ANNUAL REPORT | 2016

UMIT RESEARCH LAB

UMEÅ UNIVERSITY

The UMIT Staff. Full list of employees on page 22

About UMIT

UMIT Research Lab is a strategic initiative in computational science and engineering with a focus on industrial applications and innovative software tools. The lab is a dynamic, intellectual and physical environment enabling world class interdisciplinary research in scientific, high-performance, distributed, real-time and visual computing.

The research result in new models, methods, algorithms for advanced simulations and analysis of complex systems and phenomena using the latest high-performance computing platforms and IT infrastructures. UMIT is engaged in many projects and collaborations that target key challenges in industry and society, including solutions for more sustainable use of energy and materials in manufacturing and transportations and flexible yet powerful tools for understanding, exploring and collaborate on the design and control of complex systems.

Research lab

The lab is a natural meeting place for interdisciplinary research and development, with affiliated staff from the departments of computing science, mathematics, mathematical statistics, physics and applied physics and electronics. Around 50 researchers and developers are involved in the UMIT environment, and about 30 of them work in the lab. The lab offers access to special equipment and software. Seminars and workshops are centered around recent research results and advances in numerical methods, software, and hardware architectures, as well as scientific and industrial applications and new work methods.

Applications

Since 2009, the UMIT Research Lab has featured many recruitments, projects, and spinoffs. This work has established the lab as a leading center in the field of computational science and engineering. In addition to conducting fundamental research, UMIT is active in the development of new software technologies. The lab frequently participates in various collaborations with partners from industry and society, in order to explore the science, engineering, media, and entertainment applications for its research. Many projects have led to new or better products, more energy efficient and environmental solutions, and have contributed new job opportunities.

Top-class infrastructure

The High Performance Computing Center North (HPC2N), which is part of the national meta center SNIC, provides UMIT with expertise and e-infrastructure for grid and cloud computing, high-performance, and parallel computing, which includes effective mass-storage solutions.

Funding

The original funders are the EU Structural Fund Objective 2, Umeå municipality, Umeå University and the Baltic Donation Fund. Other sources of funding and agencies include Swedish Research Council, Swedish Foundation for Strategic Research, Formas, EU FP7/Horizon 2020, VINNOVA, Kempe Foundations, ProcessIT Innovations, Skogstekniska Klustret, Wallenberg Foundations and a number of private companies.

2016 – A brief review

Projects and grants

The Distributed Systems group has during the year started participation in two new recently granted Horizon 2020 projects, *RECAP* (710 kEUR) and *ACTiCLOUD* (500 kEUR). Also the Kempe foundations has decided to support the research on autonomous systems at Umeå University by granting 8 postdoctoral stipendiums of which 3 are initiated and hosted by UMIT researchers. The 3-year VINNOVA supported project Control of Granular Processes was concluded and was spun off with the project *Computer Vision in Granular Processes by Realtime Physics* where ABB and Boliden join as collaborating partners. A three year EU Botnia-Atlantica project, named *BA Innovation* with the goal of increased innovation by cooperation between regional SME and universities, was also granted in partnership with Centria and Novia in Finland, and the inland technology park situated in Vilhelmina.

Activities

The 8th and 9th Cloud Control Workshop were held in 2016, gathering the leading researchers in Sweden and some of the internationally leading experts in the area. The annual Swedish e-Science Academy was held in October with many participants from UMIT. UMIT arranged a workshop and theme day on computational design and digitization of industrial crane manipulators that gathered 60 researchers, engineers and entrepreneurs.

Spinoffs

UMIT research is disseminated also through a number of spinoff companies. During 2016 we noted that Algoryx Simulation AB joint an European consortium that addresses virtual commissioning of smart factories, including Daimler, Festo, Schneider Elerctronics Tarakos and Volvo Trucks. License agreements was closed with Rheinmetall in Germany and Longtek, which is the first entry on the Chinese market. Elastisys AB released Scalable WordPress, an application based on their cloud automation platform.

People

During 2016 UMIT welcomed Dung Ngoc Do as guest researcher, Daniel Elfversson and Mirko Myllykoski as postdocs, Chanh Le Tan Nguyen and Angelika Schwarz as PhD students, Simon Kollberg, Daniel Lindmark, Emil Marklund, Markus Pogulis and Jonas Sandqvist as research assistant. Esubalewe Lakie Yedeg and Mina Sedaghat defended their theses and earned their doctoral degree. Johan Tordsson was awarded Nordeas Scientific Prize and Bo Kågström was appointed Fellow in the Society for Industrial and Applied Mathematics (SIAM). Furthermore, André Massing became Assistant Professor and we enjoyed having Ida Bodén as UMIT affiliate during the year.
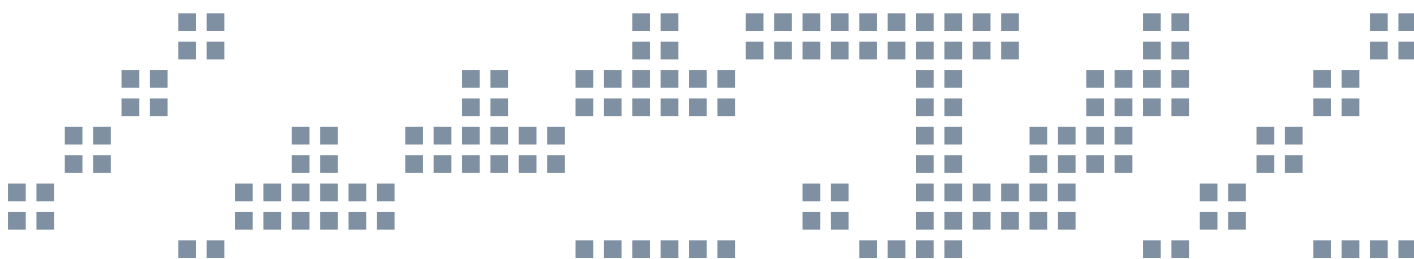
Project Highlights

"It's great fun that my research is brought to attention in this way! Data centers is a key technology for the ongoing digital revolution as these are the engines that drives all Internet services. The subject is also noted nationally through several major establishments in northern Sweden in recent years. As an addition to the positive response from research colleagues and industrial partners I see this award as a sign that we are right track" says Johan.

Johan Tordsson's research is looking for solutions for the future data center with the help of methods for autonomous systems, with the goal that data centers should be able to configure, repair, and optimize themselves without human involvement. He focuses his research primarily on two key issues for data center owners as well as users, namely virtualization and energy efficiency. The need for flexible solutions in the cloud, which are both large-scale, environmentally friendly and reliable, is large for customer-focused businesses like banks and insurance companies, where performance and availability are key concepts.

Tordsson's research aims to develop today's system to become both more robust and effective.
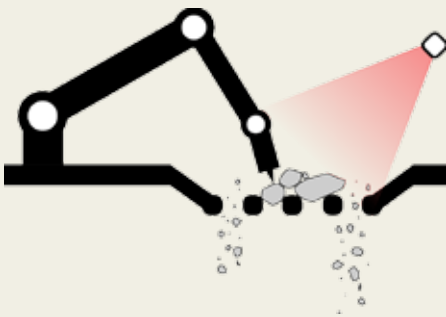
### Cloud expert recieves Nordeas science prize

Johan Tordsson, Assistant professor at the department of computing science, has received an award from Nordeas Norrlandsstiftelse for his research in future data centers. The prize summing up to SEK 100,000 was awarded at Umeå University's Annual ceremony on October 22nd.
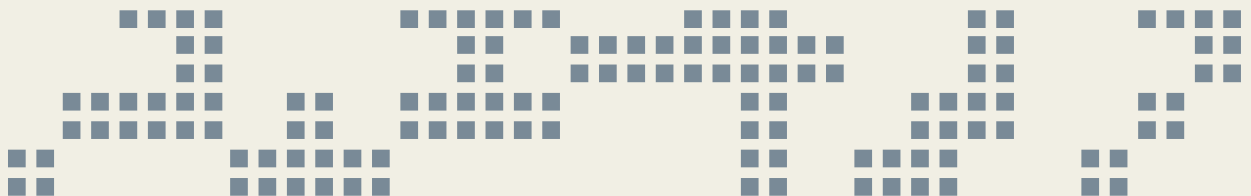
Computer vision in granular processes through real-time physics.

