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The 61st SIMS Conference on Simulation and Modelling SIMS 2020

Editors: Esko Juuso, Bernt Lie, Erik Dahlquist, and Jari Ruuska

Organized by University of Oulu
Finnish Simulation Forum (FinSim)
and
Finnish Society of Automation

Proceedings of
The 61st SIMS Conference on Simulation and Modelling
SIMS 2020

Virtual Conference, Finland, 22-24 September 2020

Editors:
Esko Juuso, Bernt Lie, Erik Dahlquist, and Jari Ruuska

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in cooperation with:
Scandinavian Simulation Society (SIMS)

Preface

The 61st SIMS conference on Simulation and Modelling (SIMS 2020) was organized as a virtual conference. Originally, this conference was planned to be the first SIMS EUROSIM conference and organized in Oulu, Finland. The COVID-19 pandemic presented tremendous challenges for the global research community and for the entire world. The organizers were first postponing the deadlines and keeping the plan of organizing the conference in person. Since the pandemic was continuing strongly, the plans were changed: the SIMS 2020 was decided to organize as a virtual conference in September 2020 and the first SIMS EUROSIM conference in September 2021.

The Scandinavian Simulation Society consists of members from five Nordic countries: Denmark, Finland, Norway, Sweden, and Iceland. The goal of SIMS is to further develop the science and practice of modelling and simulation in all application areas and to be a forum for information interchange between professionals and non-professionals in the Nordic countries. SIMS is a member society of The Federation of European Simulation Societies (EUROSIM) was set up in 1989. The purpose of EUROSIM is to provide a European forum for regional and national simulation societies to promote the advancement of modelling and simulation in industry, research and development. EUROSIM consists of 17 European Simulation Societies. The Scandinavian simulation society (SIMS) had Board and Annual Meetings during the conference.

The conference program consisted of four keynote presentations, a SIMS history review, 70 regular presentations and a panel discussion. The proceedings include 68 full papers. The keynotes and the history review are included as abstracts. The call for papers resulted in 81 submissions prepared by 181 authors from eleven countries. The reviews of all submissions were done by four chairs, eleven IPC members and 37 international reviewers. Full papers were selected on the grounds of academic merit and relevance to the conference theme. Each submission had 2-4 reviews and the acceptance rate was 84% for the full papers published in the proceedings.

The SIMS 61 conference covered broad aspects of simulation, modeling and optimization in engineering applications, including many papers on energy, industry, circular economy, automation and methodologies. Energy papers focus on buildings, district heating, hydro power and heat production. Industry includes papers on steel industry, material processing, granulation, oil and gas industry and transportation. Chircular economy related papers study anaerobic digestion, pyrolysis, condensation and microbial electrosynthesis. The part of CO_2 capture and use include CO_2 injection, heat exchangers in CO_2 capture and CO_2 absorption. Automation related papers focus on monitoring and control. Digital twins are studied in industrial processes, fault detection and ERP and MES. Fluid dynamic part include CFD and CPFD models, computational studies of fluidized beds, a gasification reactor and subcooled boiling heat transfer. Statistical and intelligent methodologies papers use the Bayesian approach, partial least squares, intelligent methodologies and agent-based simulations.

Panel discussions were organised on future challenges and possibilities for simulation. The discussion focused on five areas: simulation, energy systems, big data, environment and simulation toolboxes. The virtual conference did not include technical tours. Industrial and environmental applications, development of modelling and simulation tools and strong support for PhD students continue for stimulating process development model-based automation.

We would like to express our sincere thanks to the keynote speakers, authors, session chairs, members of the program committee and additional reviewers who made this conference such an outstanding success. Finally, we hope that you will find the proceedings to be a valuable resource in your professional, research, and educational activities whether you are a student, academic, researcher, or a practicing professional.

Esko Juuso, Bernt Lie, Erik Dahlquist, and Jari Ruuska

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- Adj. prof. Esko Juuso, Conference Chair, University of Oulu, Finland

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Peter Fritzson, Department of Computer and Information Science, Linköping University, Sweden

Real-time optimization and control with inaccurate model
Prof. Sebastian Engell, Process Dynamics and Operations Group, Biochemical and Chemical Engineering Department TU Dortmund, Germany

Digital Twins utilization throughout the Life Cycle of Industrial Processes
Dr. Tuula Ruokonen, Digital Services Solutions in Valmet Technologies Oy, Finland

SIMS 60+

Scandinavian Simulation Society 60+ ready for future challenges
Esko Juuso, University of Oulu, Finland,

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Chair: Adj. prof. Jari Ruuska, University of Oulu, Finland

Panelists:
Prof. Peter Fritzson, Linköping University, Sweden
Prof. Sebastian Engell, TU Dortmund, Germany
Dr. Tuula Ruokonen, Valmet Technologies Oy, Finland
Prof. Bernt Lie, University of South-Eastern Norway, Norway
Senior prof. Erik Dahlquist, Mälardalen University, Sweden
Adj. prof. Esko Juuso, University of Oulu, Finland

Conference program

Each conference day started with a keynote and continued with 2 – 3 parallel sessions. The Annual SIMS meeting was in the end of the second day. The third day ended with the SIMS 60+ presentation and the panel discussion. More information is available at SIMS website (https://www.scansims.org/).

