INDUSTRIAL MATHEMATICS

Place and time: In M107 on Thursday, Jan 4, at 10:30–12:00
Organizers: Jukka Tuomela (University of Eastern Finland)
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A European Technology Platform for MSO

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Abstract. The current and future technological and economic development of the industrial Europe is characterized by a steadily growing complexity of modern products and processes, as well as ever shorter innovation cycles. Principal issues which must be addressed are the scarcity of resources, recycling, climate change, assessment of the risks to the environment and society, as well as increased automation and a holistic view of the life cycle of a product. The long-term and sustainable solution to these problems is only possible through an intensive support of the development procedures of new products and production processes via a holistic mathematical Modeling, Simulation and Optimization (MSO) approach, where in each case parallel to each product or process a virtual product or process (the digital twin) is generated. On this basis a simulation of functionality and design, as well as of long-term effects and risks, one is able to design optimized products and sustainable process controls. In addition to the classic areas of mechanical and vehicle engineering in which a modularized and component- based development on the basis of mathematical models is already established, this approach is also essential in the development of Industry 4.0 as a key technology and a decisive competitive advantage. This procedure also plays a central role in all other fields of science, economy and society and the aim must be to strengthen the leading position of Europe in this system- oriented approach. Success of the above mentioned approach relies heavily on the further advancement of Mathematical Technologies. Mathematical Technologies play already an essential role in almost all areas of industrial and societal relevance. As numerous success stories show, Mathematical Technologies, in particular Modelling, Simulation and Optimization tools, provide real and production processes, analysing data, enabling virtual prototyping of new products and reducing costs. Mathematical Technologies find application in a wide range of scientific and technological fields, and it is expected that in the coming years, with the increased use of technology and availability of ever more powerful high performance computers, the impact of MSO tools will become even more significant.

There is a clear need to bring together the existing European National Networks of Research Centres for Industrial and Applied Mathematical Technologies, to ensure a common effort towards one main and shared objective: providing the industrial and scientific communities with a single coordinated and comprehensive infrastructure for Mathematical Modelling, Simulation and Optimization, and resulting research programs. This is organized on a European scale by EU-MATHS-IN – a European Network of Mathematics for Industry and Innovation.

This network is a collaboration of national organizations from currently 17 European countries. The promoting partners of EU-MATHS-IN are the European Mathematical Society and the European Consortium for Mathematics in Industry. The primary objective of this network is to discuss success stories and share experiences and best practices of organizing collaborative research projects with industry, as well as to discuss and brainstorm about joint future activities.

One of the major obstacles to be addressed is the low visibility of mathematical technologies in European programs. We will also discuss measures facilitating awareness about existing expertise in Europe and knowledge transfer. Currently, together with renowned industry partners, EU-MATHS-IN is discussing the set-up of a so-called European Technology Platform for Mathematical Modeling, Simulation and Optimization. In the talk, the preparations for this will be discussed: there have been several workshops in Amsterdam to discuss in-depth with industry, and recently a larger research workshop was organized in Leiden at the Lorentz Center, see:

`https://www.lorentzcenter.nl/lc/web/2017/954/poster.pdf`

Platform for Modelling Education and Industrial Math

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Abstract. The cutting edge knowledge in applied & industrial mathematics is dispersed at small nodes of expertise. Online environments are a viable media to access this knowledge and support innovative processes, training and educational needs. Collaborative multi-campus courses is one possibility.

The Laboratory of Mathematics at Tampere University of Technology has coordinated since 2002 a national network project on modelling education. The project has developed a Web-based learning and teaching environment. The purpose is to study methods, to facilitate content production to support web-based learning and teaching. Ten universities and research institutes participate in the project. Students from different universities can study modelling courses on-line both individually and collaboratively.

We envisage also a possibility to build a European digital environment and web-portal for applied & industrial mathematics. Such environment would be suitable for students in applied mathematics and engineering programs and also for persons who are already in their working life and are looking for continuing education and professional development. An ECMI Special Interest Group was formed to work towards such e-learning portal. The partners have also founded Finnish National Network on Mathematical Modelling, which is the Finnish member of EU-MATHS-IN-network.

This talk describes the Finnish National Network of Modeling and the visions for future and international cooperation.

Joint work with Seppo Pohjolainen.

Improvement of satellite orbit prediction accuracy with deep learning

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Abstract. In this paper, satellite orbit predictions are done with self assisted GNSS in mind. The goal of self assisted GNSS is to reduce the Time to First Fix (TTFF), which is the time from when device is turned on until an estimate of the position of the user is given. Satellite position data can be used to predict the position of a satellite days and even weeks, which can reduce the TTFF from 30 to 5 seconds.

In our previous research, satellite orbit accuracy has been improved using analytical and data-driven models. In this study, we consider methods of deep learning to improve accuracy of GNSS satellite orbit predictions.

The improvement in accuracy was obtained with convolutional neural networks. A convolutional neural network was used to predict Radial, Tangential and Normal components (RTN) of prediction errors of existing orbit models. The errors were predicted from the errors from a shorter period in the beginning of the orbit prediction. With these error predictions the orbit prediction can be corrected.

The main results of this study was that even a simple convolutional neural network can improve orbit prediction accuracy significantly. Two different methods for error correction with convolutional neural networks were created and tested with GPS satellites. The better method was also tested with BeiDou satellites of all orbit types. On average, over a two weeks prediction interval, the proposed method improves orbit prediction accuracy more than 40% for all GPS and BeiDou satellites. The best improvements in accuracy were achieved with GEO and IGSO satellites. After a week from the start of the prediction, when a GPS satellite has orbited the earth 14 times (4.7 million kilometers), the prediction error contributes less than 5 meters to GPS user positioning error.

More detailed information on the topic can be found on Jaakko's master's thesis here [http://URN.fi/URN:NBN:fi:tty-201710262067].

Joint work with Helena Leppäkoski and Robert Piché.

Bayesian data fusion of airborne, space-borne and ground-based observations for forest map production

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Abstract. Forest maps represent a slowly evolving dynamical system that is defined on a discrete 2+1 -dimensional manifold, with a vector-valued stalk where the components are hyper-parameter estimates that characterize the distribution of each forest parameter on the local map. The manifold atlas is normally only locally smooth and therefore the vector bundle maps are only continuous in the base space but not as bundle maps - not even along the time axis.

This "ill-behaved" nature of managed forests with frequent human and nat-

ural interference makes the production and maintenance of forest maps rather challenging. This challenge is compounded by the ill-posedness of the estimation problem of hyper-parameters from field-based and remotely sensed data. Typically all sensing modalities have highly non-trivial kernels and even when taken together in a Bayesian data fusion process, they do not constitute a frame for the piece-wise discontinuous bundle map.

The production of forest maps therefore remains an art rather than science, thereby providing a livid battleground for Bayesian and Fisherian statisticians, remote sensing scientists, foresters and biometricians. This is rather unfortunate also because forests are the most important front on which we can hope to revert some of the damage caused by global warming due to greenhouse gas emissions, not to speak of their economic and ecological value and their impact on livelihoods in many countries and on biodiversity. The talk will illustrate in practical terms the issues and challenges that forest maps present, in the hope of inviting also the more theoretically oriented experts to make a contribution to this important field.

Joint work with V. Junttila.