Mathematics in Industry Study Group

South Africa

2020

Information Booklet

MISG

South Africa

2020

Contents

Background

A Mathematics in Industry Study Group (MISG) is a five-day workshop at which academic researchers and graduate students work collaboratively with representatives from industry on research problems submitted by local industry. These Study Groups have been organized for over forty years in many countries around the world; the first Study Group in South Africa was held in 2004.

This year’s Study Group will be held from Monday 13 to Friday 17 January 2020, at the University of Zululand in Kwazulu-Natal. The groups will be made up of graduate students attending and academics and applied mathematicians from South African Universities and invited international guests.

Design of the Study Group

- On the first day of the meeting, the industry representatives provide an outline of the problems posed by local industry.
- Applied mathematicians and graduate students, divided into small groups, then work collaboratively on the problems of their choice for three days. On the last day of the meeting, progress reports and/or presentations are presented back to the industry representatives.
- Further work is done on the problems after the event and a technical report for the proceedings, featuring outcomes, is produced for each problem later in the year.

Benefits of the Study Group

For industry

- Have leading South African and international mathematicians work on their proposed problem.
- Obtain an initial modelling of their problem and a development of the solution process. Hence, new perspectives and fresh ideas are brought to the problem.
- Establish research links with applied mathematicians which can develop far beyond the problem posed and establish contacts and develop employment opportunities for graduate students.

For academics

- Work on problems of genuine practical importance and perform good mathematics in the process and apply knowledge and skills to significant practical problems.
- Open up new research areas, leading to publications and new research collaborations.

For graduate students

- Learn to model and solve problems of genuine practical importance by working closely with leading academics and invited guests.
- Learn leadership skills by observing the way the moderator coordinates the work on the problem.
- Develop skills in presenting research material and skills in scientific communication.

Confidentiality and Intellectual Property

All information pertaining to both the problem statements in their initial form, the work done, and the outcomes of the problems is regarded as Open Access. For this reason, no money is accepted from industry nor the invited guests for their participation in the Study Group.

Information for companies

- Most industrial problems can be modelled mathematically. Problems that Study Groups in South Africa have investigated include rock bursts, hydraulic fracturing, optimization in mining, traffic flow, flow of molten glass, HIV in the work place, optimal distribution of goods, renewable energy, wind turbines, robot motion, and image processing.
- Since the Study Group discuss the problems openly, the problems must not be of a confidential nature, and must be such that the results can be published.
- There is no charge for submitting a problem.
- Once a problem is selected, the industry representative needs to submit a detailed problem description well before the meeting and present the problem at the first day of the Study Group.
- The industry representative is expected to be present or contactable during the whole week to assist the academic participants.

Information for participants

- There is no registration fee, because participants give their expertise free of charge.
- Morning and afternoon tea, lunch, and a buffet dinner are provided.
- The Centre of Excellence in Mathematical and Statistical Sciences will fund the participation at the MISG of one academic staff member and one graduate student from the African Institute for Mathematical Sciences (AIMS) and each of the 15 South African universities in the Centre.

Previous projects

Previous project 1 – Optimising Urban and Rooftop Farming in Soweto and South Johannesburg (2019)

Industry: Agriculture

Problem Statement:

Urban and roof-top farming is important for food security in South Africa, and entrepreneurial and employment opportunities in urban farming have risen significantly in Soweto and South Johannesburg.

In contrast to traditional farming, urban and roof-top farming yields small crop sizes and are spread out throughout the city, and roof-top farming can be done year-round as it is farmed hydroponically under controlled conditions. Hydroponic farming requires no soil; instead, the roots are suspended in mineral-rich static water, or continuously moving water, while ultraviolet lamps provide continuous artificial sunlight. On roof-tops, plants are grown in greenhouses to protect them from extreme temperatures, wind and pests. Farms can now produce food throughout the year.

The produce of the farms must be collected and transported to the market. With urban farming, there are many smaller farms in contrast to the norm of one or two large farms, and these smaller farms are also separated by some distance.

Since the farming can be done throughout the year, the Study Group was asked to optimise the plant and harvest times for many farms producing a range of products. Prices at different times of the year in South Africa and growing times for the produce were provided.