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Adjuct prof. Esko Juuso, University of Oulu, Finland

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Dr.	Nathan	Zimmerman	Mälardalen University	Sweden

Overview and Outlook for the OpenModelica Environment and its Use for Cyber-physical System Development

Peter Fritzson

Department of Computer and Information Science
Linköping University, Linköping, Sweden

Abstract

The industry is currently seeing a rapid development of cyber-physical system products containing integrated software, hardware, and communication components. The increasing system complexity in the automotive and aerospace industries are some examples. The systems, that are developed, have increasing demands of dependability and usability. Moreover, lead time and cost efficiency continue to be essential for industry competitiveness. The extensive use of modeling and simulation - Model-Based Systems Engineering tools - throughout the value chain and system life-cycle is one of the most important ways to effectively target these challenges. Simultaneously there is an increased interest in open source tools that allow more control of tool features and support, and increased cooperation and shared access to knowledge and innovations between organizations.

Modelica is a modern, strongly typed, declarative, equation-based, and object-oriented (EOO) language for model-based systems engineering including modeling and simulation of complex cyber-physical systems Major features are: ease of use, visual design of models with a combination of lego-like predefined model building blocks, ability to define model libraries with reusable components, support for modeling and simulation of complex applications involving parts from several application domains, and many more useful facilities. The Modelica language is ideally suited for cyber-physical modeling tasks since it allows integrated modelling of discrete-time (embedded control software) and continuous-time (process dynamics, often for physical hardware). Modelica 3.3 extended the language with clocked synchronous constructs, which are especially well suited to model and integrate physical and digital hardware with model-based software.

This talk gives an overview and outlook of the OpenModelica environment – the most complete Modelica open-source tool for modeling, engineering, simulation, and development of systems applications (www.openmodelica.org), and its usage for cyber-physical system development. Special features are MetaModeling for efficient model transformations, debugging support for equation-based models, support (via OMSimulator) for the Functional Mockup Interface for general tool integration and model export/import between tools, model-based optimization, as well as generation of parallel code for multi-core architectures.

Moreover, also mentioned is recent work to make an OpenModelica based tool chain for developing digital controller software for embedded systems, and in generating embedded controller code for very small target platforms like Arduino Boards with down to 2 kbyte memory. This work is extended in the ongoing EMPHYSIS project where the FMI standard is extended into the eFMI standard for embedded systems.

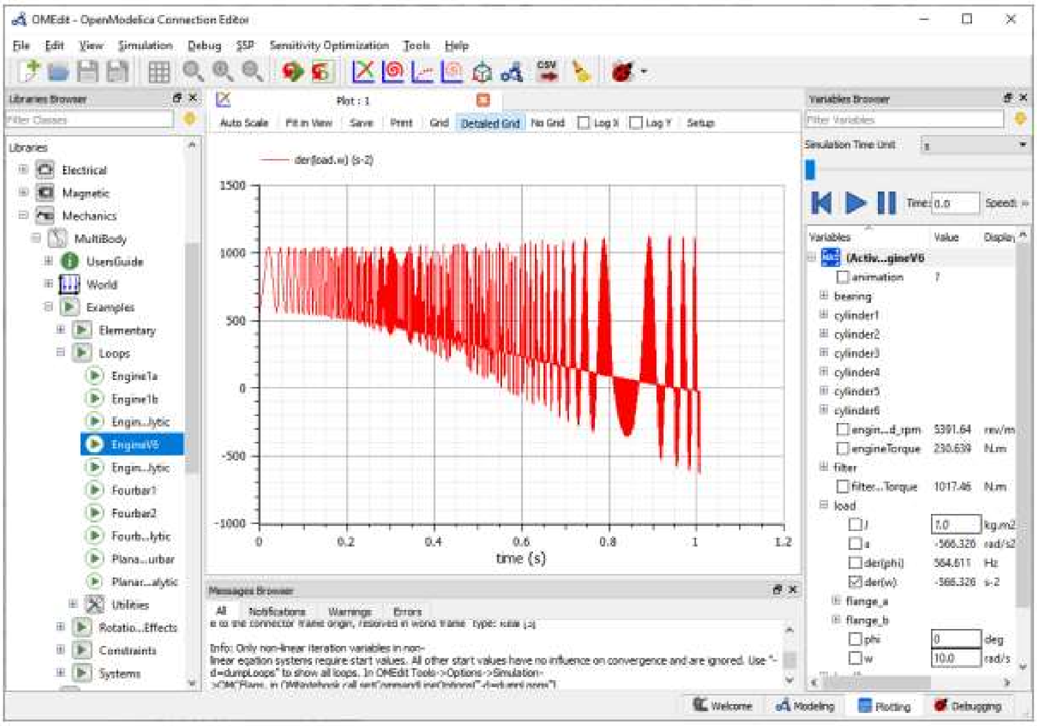

Figure 1. OpenModelica simulation of the V6Engine model with 11000 equations. Plotting simulation results using OMEdit. Left: Model browser. Right: Plot variable browser. Bottom: message browser window.