Martin Servin from UMIT Research lab has been granted 500 000 SEK from Vinnova for the project "Computer vision in granular processes through real-time physics". The aim of the project is to find stable methods for computer vision of granular material in loading, storage, and transport steps in mining and mineral processing. The purpose is to increase the rate of remote control and automation in the processes and give an improved possibility to trace the material flow in order to do a cause-effect analysis and optimize the process. The project spans over a one year period and is also aiming to find new entry points for further projects. Participating organization in the project are ABB, Algoryx Simulation, Boliden, LKAB, MBV Systems, Optimation and Umeå University.
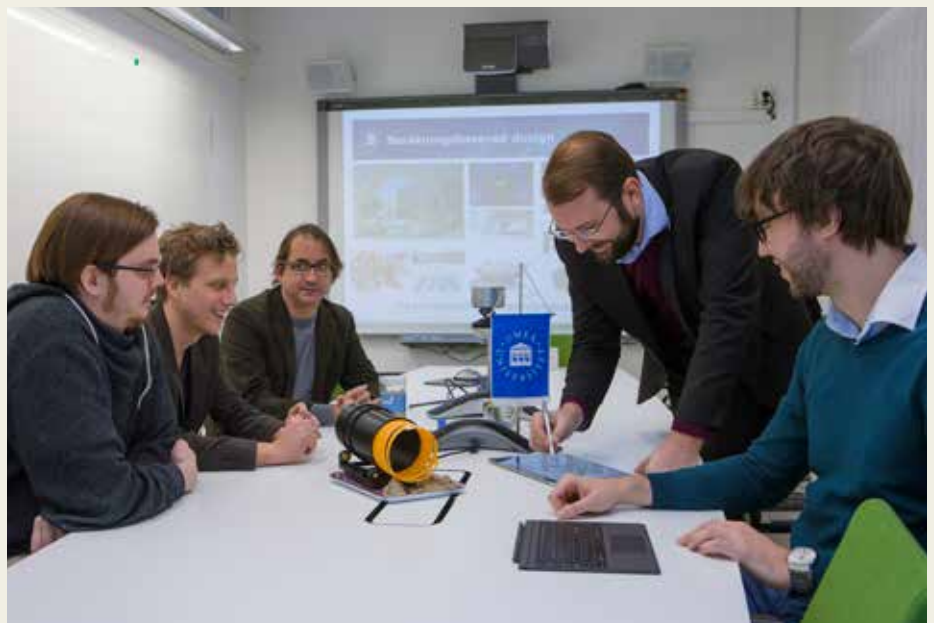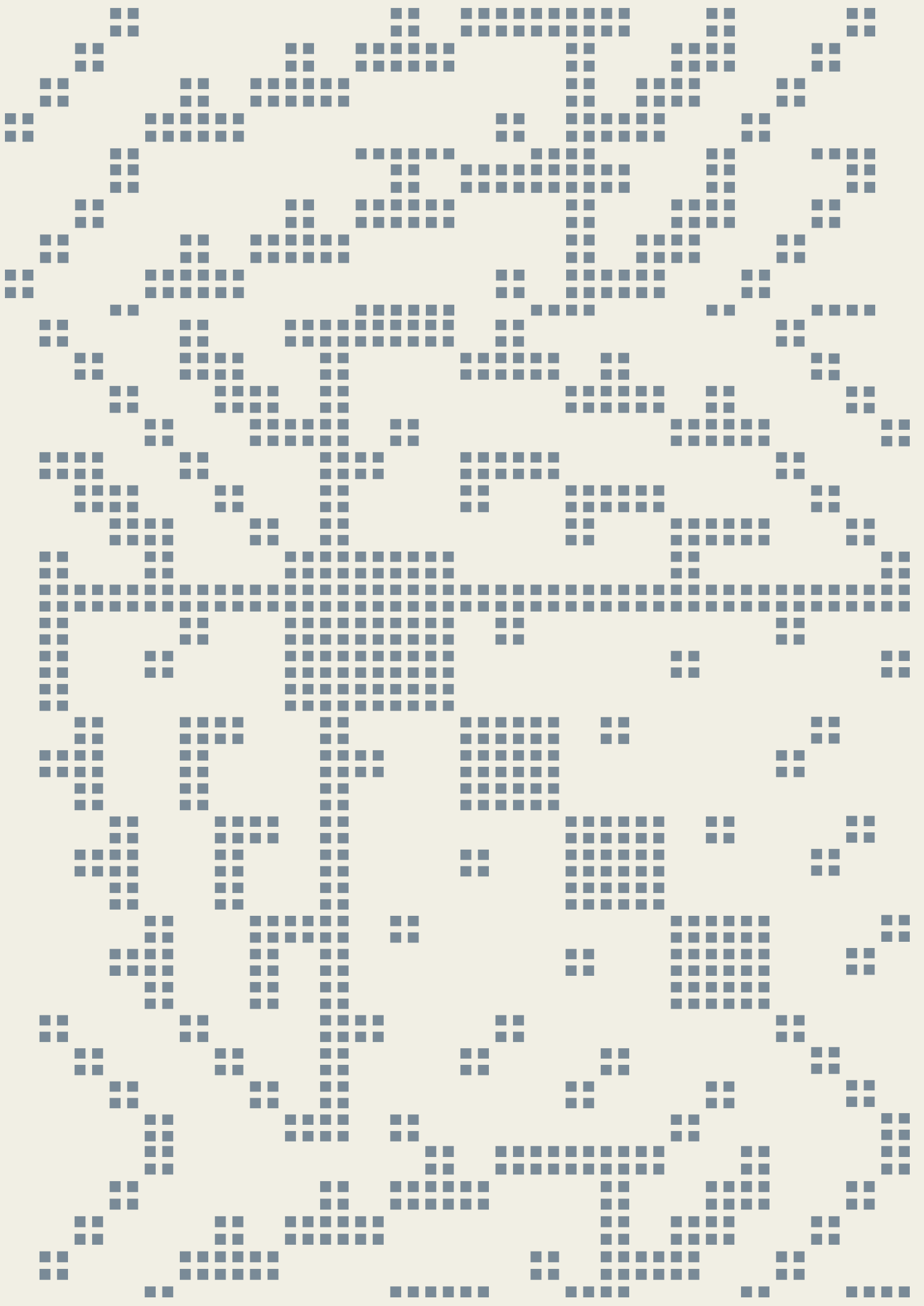
Massive effort on autonomous systems for industry and society

The Kempe Foundations have granted two years of funding for eight postdoctoral researchers in autonomous systems in a major investment at Umeå University. Autonomous systems consist of software and infrastructure that together with humans provide increased functionality, sustainability, and efficiency for society, such as self-driving cars, industry robots, and socially intelligent computer systems that can help people in their everyday life.

"We are facing a dramatic transformation of industry and society, a transformation expected to be as dramatic as the industrialisation in the early 1900s," says Erik Elmroth, professor in Computing Science at Umeå University and the leader of this effort.

Classic examples of autonomous systems are those where the system is assumed to replace the human, such as industry robots and self-driving cars. The potential for revolutionising industry and society is, however, much larger than that. Autonomous systems will be central to smart buildings, smart cities, digital cognitive agents, and production processes within broad fields. In these cases, the autonomous systems support the human ability to manage complexity, by analysis and decision-making, often based on vast amounts of data and under hard time requirements.

Another important area for autonomous systems is the management of the enormous IT infrastructure, including self-managing datacenters and networks, where autonomous systems make the decisions on how, when, and where capacity should be allocated. "This investment in autonomous systems is important to place the region and Umeå University in the forefront for the development of this area," says Erik Elmroth.

Eight new researchers

The investment complements the University's participation in the Wallenberg Autonomous Systems Program and comprises eight new postdoctoral researches to be led by eight different project leaders at three departments.

"Since autonomous systems cannot be developed in isolation from the areas in which they will be used, this research has to be multidisciplinary to be successful. Therefore, it is particularly important that this investment spans many scientific areas and departments," Erik Elmroth continues.

The recruitment of the eight researchers starts immediately. The ambition is to have all of them starting before Summer 2017.

The project leaders and the topics for the eight postdoctoral researchers:

- Erik Elmroth: Autonomous anomaly detection in future cloud computing infrastructures

- Leonid Freidovich: Automation for heavy-duty mobile hydraulic cranes with applications in agriculture and forestry

- Thomas Hellström: Recognition of human intention in verbal human-robot interaction

- Helena Lindgren: Digital Companions: Socially intelligent autonomous systems

- Juan Carlos Nieves: Autonomous systems that recognise, explain, and predict complex human activities

- Kai-Florian Richter: Autonomous systems' ability to understand their own limitations

- Martin Servin: Realtime physics-based computer vision for crane manipulators

- Johan Tordsson: Autonomous resource allocation for rack-scale systems

Professor at UMIT receives honorary fellowship

Bo Kågström, senior professor of Computing Science at Umeå University and active at the UMIT Research Lab has been appointed Society for Industrial and Applied Mathematics Fellow of 2016. He is being honoured for contributions to the understanding of matrix pencils and for leadership within the European high performance computing community.

"I am of course both happy and proud to be appointed as SIAM Fellow 2016, especially since the award gives recognition of your work and career in the worldwide SIAM Community. At the same time I want to emphasize that the award is a result of a very fruitful teamwork with current and former members of our research group - thanks to all of you!" says Bo Kågström and continues "Our contributions to parallel, high performance and scientific computing, includes theory, algorithms and software tools for dense and structured matrix computations with a broad spectrum of applications in science and engineering."

Recently, Umeå University, as coordinator, together with three international partners have been funded with nearly 4 Million Euro by Horizon 2020 for a front-line research project focusing on novel methods and software for the future supercomputer systems.

The Society for Industrial and Applied Mathematics, SIAM, designates fellows each year to recognise members of the community for their distinguished contributions to the disciplines of applied mathematics, computational science and related fields. The Fellows Selection Committee selects fellows based on nominations by SIAM members.