The Study Group was also asked to optimise the routes, by road, between the farms during the collection of produce. Some produce requires refrigeration, which not all vehicles have. The optimal routes for non-refrigerated vehicles therefore differ from that for refrigerated vehicles. The locations of the farms were provided. The Study Group had to determine how the routes were calculated, for example, with Google maps.

Outcomes:

- The model allows for the coordinated logistics and transportation of farm produce.
- The results can be used as a benchmark for the mathematical model formulation problem.
- The main points to improve are:
    - formulating and finding an effective solution of the predictive price model for planting and harvesting times,
    - find efficient solution of the mathematical model for routing planning,
    - possibly combine the two models which were developed to have a better coordinated logistics system among the farms.

Previous project 2 – Lake Kivu Surface Water Pollution (2019)

Industry: Energy

Problem Statement:

Lake Kivu in East Africa is known to be a dangerous lake, and a new type of hazard has recently been taken under consideration regarding its relationship with the existence of high concentration of dissolved gas in the water at depth in the lake. This new hazard is water pollution, and it seems that living around Lake Kivu means accepting a higher risk than living elsewhere in the region.

The most obvious type of water pollution affects surface water, and most water pollution does not begin in the water itself. The literature argues that there is a quantity of gas vented in the atmosphere during the harvest and there are other toxic substances entering the lake; all those substances get dissolved or lie suspended in water, and chemicals released by smokestacks (chimneys) can enter the atmosphere and then fall back to earth as rain, entering the lake and causing water pollution. The pollution may cause the quality of the water to deteriorate, and further affects the aquatic ecosystems. These pollutants can also seep down and affect the groundwater deposits or disturb density-stratified lake waters.

In general, water pollution has many different causes, and this is one of the reasons why it is such an interesting problem to solve. There is a clear danger lying ahead, and something needs to be done in advance to alert decision-makers from all points of view; environmentally, and economically.

Methane extraction by venting a certain percentage of gas in the atmosphere would increase the risk of water pollution, which is why the continuous monitoring and regulation is mandatory. Therefore, the extraction projects must be regulated and well monitored. The Study Group were asked to model the surface water pollution in Lake Kivu.

Outcomes:

- The released gases and particles end up in the lake either during or directly after rain.
- These gases and particles can affect the health of inhabitants, animals and water life.
- This project illustrates an approach that may be used to obtain crude estimates for the severity of the pollution problem.

Previous project 3 – Algorithm to count modern houses from lidar data sets over rural areas in Mpumalanga (2018)

Industry: Environmental monitoring

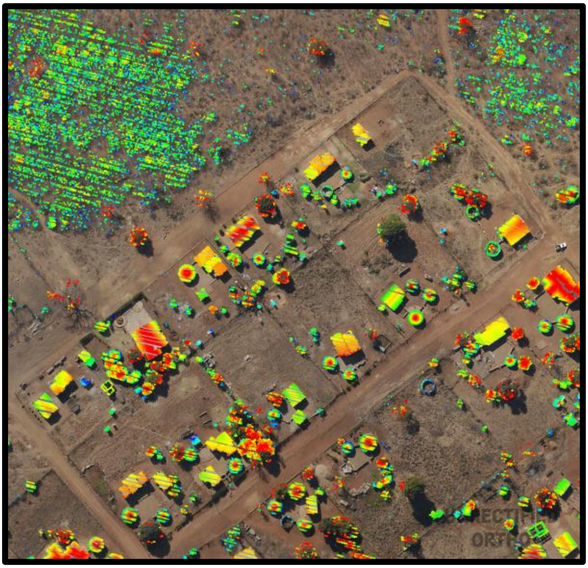
Problem statement:

Air-born Light image Detection And Ranging (LiDAR) systems provide a high resolution, 3-D picture of any landscape. The picture is generated by tracking the time-to-return of individual laser pulses that bounce off objects on the ground. The time-to-return is used to measure height and combined with highly accurate GPS systems, generates a 3-D point cloud, with each point marking where a laser pulse hit an object.

Modern lidar systems create point clouds with up to 20 points per square meter, over potentially thousands of hectares, resulting in very large data sets of x-y-z data. Off-the-shelf processing tools are very good at extracting features of interest (e.g. power lines, trees, roads, roofs etc.) from this data set, but these are typically designed for European urban environments. Through a large research collaboration, we have acquired extensive lidar data sets over rural areas in Mpumalanga, and we need an algorithm to count modern houses. By modern, we refer to brick structures, with angled and tiled roofs, constructed with pre-fab wooden trusses. By counting the change in the number of such tiled roofs, we could develop a measure of economic welfare that covers much larger areas than would be possible through conventional survey techniques. The challenge is to extract a clustered collection of connected, small angled planar surfaces, that would represent the roof of a new house, from a large 3D point cloud of millions of points.