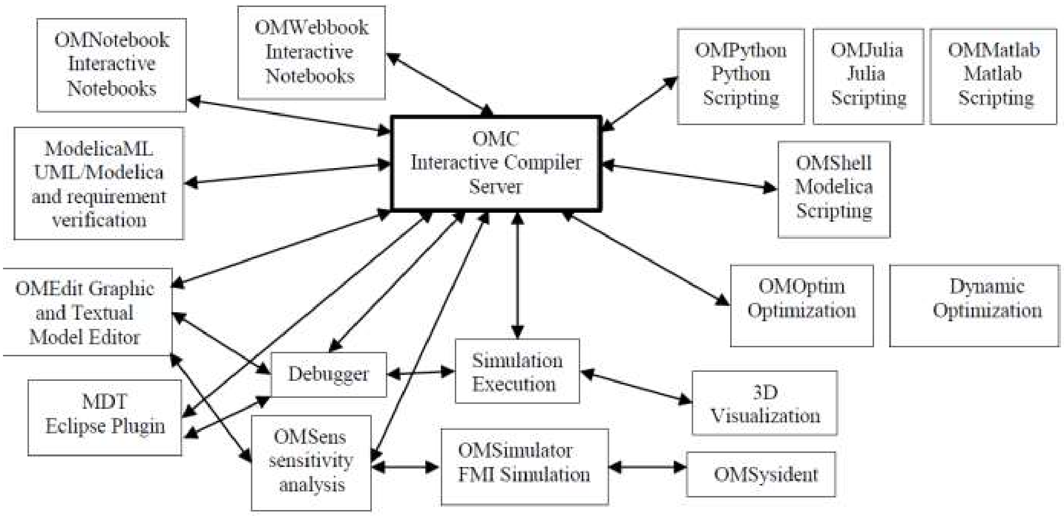

Figure 2. The architecture of the OpenModelica environment. Arrows denote data and control flow.

Biography

Peter Fritzson is the professor and research director of the Programming Environment Laboratory, at Linköping University (LiU). He is also the vice director of the Open Source Modelica Consortium, the vice director of the MODPROD center for model-based product development, (previously the director of both) organizations he took initiative to establish. During 1999-2007, he served as chairman of the Scandinavian Simulation Society, and secretary of the European simulation organization, EuroSim. During 2000-2020, he was vice Chairman of the Modelica Association. Prof. Fritzson's current research interests are in software technology, especially programming languages, tools and environments; parallel and multi-core computing; compilers and compiler generators, high level specification and modeling languages with special emphasis on tools for object-oriented modeling and simulation where he is one of the main contributors and founders of the Modelica language.

He received PhD degree in Computer Science at LiU in 1984. The thesis title was "Towards a Distributed Programming Environment Based on Incremental Compilation". In 1985-86, he was the project leader of the subproject on incremental compilation at Sun MicroSystems, Mountain View, California. In 1989, he became associate professor and director of the Programming Environment Laboratory (PELAB) in Department of Computer and Information Science at LiU. In 1992, he qualified as docent at LiU. From 1995 to 2019 he has been a full professor at LiU and continued from 2020 as a full professor emeritus at LiU. The research director position of PELAB he has had since 1995. Prof. Fritzson has many positions in scientific organizations: the vice chairman of the Modelica Association since 1999, the director of the Open Source Modelica Consortium since 2007, and the research leader at RISE, SICS East, St Anna Research Institute since 2007.

Professor Fritzson has authored or co-authored 319 technical publications, including 21 books/proceedings, 1 book draft, 45 journal papers, and 251 papers in conference proceedings or external book chapters, of which 249 are refereed, 5 are invited, and 2 are nonrefereed. Google scholar link:
https://scholar.google.com/citations?authuser=1&user=KXUHIl4AAAAJ

Selected books:

Peter Fritzson. *Principles of Object Oriented Modeling and Simulation with Modelica 2.1*. 940 pp, Wiley-IEEE Press, 2004.

Peter Fritzson. *Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica*. 232 pages, ISBN: 978-1-1180-1068-6, Wiley-IEEE Press, September, 2011

Peter Fritzson. *Principles of Object Oriented Modeling and Simulation with Modelica 3.3: A Cyber-Physical Approach*. 1250 pages. ISBN 9781-118-859124, Wiley IEEE Press, 2014.