Bo Kågström is professor of Numerical Analysis and Parallel Computing and Director of High Performance Computing Center North (HPC2N) at Umeå University. Kågström has 25 publications in SIAM books and journals. He was a corresponding editor of the SIAM Journal on Matrix Analysis and Applications, was awarded the SIAM/SIAG Linear Algebra Prize in 2000, and has served on multiple SIAM prize committees, among other involvements.

Together with the other SIAM Fellows of 2016 he will be honoured at the 12 July SIAM Business Meeting during the SIAM Annual Meeting, which takes place on 11-15 July 2016 in Boston, MA, United States.

"Notably, Umeå University and the Department of Computing Science will also be highlighted at this conference on the occasion of my former graduate student Dr Andrii Dmytryshyn receiving the SIAM Student Paper Prize 2015," concludes Bo Kågström.
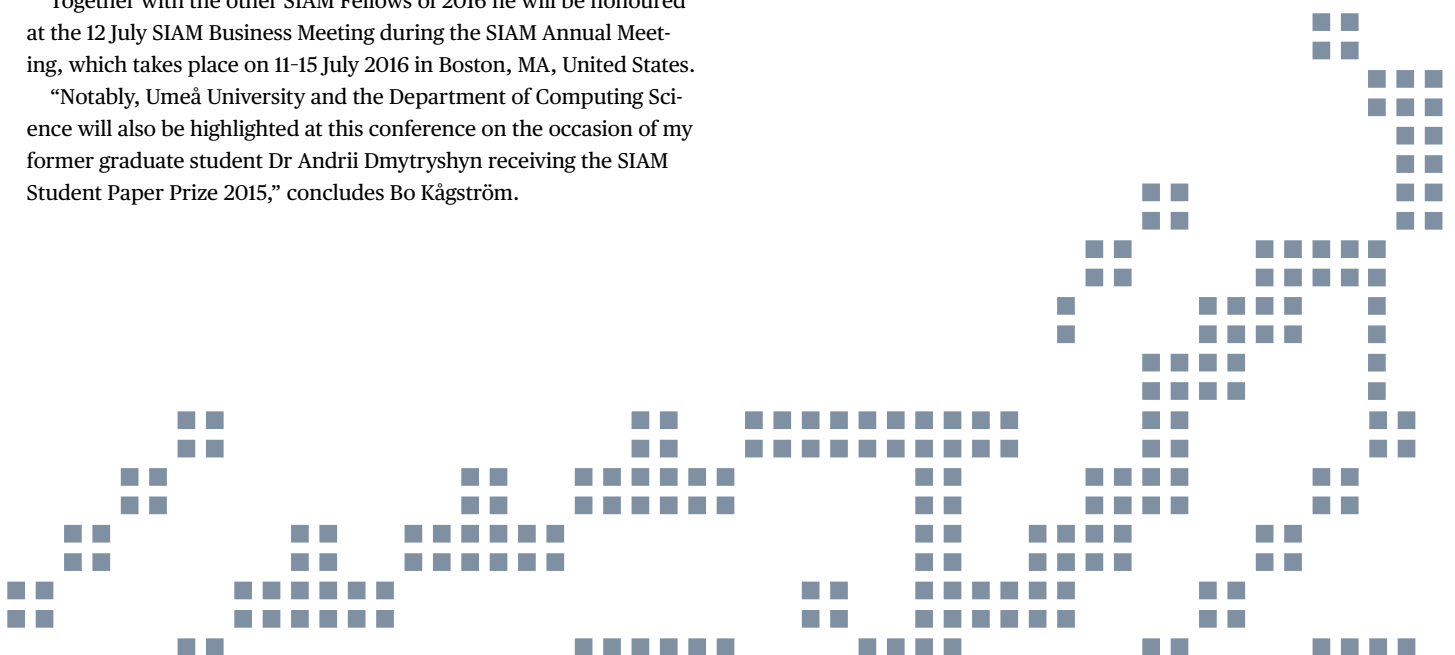
The future of cranes is digital

Digitization also affect the future of cranes. This was clear during a theme day in Umeå, which gathered some 60 researchers and entrepreneurs.

Umeå University and many companies in the region is far ahead in the development of digital platforms for future cranes. This became clear during a theme day Umeå on the design and manufacture of crane manipulators and their control systems. The theme day was organized by UMIT Research Lab at Umeå University with Dohi. The theme day was aimed at engineers, scientists and decision makers with an interest in how modern computational science and the industrial digitization is changing the way we design, produce, analyze and control the so-called cyber-physical systems found in mine, marine and forest environments and to future IT infrastructures machines could be part of.

"It is a good composition of industry and academia that signed up for the day. The region is unique in having world leading manufacturer of industrial crane manipulators and of systems equipped with them. We look forward to interesting discussions", said Martin Servin from UMIT who opened the theme day with Anna Alnefelt from Dohi.

State-of-art in computational science and engineering

The day began with a series of short talks covering the state-of-art in computational science and engineering, on-going innovation projects and how this can be exploited to understand the future of crane manipulators. This included computational optimization, mobile autonomous distributed IT-systems, new techniques for geometry meshing, automation and remote operation of forestry cranes and construction machines, simulation based design and mathematical statistics on big data sets.

Simulators

One of the companies that were in place were Oryx Simulations, which develops simulators, among other crane manufacturers. Their simulators have also increasingly a place in the research and development crane manufacturer engaged.

"This day is a very nice initiative. Oryx belongs to a world of unique cluster here in the region by companies and universities that we like are in. We want to contribute to the development of the cluster and provide virtual real-time solutions that are in demand," said Clarence Jacobson, CEO of Oryx.

From Luleå University of Technology and Process IT Innovations participated Ulf Andersson.

"Our workshop went well. I certainly agree with the importance of universities and business mixed up. Collaboration between industry and academia need to be encouraged with an overlap that works for both," said Ulf Andersson.

Workshop on the future of cranes

During the day, participants in six groups to discuss different opportunities for the future of cranes in different environments. A variation on the NABC model, a method often used to provide start-up companies with deeper insight into their business, were used extensively during the talks. NABC stands for customer needs (need), what solutions the company has (approach), customer benefits (benefits) and knowledge of what others are doing (competition) would be answered. The fourth part was replaced with cooperation (Cooperation).

Cranes should be seen as robots

"Three clear trends emerged when we summarized the day," concludes Martin Servin. Large amounts of sensor data, machine-machine interaction and open analysis and computing platforms that enable cross-border cooperation. It is clear that cranes should be seen as a robot rather than a mechanical system.

About 60 people attended the theme day. The participating organizations where ABB, Algoryx Simulations, Alten, Cranab, Dohi, HIAB, Indexator, Knowit, Komatsu Forest, Luleå tekniska universitet, MacGregor, Oryx Simulation, Skogforsk, Skogtekniska Klustret, Sweco, Swekip, Sveriges Lantbruksuniversitet, Tempus Information Systems, Umeå universitet and Ålö.

Research areas

UMIT unites excellent fundamental research in computational science and engineering with innovative and application-oriented research and software development. Within UMIT are scientists from the areas of computing science, mathematics, physics, and engineering. The science produced is internationally competitive and has strong support from VR, Vetenskapsrådet, Vinnova and the EU's 7th Framework Program.

- **Computational design optimization**

- **Computational mathematics**
  - **Finite elements**
  - **Geometric Numerical Integration**
  - **Spectral theory**

- **Distributed systems**

- **Interactive multiphysics and complex mechanical systems**

- **Parallel and scientific computing**
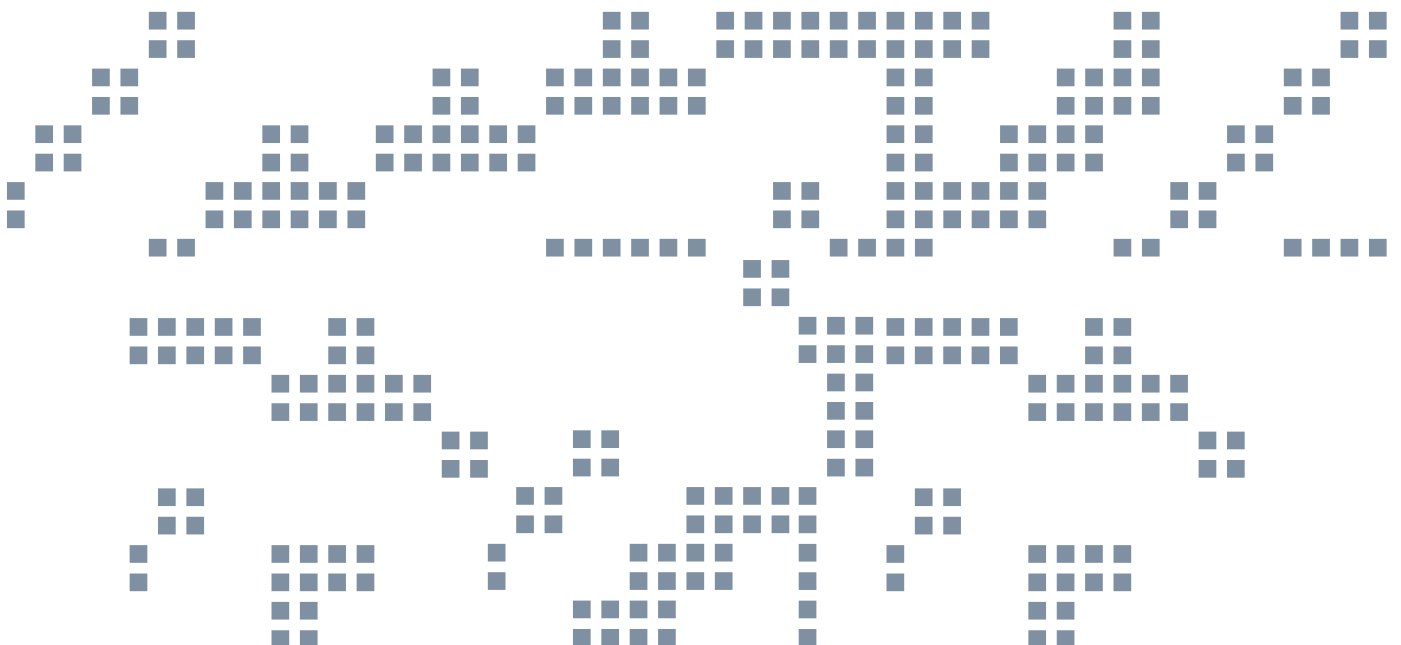
Computational design optimization

