PROCEEDINGS OF THE MATHEMATICS IN INDUSTRY STUDY GROUP

2014

Mathematics in Industry Study Group South Africa
MISGSA 2014

The manuscripts for the Proceedings of the MISGSA were written by the problem moderators in consultation with the other members of the study group for that problem and the industry representative.

The Editor of the Proceedings was

Prof D P Mason (University of the Witwatersrand, Johannesburg)

The Technical Reports were submitted to the Editor. Each Report was refereed by one referee. On the recommendation of the referees the Reports were accepted for the Proceedings subject to corrections and minor revisions. The Editor would like to thank the referees for their assistance by refereeing the Reports for the Proceedings.

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PREFACE

The eleventh Mathematics in Industry Study Group (MISG) in South Africa was held in the School of Computational and Applied Mathematics at the University of the Witwatersrand, Johannesburg, from Monday 13 January to Friday 17 January 2014.

The total number of registered participants at the MISG was70. There were twelve academic staff, forty-five graduate students, two postdoctoral fellows, six industry representatives and five invited guests. The invited guests were:

Neville Fowkes	University of Western Australia, Australia
Graeme Hocking	Murdoch University, Western Australia, Australia
Kamil Kulesza	Centre for Industrial Applications of Mathematics and Systems Engineering, Warsaw, Poland
Jim McKenzie	Max-Planck Institute (Retired), University of KwaZulu -Natal (Emeritus) Duraban University of Technology (Honorary)
Sarah Mitchell	University of Limerick, Ireland
Tim Myers	Centre de Recerca Matematica, Barcelona, Spain

One graduate student participated from:

University of Oxford, United Kingdom

The South African Universities and Institutes which were represented were:

African Institute for Mathematical Sciences
North-West University
University of KwaZulu-Natal
University of Venda
University of the Witwatersrand, Johannesburg

The MISG Workshop was opened by Professor Helder Marques, Dean of Science at the University of the Witwatersrand.

The MISG Workshop followed the established format for Study Group meetings held throughout the world. South African industry had been approached to submit problems during 2013. Eight problems were submitted. On Monday morning each Industry Representative made a twenty-five minute presentation in which the problem was described and outlined. The academics and graduate students then split into small study groups and worked on the problems of their choice. Some participants worked on one problem while others moved between problems and made contributions to several problems. Each problem was co-ordinated by a senior moderator and one or more student moderators. The role of the senior moderator was to co-ordinate the research on the problem during the week of the meeting and also to do preparatory work including literature searches before the meeting. The main function of the student moderators was to present short reports at the end of each working day on the progress made that day. The moderators were in contact with the Industry Representatives throughout the meeting. On Friday morning there was a full report back session to industry. Each senior moderator, with assistance from the student moderators, made a twenty-five minute presentation, summing up the progress made and the results that were obtained. Each Industry Representative then had five minutes to comment on the progress and the results which were reported. Work was done on seven of the eight problems submitted. There were not enough participants knowledgeable in data analysis to work on the second data analysis problem. The MISG ended at lunch time on Friday.

The MISG was preceded by a Graduate Workshop from Wednesday 8 January to Saturday 11 January 2014. The objective of the graduate Workshop is to provide the graduate students with the necessary background to make a positive contribution to the MISG the following week. The students were given hands-on experience at working in small groups on problems of industrial origin, some of which were presented at previous MISG meetings, at interacting scientifically and at presenting oral reports on their findings. Four problems were presented to the graduate students, The problems and the presenters were:

Traffic lights or traffic circles:	Neville Fowkes, University of Western Australia
Predicting survival on the Titanic:	Charles Fodya, University of the Witwatersrand
Application of Euler-Bernoulli beam theory to fracturing in rock layers and surface buckling:	Ashleigh Huchinson, University of the Witwatersrand
Warehouse stock layout:	Alan Watson, Highveld PFS

The graduate students worked in small study groups on the problem of their choice. Each group presented their results at a report back session on Saturday afternoon.

The sponsors of the Graduate Workshop and the MISG were:

- Hermann Ohlthaver Trust
- African Institute for Mathematical Sciences
- Centre de Recerca Matematica, Barcelona, Spain
- Oxford Centre for Collaborative Applied Mathematics (OCCAM)

We thank the sponsors without whose support the Graduate Workshop and the MISG could not have taken place.