Outcomes:

- The Hough transform offers a reliable measure of the number of planes in the candidate house, thus allowing machine classification of all the houses in the image.
- In addition to implementing the 3-D Hough transform, an additional multi-model fitting algorithm should be investigated.
- A significant amount of coding and testing needs to be done to create an efficient software system.
- A convolutional neural network might be able to learn the signature of a modern house directly, from a fairly large set of LiDAR training data. If this works, it could lead to an extremely efficient counting algorithm.



Previous project 4 – Spontaneous combustion of stock-piled coal (2018)

Industry: Coal mining

Problem statement:

Spontaneous combustion of stock-piled coal is a well-known problem in the coal mining industry. The effects of individual causal factors are known, but typically for a specific location, or conditions at a location.

The interaction between causal effects, and how their relative importance varies with environmental conditions, are not well understood. The height and shape of a stockpile, variation in grain size, degree of compaction, oxygen availability, moisture content, and chemical composition of the coal are all known contributing factors to the probability of spontaneous combustion in coal.

Outcomes:

- Pile size was found to be a strong contributing factor.
- For accuracy of the model, the internal consumption and transport of oxygen must be taken into account.
- These models form a basis for future investigations using sophisticated models which could, for example, explore the influence of stockpile geometry.

MISG 2020 Organising Committee

Professor David Mason, University of the Witwatersrand, Johannesburg

Prof Mason is an Emeritus Research Professor in the School of Computer Science and Applied Mathematics at the University of Witwatersrand, Johannesburg. He has conducted pioneering work in the modelling of problems in solid and fluid mechanics and the use of mathematical techniques to tease out analytical solutions. As the founder of MISG South Africa, he has overseen the event since 2004. **Email:** David.Mason@wits.ac.za

Dr Ashleigh Hutchinson, University of the Witwatersrand, Johannesburg

Dr Hutchinson has a PhD in from the University of Witwatersrand, Johannesburg, where she has been lecturing in the School of Computer Science and Applied Mathematics since 2013. She has published various works in the areas of applied mathematical modelling, fluid mechanics, and mining sciences. She is also the Deputy Director of the Centre of Excellence in Mathematical and Statistical Sciences (CoE-MaSS). **Email:** Ashleigh.Hutchinson@wits.ac.za

Dr Syamala Krishnannair, University of Zululand

Dr Krishnannair is a senior Lecturer in the Department of Mathematical Sciences at the University of Zululand, and she holds a PhD from Stellenbosch University. Her research focuses on the development of advanced multiscale and multivariate techniques for the analysis of complex high-dimensional datasets such as time series data from chemical processes. Her current major research is on the development of an embedded artificial intelligence in mining. **Email:** KrishnannairS@unizulu.ac.za

Professor Montaz Ali, University of the Witwatersrand

Prof Ali holds a chair the School of Computer Science and Applied Mathematics at University of the Witwatersrand, Johannesburg, and has a PhD from Loughborough University, UK. He has worked as a postdoctoral fellow at Plymouth University, UK, and Abo Akademi, Finland. His research areas of interest include stochastic methods for global optimization, programming problems, and industrial mathematics. **Email:** Montaz.Ali@wits.ac.za

Dr Naeemah Modhien, University of the Witwatersrand

Dr Modhien is a lecturer in the School of Computer Science and Applied Mathematics at the University of Witwatersrand, Johannesburg. In 2017 she obtained her PhD from Wits University, entitled "The effect of suction and blowing on the spreading of a thin fluid film: a Lie point symmetry analysis". Her research interests are fluid mechanics, lie point symmetries, and partial differential equations. **Email:** Naeemah.Modhien@wits.ac.za

Professor Chaudry Masood Khalique, North West University

Prof Khalique received his PhD from the University of Dundee, UK, and he is currently a full professor in the Department of Mathematical Sciences at North West University. His research interests are in Lie group analysis of differential equations. He is a Fellow of the Royal Society of South Africa and the Institute of Mathematics and its Applications, UK, and member of the Academy of Science of South Africa, London Mathematical Society, South African Mathematical Society, and Society for Industrial and Applied Mathematics, USA. **Email:** Masood.Khalique@nwu.ac.za