Real-time optimization and control with inaccurate models

Prof. Sebastian Engell
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Fakultät Bio- und Chemieingenieurwesen / Biochemical and Chemical Engineering Department
TU Dortmund, Dortmund, Germany

Abstract

Modelling for simulation, modelling for optimization, and modelling for control follow the same principles, but have to meet different requirements. Simulation models should represent the behavior of the system under consideration for a predefined set of test cases faithfully, with the accuracy usually being measured in the time domain, i.e. by looking at the differences of the stationary values or trajectories of some key variables. Modelling for optimization is different in that the goal is that the computed optimum of the model and the optimum of the real system should match, and the model should support efficient global numerical optimization. This implies that the model must be accurate around the global optimum, but over the full range of the variables, medium accuracy is sufficient. The problem for modelling of course is that without the knowledge of the region of the global optimum, it is not possible to build such a model, and hence modelling and optimization should be interleaved.

When using models for control, the relationship between model accuracy and control performance is even more intricate than for optimization. One can control a plant satisfactorily using a coarse model (in the simplest case, the sign of the gain is sufficient), while model errors can also lead to poor performance and instability. For linear time-invariant control loops, the classical robust control theory from the 1980s tells us that a good model for control is a model that describes the dynamic behavior accurately near the gain-crossover frequency, and qualitatively correctly for lower frequencies. So what a good model is for the purpose of control depends on how fast we want to control the system.

For high-performance control, techniques based on online optimization, i.e. model-predictive control (MPC) have become the dominant technology in the last decades, due to their ability to handle constraints, nonlinear systems, and economically motivated cost functions (Engell, 2007). In contrast to the classical theory of robust control, robustness to model errors for such control strategies is difficult to analyze and, similar to stability, is usually handled using a constructive approach, i.e. by building controllers that have certain robustness properties for a given description of the uncertainty of the model. Min-max robust MPC, in which the performance is optimized for the worst case model, is the best known representative of this approach. This however comes at the price of a high conservatism.

To build good models is a costly endeavor. Therefore, both in modelling for optimization and in modelling for control, one is interested in techniques that provide good performance without huge modelling efforts. In the presentation, we discuss two recent approaches to reducing the negative effects of model errors in optimization and control. For real-time optimization, we outline the so-called modifier adaptation approach, which adds a data-based local model to a global model and updates it iteratively to ensure convergence to the true optimum of the real plant (Gao and Engell 2005, Gao, Wenzel, and Engell, 2016). For control, the multi-stage MPC approach is discussed in which the future information on the realization of the model uncertainty is included in the optimization that is performed at the current time step to reduce the conservatism of the controller (Lucia, Finkler, and Engell, 2013).

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S. Engell. Feedback control for optimal process operation. *Journal of Process Control* 17(3):203-219, 2007. doi: 10.1016/j.jprocont.2006.10.011.

W. Gao and S. Engell. Iterative set-point optimization of batch chromatography. *Computers and Chemical Engineering*, 29:1401-1409, 2005.

W. Gao, S. Wenzel, and S. Engell. A reliable modifier-adaptation strategy for real-time optimization. *Computers and Chemical Engineering*, 91:318-328, 2016. doi: 10.1016/j.compchemeng.2016.03.019.

S. Lucia, T. Finkler, ans S. Engell. Multi-stage nonlinear model predictive control applied to a semi-batch polymerization reactor under uncertainty. *Journal of Process Control*, 23:1306-1319, 2013. doi: 10.1016/j.jprocont.2013.08.008.

Biography

Prof. Engell received a Dipl.-Ing degree in Electrical Engineering from Ruhr-Universität Bochum, Germany in 1978 and the Dr.-Ing. Degree and the venia legendi in Automatic Control from Universität Duisburg in 1981 and 1987. 1984/1985 he spent a year as a PostDoc at McGill University, Montréal, Canada. 1986-1990 he was the head of an R&D group at the Fraunhofer Institut IITB in Karlsruhe, Germany. 1990 he was appointed to his present position as a Full Professor of Process Dynamics and Operations at the Department of Chemical Engineering at TU Dortmund. 2008 he was a Distinguished Visiting Professor at Carnegie Mellon University, Pittsburgh, USA. He was Department Chairman 1996-1999 and 2012-2014 and Vice-Rector for Research of TU Dortmund 2002-2006. He is currently a member of the Research Council of the Alliance of the Universities in the Ruhr Region, UA Ruhr.

Prof. Engell received an IFAC Journal of Process Control Best Paper Award, and is a co-author of the 2014 and 2016 Best Papers in Computers and Chemical Engineering. He received the Best Paper Award of the IEEE Congress on Evolutionary Computation 2010 with Thomas Tometzki on risk-conscious planning and the PSE Model-based Innovation Prize with Ala Eldin Bouaswaig. He gave the Bayer Lecture in Process Systems Engineering at Carnegie Mellon University in 2008 and the Roger Sargent Lecture at Imperial College, London, in 2012. He has published more than 120 Papers in scientific journals, more than 40 papers in edited volumes and more than 300 conference papers with peer review and full papers in proceedings. His Scopus paper count is 530 with 4900 citations. He graduated more than 70 PhD students at TU Dortmund. In 2012, he was awarded a European Advanced Investigator Grant for the Project MOBOCON – Model-based Optimizing Control – From a Vision to Industrial Reality.