Computational design optimization is based on the idea of exploiting the power of computer simulations and optimization in the engineering design process.

The computational design optimization research group develops and analyzes methods that combine physics-based mathematical modeling, computer simulations, and optimization. The purpose is to find the particular shape or material arrangement of an object that yields the most favorable performance. Presently, the group focuses particularly on problems and situations where the measure of performance involves acoustic or electromagnetic wave propagation effects. We also consider problems that, from a methodological perspective, are closely related to design optimization, such as off-line optimal control problems and inverse problems, that is, the problem of determining the properties of a system from observations.

A pair of microwave antennas on printed circuit boards optimized for nearfield sensing and communication. The device could be used, for instance, for noninvasive monitoring of bone regeneration and healing.

Experimental prototypes

Research focus
Using simulations and numerical optimization to determine material compositions or shapes of objects in order to maximize the technical performance.

Applications
- Design optimization of systems where the measure of performance involves mechanical or electromagnetic properties
- Inverse problems: determining system properties from data observations

Projects
- Metallic antenna design optimization
- Nano-optic device optimization
- Loudspeaker design optimization
- Determination of moisture content from scattered electromagnetic radiation

Results
- Accurate computational models of the systems under consideration
- Fast and robust methods for design optimization of systems with a large number of design variables
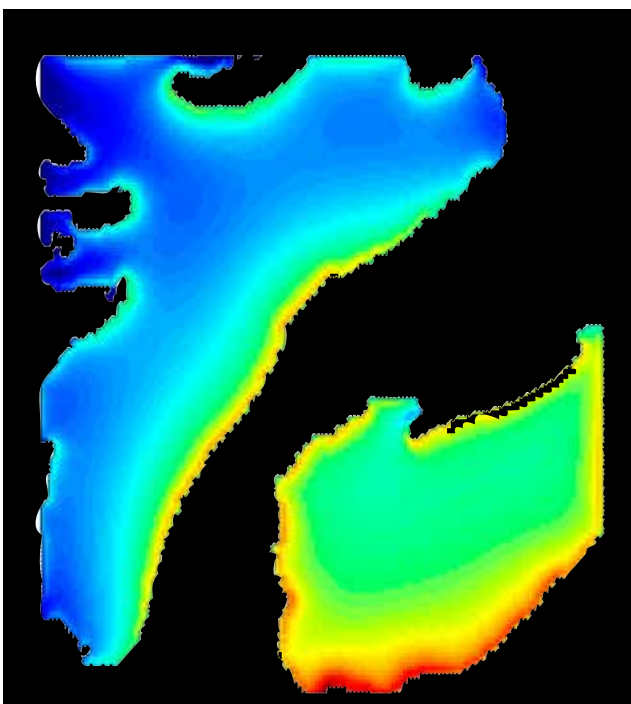- Loudspeaker horns with optimal transmission properties

Collaborations
Valutec AB, SP Sveriges tekniska forskningsinstitut, Träcentrum Norr, DAS Audio, and Limes Audio

Contact
Prof. Martin Berggren (group leader)
martinb@cs.umu.se

Dr. Eddie Wadbro
eddiew@cs.umu.se

Finite elements

The objective of the research group in computational mathematics at Umeå University is to conduct research on novel computational methods for the solution of partial differential equations and to promote their application in education, science and engineering.

Our research is interdisciplinary and located at the intersection between mathematics, computer science, engineering and their applications. We focus in particular on developing adaptive finite element methods, efficient and robust methods for solving multiscale and multiphysics problems, and model reduction techniques for large-scale problems. Applications are found, for instance, in the simulation of complex mechanical systems involving fluids and solids. Recently we have focused on the development of socalled cut finite element methods (CutFEM) that provide a new technique for simultaneous discretiza-

tion of both the geometry of the computational domain and the solution to the governing equations on a common background mesh. CutFEM is particularly interesting in situations where the geometry evolves over time or through numerical iterations, for instance in shape optimization methods. Part of our research is done in collaboration with industry. In particular, together with SKF, we are developing new model-reduction methods with improved local accuracy for the simulation of, for example, rolling bearings and gear wheels.

From left: Dr. André Massing, Prof. Mats G. Larson.

Research focus
Development, analysis, implementation, and application of novel finite element methods for partial differential equations. We consider in particular engineering applications in computational mechanics involving multiphysics and multi-scale phenomena.

Applications
Applications are found in simulations of complex mechanical systems and in biomechanics.

Projects
- Development of a two-phase fluid solver for design optimization
- CutFEM methods
- Methods and error estimates for polynomial and nonsymmetric eigenvalue problems
- Methods for higher order partial differential equations on surfaces
- Model reduction for localized stresses in rolling bearings

Results (optional)
- New finite element methods for membranes with large deformations
- New model reduction methods for viscoelastic materials implemented in SKF software
- New techniques for error analysis of finite element methods for partial differential equations on surfaces
- New software for CutFEM discretization of complicated geometries including CAD import

Collaborations
Chalmers University of Technology, Jönköping University, Royal Swedish Institute of Technology (KTH), Linköping University, Simula Research Laboratory AS, SKF

Contact information
Prof. Mats G. Larson (group leader)
mats.larson@math.umu.se

Dr. Karl Larsson
karl.larsson@math.umu.se

Geometric Numerical Integration

Differential equations appear everywhere in science and engineering, and can rarely be solved analytically, so that numerical methods have to be employed. Our group develop and analyze novel numerical algorithms for these problems.

In particular, our research concentrates in developing and analyzing so called geometric numerical integrators. Differential equations often show important qualitative features such as long-term dynamical behavior or geometry (conserved quantities, symplecticity, volume preservation, symmetries, etc.). This information is generally lost under standard discretization. On the other hand, the goal of geometric numerical integration is to design methods that preserve the particular underlying structure of such problems. This concept usually proves to offer more reliable time integrators.

The investigation done in our research group focuses in the following topics:

Highly oscillatory and multi scale problems. Such problems frequently arise in biology, geo-sciences, or molecular dynamics. We offer very competitive numerical methods for these problems.

With the increased presence of stochastic terms in mathematical models from biology, chemistry, finance, physics, and many other scientific fields, there is a strong demand for advanced numerical algorithms to handle stochastic differential equations. Our research group answers this demand by developing more advanced numerical methods for stochastic differential equations, tailored to fit specific properties of such problems.

Research focus
Development, implementation and analysis of efficient and reliable structure-preserving numerical algorithms for the discretization in time of (stochastic) differential equations.

Applications
Applications can be found in physics, molecular dynamics, and finance for example.

Projects
- Numerical methods for the discretization in time of stochastic (partial) differential equations.
- High-order time integrators for Hamiltonian partial differential equations.

Results
- Development and analysis of geometric numerical methods for highly oscillatory problems, Schrödinger equations, shallow water waves, stochastic differential equations, and stochastic partial differential equations.
- Analysis of the long-time behavior of numerical solutions to nonlinear wave equations.

Collaborations
University of Geneva, EPFL, NTNU Trondheim, Chalmers University of Technology,
Inria Lille Nord-Europe, TU Berlin, Karlsruhe Institute of Technology, University of Tübingen,
The University of Tokyo, Osaka University, Kyushu Institute of Technology, University of Oxford, University of Southampton, Autonomous University of Barcelona, Chinese Academy of Sciences.

Contact information
David Cohen, david.cohen@umu.se

Spectral theory

The objective of the research group is to study the whole chain, from physical modeling, to mathematical analysis and approximation theory, to software development. In particular, this research is concerned with the analysis and numerical solution of nonlinear spectral problems and simulation of wave phenomena.