Liste of Delegates

Academic	
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Campbell, Ian	University of the Witwatersrand
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Gibson, Emma	University of the Witwatersrand
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Louw, Kirsten	University of the Witwatersrand
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Raphulu, Dzanga	University of the Witwatersrand
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Zoras, Despina	University of the Witwatersrand
Industry Representatives	
Leempoel, Sébastien	Real Impact Analytics, Johannesburg
Loubser, Richard	Sugar Milling Research Institute, University of KwaZulu-Natal
Runge, Carl	Glass Design, Randburg
Runge, Reiner	Glass Design, Randburg
Stacey, Richard	School of Mining Engineering, University of the Witwatersrand
Watson, Alan	Highveld PFS, Contracted to Fujitsu Services (Airlines) UPD (Warehouse Logistics)

PROBLEMS

PREDICTING AND MITIGATING THE EFFECTS OF AIRBLASTS IN MINES

Industry: Mining

Industry Representative

- Richard Stacey, School of Mining Engineering, University of the Witwatersrand, Johannesburg.

Problem Statement

An airblast in a mine resulting from the collapse of rock can be extremely hazardous and may result in severe damage. Mine equipment may be annihilated, ventilation doors and seals destroyed and conveyor systems and shaft steelwork and equipment ripped out. The source of an airblast is usually the major collapse of rock in an underground mine opening that contains a large volume of air. The collapsing rock acts as a piston to compress the air in the opening. This type of situation can develop in underground coal mines, open stoping mines and caving mines in which over drawing takes place and the stope back hangs up over large spans. In such cases, sudden rock collapse leads to the displacement of the volume of air, which is then forced along any available pathways – tunnels, shafts, orepasses, access underground roadways and some will escape ``through" the collapsing mass of rock.

As an example of the effects of an airblast, a particularly severe event occurred at an Australian mine. Several lost their lives in the event. A Land Cruiser in which two persons were travelling in the mine was totally destroyed, only the engine block being found intact. All ancillary bolt-on fixtures such as starter motor and alternator were ripped off.

The questions considered to be of interest are:

1. What pressures and velocities are attained by the air in the pathways taken?
2. How easily can air escape through the collapsing broken rock mass, that is, a holey piston?

3. How can the effects be mitigated? By alternating excavation sizes, that is, artificially changing the roughness of the tunnels? By inducing reversed or counter-aiarflow? What barriers would withstand the pressures and velocities?

PREDICTION OF FRACTURING AND DYNAMIC FAILURE OF THE ROOF IN TABULAR STOPES IN A PLATINUM MINE

Industry: Mining

Industry Representative

- Richard Stacey, School of Mining Engineering, University of the Witwatersrand, Johannesburg.

Problem Statement

Suspected dynamic collapses of the hangingwall (roof) of tabular stopes have occurred in a platinum mine at a depth of about 250m. These stopes typically have a height of about 1.5m They are advanced on strike (termed breast mining) and each panel has a dip span, between rock pillars, of about 28m-31m. The roof consists of anorthosite, a brittle rock with a compressive strength of about 2000MPa. In the problem areas the thickness of this anorthosite is typically 7-10m (spotted and mottled anorthosite combined). It is effectively unjointed and contains no weak layering. The horizontal in situ stress in the strike direction is about 1.8 times the vertical stress at this shallow depth.

Roof falls have occurred, which indicate the effects of stress The formation of flat fracture planes and slabs are frequently observed.

The problem is to investigate the mechanisms that could cause the fracturing and dynamic failure of the roof in a platinum mine.

WASTAGE MINIMIZATION OF ALUMINIUM LENGTHS IN WINDOW AND DOOR INDUSTRY

Industry: Window and Door Manufacture

Industry Representatives

- Carl Runge and Reiner Runge, Glass Design, Randburg.

Problem Statement

Glass Design manufactures doors and windows from sections of aluminium lengths. Each window can have up to 9 different sections or more and each section is extruded in a “standard length”. The supplier of the aluminium lenagth offered Glass Design the choice of a “standard length” between 3 m and 8 m. The total weight of the “standard length” for each section ordered must not be less than 250 kg as requested by the supplier of the aluminium lengths. Glass Design has to order in bulk for about 1 to 20 different size doors per week, where each size of door needs up to 9 different sections or more.

Given a number of different door sizes what will be the optimal “standard length” and quantities for each section, out of up to 9 sections or more per door size so that cutting wastage is minimized subject to a 250 kg minimum order per section length.

SPINNERS DETECTION

Industry: Data Aanalysis

Industry Representative:

- Sebastien Leempoel, Real Impact Analytics, Johannesburg.

Problem Statement

Spinners are mobile phone users who change at high frequency of Mobile Network Operator (MNO) to catch the advantage of new promotions. These users often change SIM cards and are hard to detect for MNO's, who would like to detect them in order to measure what fraction of their past customers are returning to their network and at what frequency. To detect which customers are returning customers, MNO's have only few information to use, since the returning customers use a different phone number each time. The only information they are able to use is what they observe in the calling patterns of their customers: who they call and where they place calls from.

MNO's gather daily the logs of all calls and text messages of all their users, and know hence who calls and is called by each of their users. In these call logs they also have the location information of their users at the time of the call, allowing them to estimate their preferred locations.

Two customers *A* and *B* are likely to be identical if they meet the following criteria.

