varav två gånger per telefon). Ersättning har utgått till ordföranden med 34 730 kronor och till övriga ledamöter med 17 365 kronor per person.

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

Göteborg den 27 mars 2012

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

Räkenskaperna har granskats av Deloitte

Photo: Jan-Olof Yxell

Resultaträkning
110101 – 111231, (kSEK)

Intäkter	
Nettoomsättning	36 775
Summa intäkter	36 775
Kostnader	
Externa kostnader	-11 929
Personalkostnader	-24 525
Avskrivningar av materiella anläggningstillgångar	-165
Summa kostnader	-36 619
Rörelseresultat	**156**
Resultat från finansiellainvesteringar	
Ränteintäkter och liknande resultatposter	156
Räntekostnader och liknande resultatposter	-8
Resultat efter finansiella poster	**304**
Extraordinära kostnader	-273
Resultat före bokslutsdispositioner och skatt	**31**
Bokslutsdispositioner	240
Årets skatt	-157
Årets resultat	**114**

Balansräkning
111231, (kSEK)

Anläggningstillgångar	
Maskiner och inventarier	209
Summa anläggningstillgångar	209
Omsättningstillgångar	
Kundfordringar	4 432
Förutbetalda kostnader och upplupna intäkter	4 607
Övriga kortfristiga fordringar	133
Kassa och bank	8 745
Summa omsättningstillgångar	17 917
Summa tillgångar	**18 126**
Eget kapital	
Eget kapital vid årets ingång	3 167
Årets resultat	114
Summa eget kapital	3 281
Obeskattade reserver	940
Kortfristiga skulder	
Leverantörsskulder	4 208
Övriga kortfristiga skulder	541
Skatteskulder	217
Upplupna kostnader och förutbetalda intäkter	8 939
Summa kortfristiga skulder	13 905
Summa skulder och eget kapital	**18 126**

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H Andrä, F Edelvik, M Fredlund, E Glatt, M Kabel, R Lai, A Mark, L Martinsson, U Nyman, S Rief:
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Implementation of a Generic Virtual Robot Controller, Master's thesis, Chalmers, supervisors S Björkenstam, R Bohlin, D Segerdahl, examiner M Fabian, June 2011.

O Sachenkova, S Thapaliya:
Using CSP Solvers for Partial Configuration in Automotive Configuration Problems, Master's thesis, Chalmers, supervisor F Ekstedt, examiner C Strannegård, July 2011.

E Svenning:
Development of a Nonlinear Finite Element Beam Model for Dynamic Contact Problems, Master's thesis, Chalmers, supervisor B Andersson, examiner K Runesson, June 2011.

X Zhao:
Modeling and Simulation of Cultivator Load Signals with a Fatigue Damage Perspective, Master's thesis, Chalmers, supervisor M Kvarnström, examiner I Rychlik, June 2011.

Presentations/Posters/Conferences

B Andersson:

Breakup of Particles in Turbulent Flows with Application to Spray Painting, Particles in Turbulence 2011, Potsdam, Germany, March 2011.

Simulation of Spray Painting in Automotive Industry, Svenska mekanikdagarna 2011, Göteborg, Sweden, June 2011.

A Berce, F Edelvik:

Virtuella fiberflöden, Seminar at Forskningen, Säffle, November 2011.

F Edelvik:

Virtual Paint - ED, Sealants, Cavity Wax and Curing, Mötesplats för framtidens framgångsrika verkstäder, Katrineholm, May 2011.

Multi-objective Optimization of Oven Curing in Automotive Paint Shops, The 21st International Conference on Multiple Criteria Decision Making, Jyväskylä, Finland, June 2011.

Elektromagnetiska beräkningar vid FCC, Guest Lecture for Engineering Physics Program, Chalmers, October 2011.

Multi-phase Flow Simulation in IBOFlow, Itaipu, Paraguay, November 2011.

Modeling and Simulation of Coating Processes in Automotive Industry, International Conference on Mathematical Modeling in Industry, Sao Paolo, Brazil, December 2011.

J Hagmar:

Optimal Parameterization of Posterior Densities Using Homotopy, FUSION 2011, Chicago, July 2011.

M Jirstrand:

Maxsim2 – Interactive Pharmacokinetic and Pharmacodynamic Simulation, International Congress Forum Life Science 2011, Munich, March 2011.

A Mark:

Microstructure Simulation of Early Paper Forming Using Immersed Boundary Methods, Siamuf seminar, Lund, March 2011.

The Hybrid Immersed Boundary Method for Simulating Complex Flows in Industrial Applications, Seminar at Fraunhofer ITWM, Kaiserslautern, Germany, May 2011.

Virtual Paint – Spray Painting, Mötesplats för framtidens framgångsrika verkstäder, Katrineholm May 2011.

VoF Simulations of Bingham Fluids, Complex Fluids Symposium, Micronic Mydata AB, December 2011.

R Rundqvist:

Spray Painting with IPS Paint: From General Multiphase Flow to Tailored Industrial Application, Siamuf seminar, Lund, March 2011.

E Svenning:

Multi-scale Simulation of Paperboard Edge Wicking Using a Fiber-resolving Virtual Paper Model, Progress in Paper Physics Seminar, Graz, Austria, September 2011.

Microstructure Simulation of Early Paper Forming Using Immersed Boundary Methods, Progress in Paper Physics Seminar, Graz, Austria, September 2011.

Microstructure Simulation of Early Paper Forming Using Immersed Boundary Methods, EU cost action on Fibre Suspension Flow Modelling, Nancy, France, October 2011.

Other assignments

F Edelvik:

Reviewer for International Journal of Numerical Modelling: Electronic Networks, Devices and Fields.

Reviewer for IEEE Antennas and Wireless Propagation Letters.

Reviewer for IEEE Transactions on Antennas and Propagation.

Organizer of the session Simulation Based Multicriteria Decision Support, at the 21st International Conference on Multiple Criteria Decision Making, Jyväskylä, Finland, June 2011.

S Jakobsson:

Reviewer for Zentralblatt.

M Jirstrand:

Member of Chalmers Area of Advance Life Science Management Group.

Reviewer for The 16th IFAC Symposium on System Identification – SYSID 2012.

External referee of the ERC Advanced Grant 2011 project proposals.

Invited organizer of a workshop on Future Modeling Strategies in Systems Biology funded by the EU-project FutureSysBio.

A Mark:

Reviewer for Tappi Journal.

R Sandboge:

Reviewer for Noise Control Engineering Journal.

Reviewer for Tappi Journal.

E Svenning:

Reviewer for Tappi Journal.

Courses

M Jirstrand:

Introduction to Computational Systems Biology and Tutorial on PathwayLab. Invited lecturer for The 4th International Course in Yeast Systems Biology, Gothenburg, June 2011.

Photo: Jan-Olof Yxell

FCC staff on December 22, 2011, in front of the Gothenburg town hall.

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.

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ITWM

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