Prof. Engell is a Fellow of IFAC, the International Federation of Automatic Control since 2006 and has led the IFAC Fellow Selection Committee 2012-2014 He served as President of EUCA, the European Control Association and is a member of the selection committee for the European Control Award.

Prof. Engell has led several European Projects in the FP6, FP7 and Horizon 2020 Frameworks: Multiform (ICT), DYMASOS (ICT), CPSoS (Support Action, ICT), MORE (NMP) and CoPro (SPIRE, ongoing). The CPSoS project developed a roadmap for Cyber-physical Systems of Systems in Europe. He was involved in the Marie Curie Reseach Training Networks oCPS and PRONTO and currently is a partner in the EU-India project LOTUS on monitoring water quality and managing water systems.

His research areas are in the domains of model-based optimizing control, real-time optimization, and scheduling. In his research, the aspect of uncertainty about the behavior of the system that is controlled or optimized has always been in the focus.

Digital Twins utilization throughout the Life Cycle of Industrial Processes

Tuula Ruokonen, Ph.D (Eng), MBA

Director, Digital Services Solutions, in Valmet Technologies Oy;
Board Member in Automation Foundation in Finland sr.

Abstract

In this presentation, Digital Twins for industrial processes are considered from their historical and future point of view. What is actually a Digital Twin – is their only one or several for different purposes? What enables the development of Digital Twins just now? Which benefits and challenges are there in their development and implementation?

There are many definitions for Digital Twins. Most state that a Digital Twin is a virtual representation of a physical product or process, used to understand and predict the physical counterpart's performance characteristics. Digital Twins are used throughout the product life cycle to simulate, predict, and optimize the product and production system before investing in physical prototypes and assets.

Already 30 years ago, such systems and simulators were developed and utilized which for sure would nowadays be called Digital Twins, concrete examples including Computer Aided Design, Process Modelling and Dynamic Simulators, Advanced Process Control, Condition Monitoring, Expert and Knowledge-Based Systems, and even Remote Expert Services.

Digital Twins are presently at the top in their hype curve, and their enabling technologies develop strongly and rapidly. We are facing partly evolution, partly revolution in their development. For example increased computing power enables real time analytics, cloud-based computing enables flexible calculation capacity, mobile technology enables mobile and remote applications, wireless sensors enable additional measurements, and Artificial Intelligence and Machine Learning tools enable advance analytics. Furthermore important is the connection to Internet of Things and Industrial Internet applications development.

Potential to utilize Digital Twins in industrial processes and equipment is wide, them forming ideally a digital thread throughout the whole life cycle. The goal is efficient information management, its utilization and updating in all phases of the life cycle: product development, production planning, sales, project implementation, operations optimization, personnel training, process operation and maintenance.

Why is the utilization of Digital Twins still so difficult or even impossible? Challenges are created by separate functional processes and IT systems, and especially by organizational silos and suboptimization of goals, in different phases of the life cycle. Open questions exist still related to common data models and standards, and model updates. Own challenges come from the data ownership and principles of sharing data between related actors, equipment manufacturers, end users and service providers, related to design data and operation-time data management.

Looking forward that these challenges and open questions will be solved and the vision of up-to-date Digital Twins, utilized in the whole life-cycle, comes true and enables the performance optimization of processes and equipment in the future autonomous mills and plants.

Biography

Dr. Tuula Ruokonen is responsible of development of new value adding applications and service solutions in Valmet, based on remote services, industrial internet and advanced analytics. She is inspired by new business opportunities and applying new technological potentials. Special focus is in testing and taking into use new technologies, such as virtual and augmented reality, and applying AI and machine learning methods. Applications are developed in tight customer co-operation based on design thinking and the Lean Start-up method.

Dr. Ruokonen has more than 25 years of practical business management experience, from technology and product development to line management responsibilities. Especially she has wide experience in industrial service and outsourcing business and its development. She has a Ph.D. degree in Electrical Engineering (Control Engineering), Florida Atlantic University, USA, 1989. Thesis was on "Nonlinear Filtering for Failure Detection in Dynamic Systems". She has M.Sc, and Lic.Tech. degrees in Electrical Engineering (Control Engineering) from the Helsinki University of Technology. The Lic.Tech. thesis (1987) was on "Model-Based Failure Diagnosis - Structure of the System and Methods Based on Characteristic Curves". M.Sc. in Electrical Engineering (major in Control Engineering and Automation, minor in Measurements and Information Technology) was received from the Helsinki University of Technology in 1985. The M.Sc. thesis (1985) was on "Failure Diagnosis and Condition Monitoring in Power Plants. Methods and Applications, a Peat Fuelled Plant as an Example". In 1993, she received MBA degree from the Helsinki University of Technology (Aalto University).