One of the group's research focuses is photonic crystals, which are periodic structures with promising optical properties. These structures have many applications in optical communication, spectroscopy, and photonic crystal nano-cavity lasers. This project aims to achieve a greater understanding of how quantum mechanical effects and losses affect the performance of these structures. Another research focus is the analysis and computation of resonances in open structures. Possible applications include calculations of sound pressure levels in compressor blade rows, instabilities in aircraft engines, semiconductor lasers, single atom detection using microdisk resonators, and plasmonic nano-antennas. Several of the proposed projects require an interplay between spectral theory, finite element discretization, and linear algebra. Physical understanding and optimization are also highly important to the success of the projects. Therefore, members of the group collaborate closely with the physics department and other groups within UMIT Research Lab.
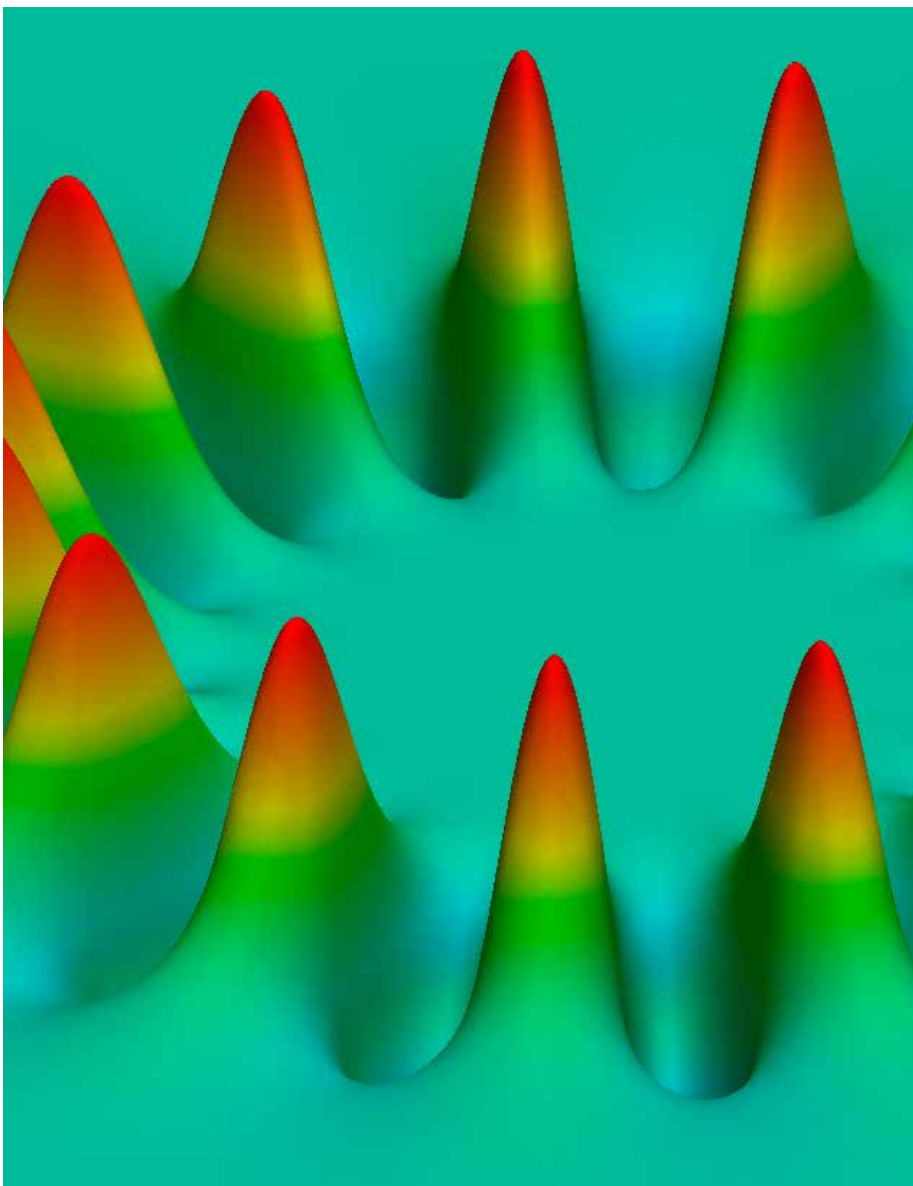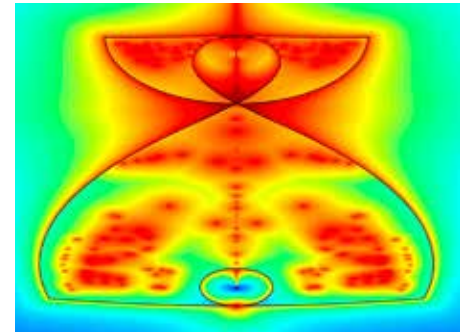
Research focus
We are working on the spectral theory of operator-valued functions relevant for problems in science and engineering, as well as the discretization of partial differential equations with high-order finite element methods.

Applications
Simulations of wave phenomena, multiphysics, and design of structures in nano-optics.

Projects
- Spectral analysis and approximation theory for a class of operator functions
- Finite element approximations of time-dependent problems in nano-optics

Results (optional)
- New spectral theory for block operator matrices
- New Galerkin spectral approximation theory for quadratic eigenvalue problems
- New perturbation theory to study non-self-adjoint perturbations of self-adjoint rational eigenvalue problems
- Development of a high-order interior penalty method code

Collaborations
Swiss Federal Institute of Technology in Zurich (ETH), École polytechnique fédérale de Lausanne (EPFL), Technical University of Berlin, Technical University of Wien, University of Bern, University of Zagreb

Contact information
Dr. Christian Engström
christian.engstrom@math.umu.se

Distributed systems

The research group focuses on autonomous management of cloud infrastructures, spanning from individual cloud infrastructures to large-scale distributed clouds, including so called telco clouds.

Research drivers are compute and data intensive applications requiring elastic localityaware infrastructures to meet the rapid capacity and locality variations of, including all of industrial services, end-user applications, Internet-of-Things applications, and largescale eScience applications. Research outcomes include autonomous infrastructure and application management systems and sophisticated tools for creating cloud-enabled applications. Examples of recent results include algorithms for Virtual Machine (VM) scheduling in clouds, methods for improved live migration of VMs, algorithms for autonomous capacity scaling, as well as methods for service differentiation and for enhancing energy efficiency, fault tolerance, and disaster recovery. Ongoing projects with immediate industrial benefits include collaborations with Intel Ireland, Ericsson Research, IBM Haifa, Red Hat, and Google in Mountain View, CA. Another result with industrial applications is the creation of the Elastisys spinoff company, with a focus on cloud auto-scaling and multicloud management.

From left to right:
Dr. P-O Östberg, Peter Gardfjäll, Prof.
Erik Elmroth, Dr. Mina Sedaghat.

Research focus
Autonomous resource and application management systems for individual cloud datacenters and highly distributed clouds, including telco clouds and internet of things infrastructures.

Applications
Applications that benefit most from this research are those that have large and or varying capacity needs, and for which performance and cost efficiency is important.

Projects
Cloud Control (VR framework project), eSSENCE (Government / VR), Context-aware cloud topology optimization and simulation (CACTOS, EU FP7), Business continuity as a service (ORBIT, EU FP7), Cloudberry Datacenters (Vinnova), and the creation of Elastisys AB, a spinoff company focusing on providing a cloud management system.

Collaborations
IBM Haifa Research, SAP Software Solutions, Lund University, Intel Ireland, Ericsson Research, Red Hat, Google, and others.
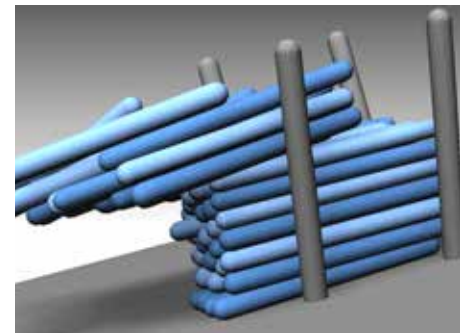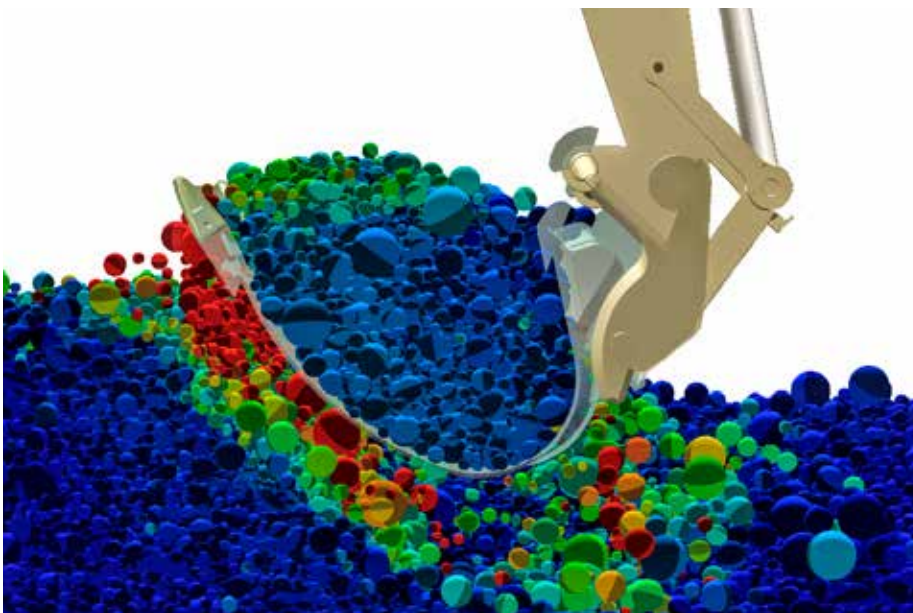
Contact
Prof. Erik Elmroth (group leader)
elmroth@cs.umu.se

Assoc. Prof. Johan Tordsson
tordsson@cs.umu.se

Dr. P-O Östberg
p-o@cs.umu.se

Interactive multiphysics and complex mechanical systems

How can the real world, with all its geometric complexity and dynamics on different time and length scales, fit in a computer program?