- *A* has made calls until a date *d* and has never called after that (*A* is called a *chumer*) and *B* has made calls only after the date $d + e$.
- The social networks of *A* and *B* are very similar.
- The places where *A* and *B* are when they make calls are very similar (usually, MNO's use top *x* locations to avoid too much variance).
- *A* has never called *B and vice-versa.*

The aim of an MNO is hence to build a list of potential spinners, with their old and new identifier.

The tasks considered to be of interest are:

1. Formalize the problem in mathematical terms. In particular the study group will need to decide how to measure similarity of social networks and mobility between two users.
2. Suggest and implement an algorithm to detect spinners on a small synthetic set of Call Data Records/(CDRs), which will be provided by Real Impact.
3. Test their method on a large synthetic set of CDRs and adjust their method to computational constraints.
4. (optional) If their method performs correctly (both in speed and results) on the large synthetic CDRs, their method will be tested by Real Impact on real-world data, to observe the behavior of the method in real-market situations. The performance of the method will be shared with the study group (for confidentiality reasons direct access to real-world data will not be possible)

LIQUIDHOLD-UP IN A DIFFUSER

Industry: Sugar Cane Processing

Industry Representatives

- Ricahard Loubser, Sugar Milling Research Institute, University of KwaZulu-Natal.

Problem Statement

The preferred method of extracting sugar from sugar cane in South Africa is by means of a diffuser. The cane is shredded and then fed into one end of a diffuser and moved to the other end using an arrangement such as a chain slat conveyor. Water is added at the other end of the diffuser and allowed to percolate through the bed. The sugar juice-water mixture is collected in a tray below the cane bed and pumped to a position closer to the cane feed end where it is sprayed on the top of the bed and allowed to percolate once again through the bed. In this way a counter current extraction/washing process is established. While most of the juice leaves through the intended tray, some of the juice returns to the tray from where it was pumped while other juice bypasses a stage because the cane bed is moving.

The operation of a diffuser is not a steady state operation but rather highly time dependent. The permeability of the cane varies form consignment to consignment. Sometimes the water-juice mixture will be pumped too quickly to the top of the bed causing flooding and uncontrolled mixing of the juice of varying concentrations. This destroys the counter current concentration profiles and reduces the effectiveness of the extraction process. If the flooding occurs near the cane feed area, the juice can overflow out of the diffuser. Operators will often stop the pumps feeding the flooded area. This leads to an accumulation of juice in the tray feeding that pump. This practice can cause overflow of the trays below the diffuser. If there is insufficient juice around the cane then the sugar will not be extracted resulting in losses, so it is best to keep the level of liquid in the cane bed just below the critical point where flooding occurs.

The aim of the study is to model the time dependent nature of the flows within a diffuser so as to advise how to keep the juice quantity in the bed at the desired

level and what action should be taken when flooding or dry operation occurs. This will require a study of the factors affecting the juice hold-up in the bed such as chain speed, bed height, percolation, recycle and bypass. In addition to these, factors such as pump and pipe characteristics will need to be considered together with the tray capacity and level relationships.

AIRLINE SCHEDULE ASSIGNMENT AND CONSTRUCTION

Industry: Airline

Industry Representative

- Alan Watson, Highveld PFS.

Problem Statement

Given

- Flight schedule (individual flight legs for a period, typically a season):
- Airline's fleet of aircraft (resources).

Constraints

- Flights must connect geographically (departure airport must be same as previous arrival).
- Flights *should* have a gap ("recommended ground time") between one another, which depends on the airport.
- Flights *must* have a gap between one another (also airport dependent) which is the "minimum ground time".
- Flight legs of the same flight must have an inter-leg gap of at least the minimum passenger connecting time if there is an aircraft change (a flight is identified by a single number for all of its component legs, and a "flight date", being the departure date of the first leg).
- There are carry-in and carry-out flights at each end of the period which must also connect with the flights inside the period (including both geographic and ground time constraints).

The Study Group is asked to undertake an airline schedule assignment and construction subject to the given flight schedule and airline's fleet of aircraft and the constraints.

TRAFFIC ANALYSIS ON BUS RAPID TRANSIT (BRT) ROUTES

Industry: Traffic

Industry Representatives

- Progress Hlahla, Gauteng Traffic Department.

Problem Statement

In order to facilitate the flow of traffic in Johannesburg during peak hours the Bus Rapid Transit System (BRT) is investigating the effect of allowing minibus taxis to use the lanes presently reserved for buses either throughout the day or just during peak hours. One would expect the reduction of flow in the normal lane to result in increased car speeds in this lane and also increased speeds for the minibus taxis in the bus lane, however bus speeds may be reduced and therefore timetables not adhered to. Also there may be disruptions caused by lane changes. The Gauteng Traffic Department asked the Study Group to investigate these issues.

Technical Reports