Dr. Ruokonen has received Finnish Society of Automation bronze medal of merit 1996 and silver medal of merit 2000. She is active in automation societies, including Automation Foundation, a board member 1996-98, 2019-, Automaatioväylä magazine, a board member 1991-92, and Finnish Society of Automation, a board member 1990-92. She has been active in The Association of Electrical Engineers in Finland, a board member 1987, 1994-96, and Sähköklubi, a board member 1984, 1989-91, 2017-2019. Already during her post graduate, she was active in the IEEE student branch in Florida Atlantic University, a board member 1987-88.

Valmet is the leading global developer and supplier of technologies, automation and services for the pulp, paper and energy industries, having strong growth strategy and the aim to utilize efficiently new digitalization enablers for customer value-add and internal efficiency. Valmet's net sales in 2019 were approximately EUR 3.5 billion and it employed about 13.600 professionals around the world.

Scandinavian Simulation Society 60+ ready for future challenges

Adj. prof. Esko K. Juuso

Control Engineering, Environmental and Chemical Engineering
Faculty of Technology
University of Oulu, Finland

Abstract

Scandinavian Simulation Society (SIMS) started over 60 years ago as a society for the analog simulation: Scandinaviska Analogmaskinsällskabet (SAMS) was founded in 1959 in Västerås. The current name was taken in 1968 when SIMS moved successfully to the digital simulation. SIMS is currently a society of societies which operates in five countries Denmark, Finland, Iceland, Norway and Sweden. SAMS started in Sweden, Denmark and Norway. Finland joined in the 60s and in 1972 SIMS conference was organized the first time in Finland. In 2012, the SIMS conference went to Iceland. SIMS is the eldest active simulation society in the world. After 60 annual conferences, the 61st conference is the first virtual conference.

Applications have continuously been important parts of the conferences. Steel industry, flight simulators and atomic energy were active already in the beginning. Industry, Energy and Environment are important areas of SIMS. Applications in the energy field have extended from power plants to sustainable energy: solar, wind and geothermal, especially in Iceland. Processes, including the forest, steel and chemical industry, as well as oil & gas production have kept an important role. Increasing interests have been seen in water and wastewater treatment, biogas production and bioprocesses. The annual conferences circulate sequentially in the SIMS countries and the topics adapt in the local interests. SIMS has stimulated automation in these versatile fields, also through representative organizations like Finnish Automation, Automation region in Sweden and Norwegian Automation.

Numerical methods and combined differential and algebraic equations have formed the basis for process models first in Fortran, then Matlab and Simulink. Computational intelligence, AI and various model builders, e.g. gPROMS, became active in the 90s. The full range from PCs to supercomputers is used. The developments of new simulation tools have been important during the years: Apros was introduced in 1986 and Modelica in 1996. As a spinoff, we have the active Modelica Association. Graphics becomes more advanced, open source codes are coming more popular and the integration of methodologies and tools developed for different applications areas extend the application areas.

SIMS provides strong ***support for PhD students*** by bringing together different methodologies, applications, software tools and people. Efficient simulation tools help in bringing different ideas within the education.

International cooperation has been essential throughout the years. An agreement with International Association for Mathematics and Computers in Simulation (IMACS) dates back 1976 resulting the IMACS World Congress in Oslo 1985. The European Simulation Multiconference was organized in 1991 in Copenhagen. SIMS is an active member society in the Federation of the European Simulation Societies (EUROSIM) founded in 1992. The EUROSIM congress has been organized twice by SIMS: 1998 Helsinki and 2016 Oulu. The SIMS EUROSIM 2021 is starting a new EUROSIM conference series to be held every third year.

The ***future*** can be based on the stimulated use of new simulation tools, a wide scale of applications in industry, energy and environment, all stimulated by the automation and young generation of researchers. This combination, which has kept SIMS going for decades, needs to be adapted in the future challenges.

The ***circular economy*** aims to close the loop to make economy more sustainable and competitive. We have a broad range of technologies related to recycling, renewable energy, information technology, green transportation, electric motors, green chemistry, lighting, grey water, and more. The environment is restored with pollution removal and avoidance. What can we do in practice? Air has been a focus area in industry,

energy and traffic. Water treatment has been developed to remove undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. In industrial processes, closed water circulation is a goal which is beneficial for the environment. Wastewater treatment is needed for purifying contaminated water before returning it to the nature. Is climate change discussion sufficient? Should we take a wide view on the ecosystem?

The ***energy sector*** has new challenges and possibilities. Thermal power plants are by far, the most conventional method of generating electric power with reasonably high efficiency. Bioenergy takes an increasing portion of the production? Oil and gas hold a strong position in overall energy usage. Biofuels provide new competing alternatives and the CO_2 capture has taken a high role in research. Are we going to bioeconomy? Is the thermal power a necessity in our energy balance? Sustainable or renewable energy is considered as a future source of energy: water power is well integrated in the energy system; solar and wind are getting more popular; geothermal, wave and tide energy can be locally very important. Electricity is increasingly popular both in solar and wind power. To what level is this sufficient? Where do we use energy? Industry needs high reliable levels. Is the nuclear power a solution? Adaptation is easier in domestic use, but how to do it? Heating and cooling take the highest part. Solar energy can help but needs storage. Geothermal can be used as storage. What is the potential of buildings as storages? Do we need small scale CHP? District heating systems are good solutions to bring the thermal energy to buildings.