Well, it cannot. Something has to go. The question is what properties of the real world need to be captured in order to make a sufficiently realistic virtual replica of complex mechanical systems? And then there is the challenge of making the simulations fast and scalable, for example, to make applications run at an interactive rate or to exploit the full potential of a supercomputer. The research addresses multidomain modeling, numerical methods, and software for multibody system dynamics with nonsmooth phenomena. Discrete variational time-stepping of large-scale rigid multibody systems with frictional and impacting contacts, meshfree solids and fluids, and mechatronic systems are of particular interest. Methods are developed for sparse direct, iterative, and parallel solvers for the linear and nonlinear complementarity problems that describe the dynamics. The approach allows for fast and stable simulation of nonsmooth multidomain dynamics systems. The research has applications for various types of virtual environments, including visual interactive 3D simulation for making real-time simulators for the purpose of understanding, re-designing, control and optimization of industrial processes, robots, and vehicles; as well as for training, education or entertainment.

Research focus
Models and algorithms for fast multibody systems with nonsmooth and multidomain dynamics, for example vehicles, robots, biomechanics, granular matter, fluids, cables and cloth, electronics, and hydraulics.

Applications
- Co-simulation algorithms and infrastructure.
- Simulation-based design, control and optimization of complex mechanical systems.
- Visual real-time interactive simulation for physically faithful virtual environments.

Projects
- Computational crane
- Computer vision in granular processes by real-time physics
- Control of granular processes
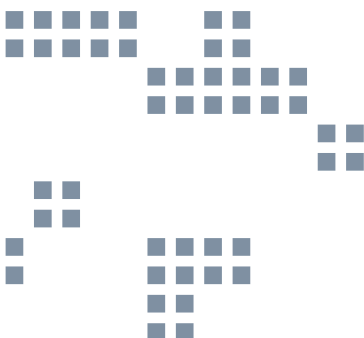- Virtual Truck and Bus

Collaborations
ABB, Algoryx Simulation, Boliden, Linköping University, LKAB, Optimation, Rensselaer Polytechnic Institute, Scania, Skogstekniska Klustret, Swedish University of Agriculture, Volvo Cars.

Contact
Dr Martin Servin
martin.servin@physics.umu.se

Dr Claude Lacoursière
claude@hpc2n.umu.se

Parallel and scientific computing

Parallelism is here to stay! Today, most computers, from laptops to supercomputers, are based on the so-called multicore architectures. Connecting many thousands of powerful, and possibly heterogeneous, multicore and accelerator based nodes using a high-performance interconnect leads to truly massive parallel systems with a tremendous performance potential.

This evolution makes it possible to solve even more complex and large-scale computational problems in science and engineering. At the same time, there is an immense demand for new and improved scalable, efficient, and reliable numerical algorithms, library software, and tools. This is essential, so that computations are carried out in a reasonable time and with the accuracy and resolution required.

Matrix computations are both fundamental and ubiquitous in the Computational Sciences, for example, in the modelling and simulation of problems ranging from galaxies to nanoscale, and in real-time airline scheduling and medical imaging. Computing the Google PageRank vector of all web pages on the Internet is called the world´s largest matrix computation of today, with a hyperlink matrix of n-by-n, where n > 50 billion.

Besides such large-scale problems, there are many challenging matrix computations in the design and analysis of linear control systems. Modeling interconnected systems (electrical circuits, for example) and mechanical systems (such as multibody contact problems) can lead to descriptor systems. Periodic models arise in several practical applications, e.g. the control of rotating machinery. We are investigating how to exploit the inherent structure of several of the associated matrix problems.

Angelika Schwarz joined the group in 2016

Mirko Myllykoski joined the group in 2016

Research focus
Design of efficient and reliable algorithms for structured and dense matrix computations targeting many-core architectures, accelerators, and massive parallelism.

Applications
Applications can be found, for example, in control system design and analysis, real-time physics simulations, biochemistry, and molecular dynamics.

Projects
- NLAFET – Parallel Numerical Linear Algebra for Extreme Scale Systems
- eSSENCE – Efficient and Reliable HPC Algorithms for Matrix Computations in Application
- Parallel and cache-efficient algorithms and data structures for multi-core and hybrid architectures.
- Design of parallel algorithms for eigenvalue problems, matrix factorizations, matrix equations, and matrix functions.
- Algorithms and tools for computing structural information of general and structured matrix pencils and polynomials. StratiGraph and the MCS Toolbox for Matlab
- Design, evaluation, and analysis of numerical algorithms for the stabilization of linear systems with periodic coefficients.
- Direct sparse solvers for constrained simulations of polypeptides submerged in water.

Results
Novel theory, algorithms, library software, and tools to be used as building blocks for various academic and industrial applications.

Collaborations
Algoryx, DLR, IBM, Niconet/SLICOT, ScaLAPACK; several universities and research institutes, including KI, UC Berkeley, Cornell, EPFL, Inst. of Mathematics Kiev, Fudan Univ., UC Louvain, INRIA-Paris, STFC-RAL, Univ. of Manchester, Univ. of Denver, Univ. of Zaragoza, Univ. of Hamburg, Univ. of Tennessee, Knoxville, Univ. of Zagreb, Universidad Carlos III de Madrid, and Uppsala Univ.

Contact
Prof. Bo Kågström (group leader)
bo.kagstrom@cs.umu.se

Asst. Prof. Lars Karlsson
larsk@cs.umu.se

Dr Andrii Dmytryshyn
andrii@cs.umu.se

Dr Stefan Johansson
stefanj@cs.umu.se

Dr Carl Christian Kjelgaard Mikkelsen
spock@cs.umu.se

List of publications 2016

Journal papers

Bosner, N. & Karlsson, L.. Parallel and Heterogeneous m-Hessenberg-Triangular-Triangular Reduction. SIAM J. Sci. Comput., 39(1), pp. C29-C47, 2016 (electronic version).

Cohen, David & Quer-Sardanyons, Lluís. A fully discrete approximation of the one-dimensional stochastic wave equation. IMA Journal of Numerical Analysis, 36(1): 400-420, 2016.

Cohen, David & Verdier, Olivier. MultiSymplectic discretisation of wave map equations. SIAM Journal on Scientific Computing, 38(2): A953-A972, 2016.

Chen, Chuchu & Cohen, David & Hong, Jialin. Conservative methods for stochastic differential equations with a conserved quantity. International Journal of Numerical Analysis and Modeling, 13(3): 435-456, 2016.

Dmytryshyn, A. & da Fonseca, C. M. & Rybalkina, T. Classification of pairs of linear mappings between two vector spaces and between their quotient space and subspace, Linear Algebra Appl., 509, pp. 228-246, 2016.

Dmytryshyn, A. Miniversal deformations of pairs of skew-symmetric matrices under congruence, Linear Algebra Appl., 506, pp. 506-534, 2016.

Karlsson, L. & Kressner, D. & Uschmajew, A. Parallel algorithms for tensor completion in the CP format. Parallel Computing, 57, pp. 222-234, 2016.

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Anton, Rikard & Cohen, David & Larsson, Stig; et al. Full discretization of semilinear stochastic wave equations driven by multiplicative noise. SIAM Journal on Numerical Analysis, 54(2): 1093-1119, 2016.

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Sedaghat, Mina & Hernández-Rodriguez, Francisco & Elmroth, Erik. Decentralized cloud datacenter reconsolidation through emergent and topology-aware behavior. Future generations computer systems, 56: 51-63, 2016.

Wadbro, Eddie & Hallberg, Per & Schedin, Staffan. Optimization of an intraocular lens for correction of advanced corneal refractive errors. Applied Optics, 55(16): 4378-4382, 2016.

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Tärneberg, William & Mehta, Amardeep & Wadbro, Eddie; et al. Dynamic application placement in the Mobile Cloud Network. Future generations computer systems, 2016.

Hosseini, Ahmad & Wadbro, Eddie. Connectivity reliability in uncertain networks with stability analysis. Expert systems with applications, 57: 337-344, 2016.

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Schmidt, Stephan & Wadbro, Eddie & Berggren, Martin. Large-Scale Three-Dimensional Acoustic Horn Optimization. SIAM Journal on Scientific Computing, 38(6): B917-B940, 2016.