Mr Erick Mubai, University of Witwatersrand, Johannesburg

Mr Mubai holds a MSc degree in Computational and Applied Mathematics and is currently pursuing a PhD at the University of the Witwatersrand. The focus for his dissertation was on using the associated Lie point symmetries to reduce the governing coupled partial differential equations of a thermal jet to ordinary differential equations. His current research area is fluid flows such as jets and wakes, and how they affect the temperature field. **Email:** Erick.Mubai@wits.ac.za

MISG 2020 Invited Guests

Professor Neville Fowkes, University of Western Australia, Australia

Prof Fowkes, a senior lecturer at the University of Western Australia, is a mathematical modeller who works mainly on continuum mechanics problems arising out of industrial contexts. He has participated in more than 60 Mathematics in Industry Study Groups held in different countries and has authored a text on mathematical modelling based largely on problems arising out of these experiences. His research interest areas include crack propagation and groundwater flow. **Email:** Neville.Fowkes@uwa.edu.au

Professor Tim Myers, Centre de Recerca Matematic, Barcelona, Spain

Prof Myers is currently the head of the Industrial Mathematics group at the Centre de Recherches mathématiques, and an Adjunct Professor at the Universitat Politècnica de Catalunya. His research involves building and analysing models of physical problems, and one of his focus areas is nanotechnology, where he works on problems in nanofluid heat transfer, melting of nanoparticles and Ostwald ripening of nanoparticles. **Email:** tmyers@crm.cat

Professor Graeme Hocking, Murdoch University, Western Australia, Australia

Prof Hocking has been an academic since 1983, and currently hold a position at Murdoch University. He is the co-chief Editor of the Australian and New Zealand Industrial and Applied Mathematics (ANZIAM) Journal and vice-President of ANZIAM. He has attended more than 30 Mathematics-in-Industry Study Groups around the world. His research covers fluid dynamics, porous media flow and industry modelling. **Email:** G.Hocking@murdoch.edu.au

Dr Denis Ndanguza, University of Rwanda, Rwanda

Dr Ndanguza is currently Dean of School of Science at the University of Rwanda, Kigali. He is involved in inter-university cooperation, linking departments with industry, and coordination of projects within the school. He holds a PhD in Applied Mathematics from Lappeenranta University of Technology, Finland. His areas of interest are mathematical modelling through ordinary differential equations, Bayesian analysis, and Kalman filtering methods. **Email:** dndanguza@gmail.com

MISG 2020 Sponsors

DSI-NRF Centre of Excellence in Mathematical and Statistical Sciences

The DSI-NRF Centre of Excellence in Mathematical and Statistical Sciences (CoE-MaSS) was established on 1st April 2014 in order to bring together areas of research excellence in the Mathematical Sciences and Statistics in South Africa.

MaSS
DSI-NRF CENTRE OF EXCELLENCE IN MATHEMATICAL & STATISTICAL SCIENCES

The CoE-MaSS brings together pure mathematics, applied mathematics and statistics researchers from 16 Node Institutions around South Africa to focus on advancing cross-disciplinary research topics and developing national capacity in these scarce fields.

University of Zululand

The University of Zululand is located within the Umhlathuze Municipality, the fastest growing industrial hub and employer in northern KwaZulu-Natal. This is a comprehensive university offering approximately 252 accredited degrees, diploma and certificate courses across the faculties of Arts; Education; Science and Agriculture as well as Commerce, Administration and Law at the KwaDlangezwa and Richards Bay campuses.

Hermann Ohlthaver Trust

The Hermann Ohlthaver Trust is a charitable organisation which supports a range of Institutions and community-based organisations in South Africa and Namibia. The Trust dedicates a significant amount of its funding to programmes which focus on mathematics and science.

African Institute for Mathematical Sciences

The African Institute for Mathematical Sciences (AIMS) is Africa's first network of Centres of Excellence in Mathematical sciences. They enable the continent's youth to shape the continent's future through Science, Technology, Engineering and Mathematics (STEM) education-training Africa's next generation of leaders. AIMS South Africa is one of the Centres of Excellence for training, research and public engagement in Cape Town, South Africa.

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