In the ***industry***, intelligent systems have been developed for integrating data and expertise to develop smart adaptive applications. Recently, big data, cloud computing and data analysis has been presented as a solution for all kinds of problems. Can we take this as a general solution for automation? Wireless solutions are improving fast: 3G, 4G, 5G. But can we transfer signals to clouds and store the data? Is this too much? Where is the expertise? Obviously, local calculations are needed. Are they based on intelligent systems? Transport systems are analyzed as discrete event systems to find bottlenecks and avoid risks. Urban traffic is becoming an important area. Autonomous driving is a hot topic. What is needed to embed this in the urban traffic? Are there analogies with industrial systems? What are the main differences between industrial systems and transport systems? Can we use similar control solutions? What can we learn from other areas? Can we find analogies? What is common? Where do we have differences? What kind of models do we need?

Highly complicated systems with various interactions are at hand. What researchers within SIMS community can do? Do we have tools and methodologies to help in solving these problems? The modelling and simulation is coming increasingly important in various fields.

Biography

Senior Research Fellow Esko Juuso has D.Sc. (Tech.) on Control and Systems Engineering from the Department of Process and Environmental Engineering at the University of Oulu. He is an adjunct professor in Computational Intelligence at the University of Oulu. He also has a M.Sc. (Tech.) degree in Technical Physics (Material Physics) from the University of Oulu. He worked earlier several years as a research engineer and process computer analyst in the metal industry. He has been a team leader and a project manager of several research projects on intelligent systems applications. Adjunct professor Juuso is the Fellow of International Society of Condition Monitoring (ISCM), a member of ISCM Management Committee and the Chair of the ISCM Publication Committee. In the Scandinavian Simulation Society (SIMS), he has been a member of the Board of SIMS since 1996 and the President of SIMS 2007-2013. He is a founding member of the Finnish Simulation Forum (FinSim), 2006, and the International Society for Condition Monitoring (ISCM), 2010. He is the chair of SIMS 2020 and he has chaired SIMS conferences in 2002, 2006 and 2010. Since 2006, he has been the SIMS representative in the Board of the Federation of European Simulation Societies (Eurosim), the secretary of Eurosim 2007-2010 and the President of Eurosim 2013-2016.

Panel discussion: Future challenges and possibilities for simulation

Chair: Adj. prof. Jari Ruuska, University of Oulu, Finland
Panelists:
Prof. Peter Fritzson, Linköping University, Sweden
Prof. Sebastian Engell, TU Dortmund, Germany
Dr. Tuula Ruokonen, Valmet Technologies Oy, Finland
Prof. Bernt Lie, University of South-Eastern Norway, Norway
Senior prof. Erik Dahlquist, Mälardalen University, Sweden
Adj. prof. Esko Juuso, University of Oulu, Finland

The panel discussion was the last part the conference. The panelist were the keynote presenters, the current and two past presidents of SIMS, including the chair of the conference. The chair of the national organizing committee was the chair of the panel. The discussion focused on five questions: simulation, energy systems, big data, environment and simulation toolboxes. The questions were presented by the panel chair.

1 How would you define term simulation?

Peter: Simulation answers the questions about the model.

Sebastian: nothing to add.

Tuula: There are often several interpretations about the terms. Simulation is often understood only as process simulation but there are also reliability models considering e.g. maintenance, management, and also business-related models.

Bernt: Experiments with models are used to find out answers – model is a wide concept not only including mathematical models but also pilot plants in principle or economic models

Erik: Model building means including new information in the simulation model to see what would happen. It can also be a non-mathematical tool.

Esko: Tool for comparing alternatives – application related in that sense. We can use it to find best alternatives to use. It is different when you are controlling something, designing something, or finding an optimal control point or balance. One should consider "how detailed simulation you need for your job?"

2 Energy systems are needed everywhere but demand of energy changes a lot between seasons and time of the day – How to use simulations to aid in this subject and predict changes?

Peter: You can include all the energy sources in your simulation including the consumers to create a comprehensive model. Historical data about the location's energy usage in conjunction with real-time weather data can be used to generate good predictions.

Sebastian: You have individual systems that are coupled. It is quite a big task for modeling, simulation, and optimization to co-ordinate such individual systems. German airports have saved lots of CO_2 by optimizing airplane approaches to the airport. Philosophically it is more beneficial to have a good aggregate model that you can use for decision making between the models than a huge, detailed model about everything. How to do this in an optimal way is very interesting research question.

Tuula: Distributed energy production and usage; Low level decision making for individual needs. IoT with plenty of measurements – energy usage of all the members and their effect on costs. Big savings are potential in total optimization.