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Farokhi, Soodeh & Jamshidi, Pooyan & Lakew, Ewnetu Bayuh; et al. A hybrid cloud controller for vertical memory elasticity: a control-theoretic approach. Future generations computer systems, 65: 57-72, 2016.

Burman, Erik & Hansbo, Peter & Larson, Mats G; et al. Full gradient stabilized cut finite element methods for surface partial differential equations. Computer Methods in Applied Mechanics and Engineering, 310: 278-296, 2016.

Hosseini, Ahmad & Wadbro, Eddie. A feasibility evaluation approach for time-evolving multi-item production-distribution networks. Optimization Methods and Software, 31(3): 562-576, 2016.

Cenanovic, Mirza & Hansbo, Peter & Larson, Mats G. Cut finite element modeling of linear membranes. Computer Methods in Applied Mechanics and Engineering, 310: 98-111, 2016.

Papadopoulos, Alessandro Vittorio & Klein, Cristian & Maggio, Martina; et al. Control-based load-balancing techniques: Analysis and performance evaluation via a randomized optimization approach. Control Engineering Practice, 52: 24-34, 2016.

Yedeg, Esubalewe Lakie & Wadbro, Eddie & Hansbo, Peter; et al. A Nitsche-type Method for Helmholtz Equation with an Embedded Acoustically Permeable Interface. Computer Methods in Applied Mechanics and Engineering, 304: 479-500, 2016.

Wang, Da & Servin, Martin & Berglund, Tomas. Warm starting the projected Gauss-Seidel algorithm for granular matter simulation. Computational Particle Mechanics, 3(1): 43-52, 2016.

Hansbo, Peter & Larson, Mats G. & Zahedi, Sara. A cut finite element method for coupled bulk-surface problems on time-dependent domains. Computer Methods in Applied Mechanics and Engineering, 307: 96-116, 2016.

Servin, Martin & Wang, Da. Adaptive model reduction for nonsmooth discrete element simulation. Computational Particle Mechanics, 3(1): 107-121, 2016.

Engström, Christian & Giani, Stefano & Grubisic, Luka. Efficient and reliable hp-FEM estimates for quadratic eigenvalue problems and photonic crystal applications. Computers and Mathematics with Applications, 72(4): 952-973, 2016.

Engström, C. & Langer, H & Tretter, C. Rational eigenvalue problems and applications to photonic crystals, Journal of Mathematical Analysis and Applications, 445(1):240-279, 2017.

Conference papers

Tomas, Luis & Saeid Masoumzadeh, Seyed & Hlavacs, Helmut. Self-Adaptive Capacity Controller: A Reinforcement Learning Approach, 2016.

Kostentinos Tesfatsion, Selome & Wadbro, Eddie & Tordsson, Johan. Autonomic resource management for optimized power and performance in multi-tenant clouds. 2016 IEEE International Conference on Autonomic Computing (ICAC): 85-94, 2016.

Tomas, Luis & Bayuh Lakew, Ewnetu & Elmroth, Erik. Service Level and Performance Aware Dynamic Resource Allocation in Overbooked Data Centers. 2016 16TH IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGRID): 42-51, 2016.

Tomas, Luis & Masoumzadeh, Seyed Saeid & Hlavacs, Helmut. Self-Adaptive Capacity Controller: A Reinforcement Learning Approach. 2016 IEEE International Conference on Autonomic Computing (ICAC): 233-234, 2016.

Ibidunmoye, Olumuyiwa & Metsch, Thijs & Elmroth, Erik. Real-time Detection of Performance Anomalies for Cloud Services. 2016 IEEE/ACM 24th International Symposium on Quality of Service (IWQoS 2016): 164-165, 2016.

Kjelgaard Mikkelsen, Carl Christian. Accelerating sparse arithmetic in the context of Newton's method for small molecules with bond constraints. PPAM 2015: Parallel Processing and Applied Mathematics: 160-171, 2016.

Durango, Jonas & Tarneberg, William & Tomas, Luis; et al. A control theoretical approach to non-intrusive geo-replication for cloud services, 2016.

Saeid Masoumzadeh, Seyed & Hlavacs, Helmut & Tomas, Luis. A Self-Adaptive Performance-Aware Capacity Controller in Overbooked Datacenters. 2016 IEEE International Conference on Autonomic Computing (ICCAC): 12-23, 2016.

Sedaghat, Mina & Wadbro, Eddie & Wilkes, John; et al. Die-Hard:Reliable Scheduling to Survive Correlated failures in Cloud Data Centers. 2016

Sedaghat, Mina & Wadbro, Eddie & Wilkes, John; et al. DieHard: reliable scheduling to survive correlated failures in cloud data centers. 2016 16TH IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGRID): 52-59, 2016.

Mehta, Amardeep & Tärneberg, William & Klein, Cristian; et al. How Beneficial are intermediate layer Data Centers in Mobile Edge Networks? 2016 IEEE 1st International Workshops on Foundations and Applications of Self-* Systems: 222-229, 2016.

Rodrigo, Gonzalo P. & Östberg, Per-Olov & Elmroth, Erik; et al. Towards Understanding Job Heterogeneity in HPC: A NERSC Case Study. 2016 16TH IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGRID): 521-526, 2016.

Theses

Adlerborn, B. Parallel Algorithms and Library Software for the Generalized Eigenvalue Problem on Distributed Memory Computer Systems. Licentiate Thesis, Department of Computing Science, Umeå University, 2016.

Lindmark, Daniel. Simulation based exploration of a loading strategy for a LHD-vehicle, Master's thesis for the degree in Engineering Physics, 2016.

Le, Tuan Anh. Workload prediction for resource management in data centers, Master's thesis for the degree in Computational Science and Engineering, 2016.

Submitted papers and reports

Adlerborn, B. & Kågström, B. & Karlsson, K. Distributed One-stage Hessenberg-triangular Reduction with Wavefront Scheduling. Report UMINF 16.10, Department of Computing Science, Umeå University. (Submitted 2016)

Dmytryshyn, A. & Futorny, V. & Klymchuk, T. & Sergeichuk, V. Generalization of Roth's solvability criteria to systems of matrix equations. (Submitted 2016)

Dmytryshyn, A. & Dopico, F. M. Generic matrix polynomials with fixed rank and fixed degree, Report UMINF 16.19, Department of Computing Science, Umeå University. (Submitted 2016)

Eljammaly, M. & Karlsson, L. & Kågström, B. Evaluation of the Tunability of a New NUMA Aware Hessenberg Reduction Algorithm. Report UMINF 16.22. Department of Computing Science, Umeå University.

Myllykoski, M. & Rossi, T. & Toivanen, J. On solving separable block tridiagonal linear systems using a GPU implementation of radix-4 PSCR method, University of Jyväskylä and Umeå University. (Submitted 2016)

Dissertation 2016

Mina Sedaghat

Thesis title
Cluster Scheduling and Management for Large-Scale Compute Clouds.

Description
Mina Sedaghat has developed techniques and algorithms to manage and schedule the resources in large data centres at a lesser cost, more efficiently, more reliably and with a lower environmental impact. Her research has been in done in collaboration with Google Inc. Departments and Royal Institute of Technology (KTH).
www.teknat.umu.se/pressinformation/nyhetsvisning/nya-metoder-for-effektivare-och-energisnalare-internettjanster.cid262083

Does Today
Mina is now working as an Infrastructure Analyst at Accenture in Stockholm, Sweden.

Esubalewe Lakie Yedeg

Thesis title
Analysis, Control, and Design Optimization of Engineering Mechanics Systems

Description
Esubalewe Lakie Yedeg has in his research developed computer simulation approaches and applied them to the design of various acoustic devices. A particular issue that he has studied in detail is how to model and optimize the distribution of very thin and elongated structures. This as been applied to the design of so-called reactive mufflers.

Does today
Esubalewe is now Postdoc at the Division of numerical analysis at KTH Royal Institute of Technology
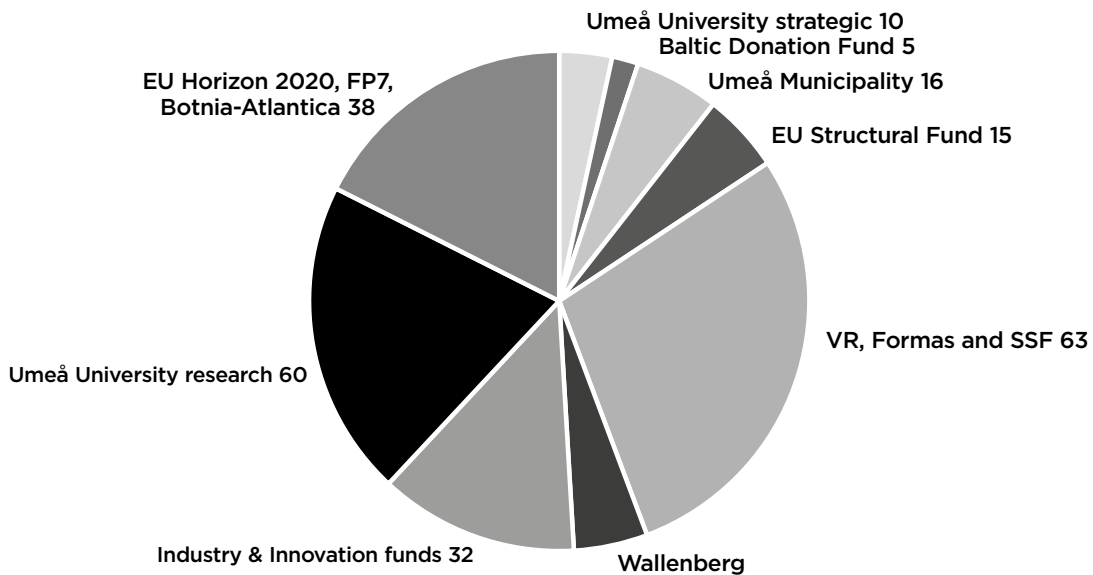
Financing