Bernt: Future energy is related to United Nations' goals to provide energy for everybody. A combined system where all the energy sources work better together. Circular economy where energy streams are more integrated: one operator's waste is a raw material for another. This needs simulation tools – short & long -term simulations

Erik: Energy technologies develop in long time perspective, so it is important to consider these long-term changes. Biofuels and batteries will replace oil in transportation systems in future. Great opportunity to use simulation tools here. Boundary determination is more important than very detailed models. Simulation tools can help politicians and decision makers to make right decisions.

Esko: Energy is challenging for control and optimization. Sources that work depending on weather conditions and ones that are not connected to the weather form a diverse system that is combined and have different requirements. Many energy sources that have different fluctuations must be optimized and controlled to work as a complete system. District heating networks are good for balancing different energy sources.

3 Big Data and cloud computing have been presented as a solution for everything. Can we use this as a general solution for automation? - Can we use these solutions reliably considering data security and how to use simulations to aid this?

Peter: Mathematical model equations describing the physical world have developed a lot. Combine these mathematical models to make approximate models for machine learning to get a bigger picture.

Sebastian: Industrial perspective is always skeptical to transfer its data into cloud. There has been work done for MPC over unreliable networks. If there is a problem in considering missing information, it is better to invest in a working network than in sophisticated control solution. There are not many successful online applications of machine learning. Difficult to have sophisticated control that can handle all operating states – you could have good combinations of fundamentals. Models calculating phase equilibrium can take too long to be used in process optimization and control. Approximations using machine learning could be embedded in an overall rigorous model.

Tuula: A great number of applications are already existing for cloud-based solutions. Cyber security is one major risk, a lot of work to be done to cover this topic. Possibility to utilize data from a fleet of the processes can help us understand what the normal operating points is. Training simulators can help to utilize this understanding about the operating points. The future will be more and more in the cloud or on the edge - not only on-site. Big operators like Amazon web services must do their share in web security.

Bernt: Big data and data driven models are very modern. Physics based models can be built without a real system before building the system to give reasonably accurate prediction. Mechanistic models are typically better outside the operating points than data driven models. Both models have their unique advantages. Combining physical and data driven models – physics-based models for the phenomena you know well and data driven models for the ones you do not know so well.

Erik: We have a project (Future direction of process optimization) focusing on learning systems. There we use infrared measurement for the wood chips lignin content and physics-based model for residual alkali, i.e. how much lignin is there still in fiber. The residual alkali measurement is needed for tuning the model for lignin properties and content. Internal cloud behind the firewalls could be the solution when operators do not trust the providers.

Esko: We need expertise, models, and data driven models for the practical applications. Theoretical models alone are too complex – parameters can be learned from the data. A dangerous thing is to use unbalanced data that gives you a completely wrong answer. Simulation is a good tool when you understand what you are doing. Do not use AI to find answers to questions that experts already know. Finding suitable system size for application is important.

4 Environmental friendliness and sustainability are important but how to use simulation to promote this?

Esko: Simulation can have a big role in this. Combine different ideas and compare different things to select the best solutions – not like now that there are things you should not use and things you should.

Erik: Generate scenarios that give good data for the decision makers.

Bernt: Sufficient energy generation in the world in future needs all energy sources – fossil fuels need to be reduced in future, but it is still needed for now. Complicated systems where we need e.g. to store solar and wind energy needs simulations to see all the consequences.

Tuula: Industrial optimization is important. Optimizing processes is connected with sustainability – stability and energy efficiency. This is cost efficient for the companies and gives them an advantage, so it is win-win for everyone.

Sebastian: More complex problem that needs to consider the whole life cycle from the raw materials to end of product life which is very problematic. What kind of materials are used for water bottle, how many times this bottle will be used – lots of variables and it is hard to simulate everything.

Peter: Technical simulation gives accurate predictions, but we also need more general simulations. Decision makers (politicians) make lots of decision based on low quality information and intuition – simple, not too detailed models could give more information before making decisions. Not only energy but also materials are important: how can we use alternative materials and lower the material usage.

5 Are there some basic principles that needs to be added into our simulation toolboxes?

Esko: CSC supercomputers can help in calculations, but we need to understand all the parts of the system. We need to do intelligent calculations and understand what we are doing.

Erik: A good formulation of the problem enables e.g. the use of CFD for online applications.

Bernt: A better use of parallelization is needed for networks and graphical processing. Simple automatic way to use this is needed because it is hard if you need to first do everything manually.

Tuula: Calculation tools for online-measurements. Hybrid models are needed for combining data driven models with physical models. Help us in industry to understand what methods to use and where we do not do wrong things.

Sebastian: Quantification of calculation uncertainty is important, and it should be connected to the results.

Peter: Multiparameter sensitivity simulation in Modelica - build uncertainty into tools.

Esko: Uncertainty is unavoidable, therefore it is better to be approximately correct than exactly wrong.

6 Conclusions

The discussion covered well the future challenges and possibilities of simulation. The panel was a highly valuable conclusion for the conference in linking the keynotes and topics of the regular papers with the history and the future of the simulation.

Acknowledgements

The chair and the panelists thank doctoral student Antti Koistinen for collecting efficiently the answers of the panelists during the panel discussion.

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