The UMIT project was initiated in 2009 with a total funding budget of 40 MSEK distributed over a five-year period.
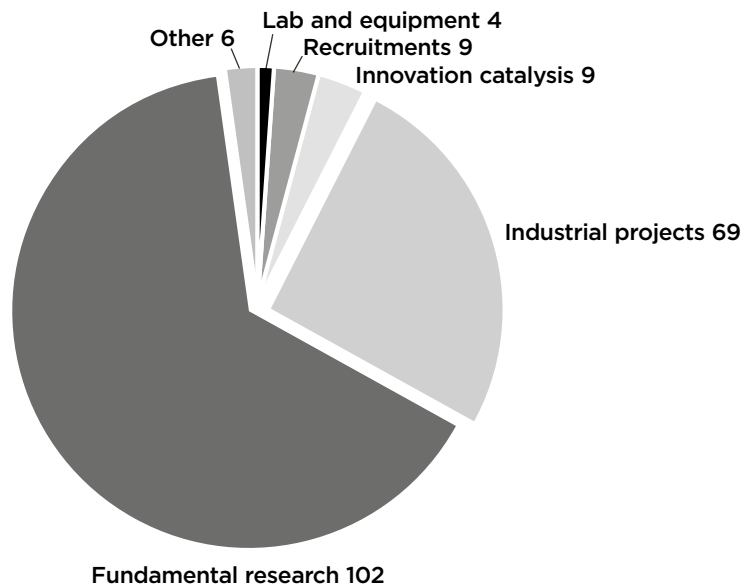
Founding financiers are the Baltic Donation Fund (5 MSEK), the EU Structural Fund-Objective 2 (15 MSEK), Umeå municipality (10 MSEK) and Umeå University (10 MSEK). In addition to the initial funding of 40 MSEK, UMIT had, by the end of 2016, raised additional 187 MSEK from external sources for the co-financing of specific projects, e.g. EU FP7, EU Bottnic-Atlantica, FOI, Kempestiftelserna, LKAB, ProcessIT Innovations, SKF, Skogtekniska Klustret, Sorubin, SSF - Swedish Foundation for Strategic Research, Surgical Science, Valutec, VINNOVA and VR – The Swedish Research Council.

This correspond to annual external funding of 20 MSEK and a strong support for both fundamental science and for applied research in industry collaboration. By the end of 2016, our affiliated scientists had in total been granted 69 MSEK from VR since 2009. The research financed by faculty and the industrial doctoral school during the same period amounts to 60 MSEK.

Accumulated funding since 2009, total 293 MSEK

- Umeå University strategic 10
- Baltic Donation Fund 5
- Umeå Municipality 16
- EU Structural Fund 15
- EU Horizon 2020, FP7, Botnia-Atlantica 38
- VR, Formas and SSF 63
- Umeå University research 60
- Industry & Innovation funds 32
- Wallenberg

Budget, total 193 MSEK

- Other 6
- Lab and equipment 4
- Recruitments 9
- Innovation catalysis 9
- Industrial projects 69
- Fundamental research 102

Management group

Martin Berggren

Professor
Dept. Computing Science

Bo Kågström

Professor
Dept. Computing
Science/HPC2N

Mats G. Larson

Professor
Dept. Mathematics and
Mathematical Statistics

Martin Servin

Assistant Professor
Dept. Physics

Christian Engström

Assistant Professor
Dept. Mathematics and
Mathematical Statistics

Erik Elmroth

Professor
Dept. Computing Science

Kenneth Bodin

IT Project Leader
HPC2N

Margareta Brinkstam

Administrator

Mats Johansson

Project Coordinator

Board members

**Åsa
Rasmuson-Lestander**
Chairman of the Board
Dean of the Faculty of
Science and Technology,
Professor, Umeå
University

**Mats G.
Larson**
Board member,
Professor, Umeå
University

**Bo
Kågström**
Board member,
Professor, Umeå
University

UMIT staff during 2016

Computational Design Optimization
Prof. Martin Berggren
Dr. Eddie Wadbro
Dr. Daniel Noreland
Emadeldeen Hassan
Dung Ngoc Do
Linus Hägg

**Computational Mathematics
Finite Elements**
Prof. Mats G Larson
Dr. Karl Larsson
Dr. André Massing
Dr. Fredrik Bengzon
Dr. Daniel Elfversson
Martin Björklund
Tobias Jonsson

Geometric numerical integration
Dr. David Cohen
Rikard Anton

Spectral theory
Dr. Christian Engström
Juan Carlos Araujo-Cabarcas
Axel Torshage

Distributed systems
Prof. Erik Elmroth
Dr. Johan Tordsson
Dr. P-O Östberg
Dr. Cristian Klein
Dr. Luis Thomás
Dr. Chanh Le Tan Nguyen
Dr. Ahmed Ali-Eldin
Dr. Ewnetu Bayuh Lakew
Dr. Gonzalo Rodrogi Alvarez
Dr. Mina Sedaghat
Olumuyiwa Ibidunmoye
Jakub Krzywda
Amardeep Mehta
Selome Kostentinos Tesfatsion
Abel Pinto
Simon Kollberg
Emil Marklund

**Interactive multiphysics and complex
mechanical systems**
Dr. Martin Servin
Dr. Claude Lacoursière
Lic Kenneth Bodin
Tomas Härdin

Mattias Linde
Daniel Lindmark
Markus Pogulis
Jonas Sandqvist

Parallel and scientific computing
Prof. Bo Kågström
Dr Andrii Dmytryshyn
Dr Pedher Johansson
Dr Stefan Johansson
Dr Lars Karlsson
Dr Carl Christian Kjelgaard Mikkelsen
Dr Mirko Myllykoski
Björn Adlerborn
Mahmoud Eljammaly
Angelika Schwarz

**Project coordination and administration**
Ida Bodén
Margareta Brinkstam
Mats Johansson

Industry collaborations

Algoryx Simulation

ABB

Boliden

DAS Audio

DLR

Elastisys

Ericsson Research

Enmesh

Google

IBM

IBM Haifa Research Labs

Intel Ireland

Komatsu Forest

Limes Audio

LKAB

MBV Systems

Modelon

Olofsfors

Optimation

Oryx Simulations

Red Hat

SAP Research

Simula Research Laboratory

SKF

Scania

Skogstekniska Klustret

SP Sveriges tekniska forsknings-institut

Träcentrum Norr

Valutec AB

Volvo
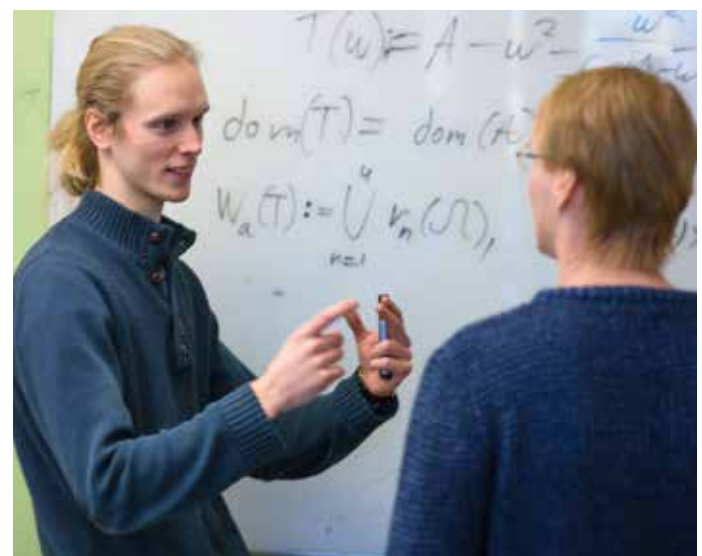
UMIT Research Lab is a strategic initiative in computational science and engineering with a focus on industrial applications and innovative software development. The research lab, formed in 2009, is a dynamic, intellectual and physical research environment enabling worldclass interdisciplinary, research in scientific, high-performance, distributed, real-time and visual computing.

The main funders are Umeå University, Umeå Municipality, the Baltic Foundation, and EU Structural Fund–Objective 2.

UMIT Research Lab

MIT-building
Umeå University, SE-901 87 Umeå Sweden

www.org.umu.se/umit/

UMEÅ UNIVERSITY

UMEÅ KOMMUN

BALTICGRUPPEN

En investering för framtiden

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonder