Forum 2019 Maths for Industry

Mathematics for the Primary Industries and the Environment

17-21 November
Auckland, New Zealand

Institute of Mathematics for Industry
Kyushu University

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Asia Pacific Consortium of Mathematics for Industry

Contents

FMfI 2019 Mathematics for the Primary

Sunday 17 November 2019	
Round Room/Functions Room	
2.00–6.00	**Registration**
2.00	**IMI IAB**
3.00	**APCMfI Board**
4.00	**APCMfI AGM**
5.00	**Journal Boards**

Monday 18 November 2019	
Round Room	
08.30–09:30	Registration
09.30–10.00	**Welcome and Opening**
10.00–10.30	Refreshment break
10.30–11.10	**Toshihiko Takemura** Japan
11.10–11.50	**Mike Plank** NZ
11.50-12.30	**Hyun Min Kim** Korea
12:30-1:30	Lunch
1.30–2.10	**Elliot Carr** Australia
2.10–2.50	**Tammy Lynch** NZ
2.50–3.10	Break
3.10–3.45	**Tanya Soboleva** MPI, NZ
3.45–4.20	**Conrad Edwards** Transpower, NZ
4:20–4.55	**Lisa Thomasen** Fonterra, NZ
4.55–5.30	**Tony Pleasants** Al Rae Centre, NZ
5.30-6.30	**Welcome Party**

Tuesday 19 November 2019	
Round Room	
09.30–10.10	**Lu Wenlian** PRC
10.10–10.50	**Steven Psaltis** Australia
10.50–11.10	Break
11.10–11.50	**Brent Clothier** NZ
11.50-12.30	**Takasi Okayasu** Japan
12:30-1:30	Lunch
1.30–2.10	**Graeme Hocking** Australia
2.10–2.50	**Nicholas Long** NZ
2.50–3.10	Break
3.10–5.30	**Poster Session**

The Round Room and Functions Room are in the Atrium Building

Industries and the Environment: Programme

Wednesday 20 November 2019	
Round Room	
09.30–10.10	**Nurul Syaza Abdul Latif** Malaysia
10.10–10.50	**Yongwimon Lenbury** Thailand
10.50–11.10	Break
11.10–11.50	**Aroon Parshotam** NZ
11.50-12.30	**Brendan Florio** Australia
12:30-1:30	Lunch **Discussion/Workshop****
1.30–6:00	**Free time** **Self-propelled exploration of Downtown Auckland**
6.00–9.00	**Dinner Cruise**

Thursday 21 November 2019	
Round Room	
09.30–10.10	**Eloise Tredenick** Australia
10.10–10.50	**Akiko Satake** Japan
10.50–11.10	Break
11.10–11.50	**Mark McGuinness** NZ
11.50-12.30	**John Burnell** NZ
12:30-1:30	Lunch
1.30–2.10	**Mark Nelson** Australia
2.10–2.50	**Kaji Shizuo** Japan
2.50–3.10	**Closing**
3.10–3.30	Refreshments

Session Chairs	
Monday 10.30–12.30	**Winston Sweatman**
1.30–2.50	**Mike Plank**
3.10–5.30	**Graeme Wake**
Tuesday 09.30–10.50	**Mark McGuinness**
11.10–12.30	**Phil Broadbridge**
1.30– 2.50	**Graham Weir**
3.10–5.30	**Robert McKibbin**
Wednesday 09.30–10.50	**Graeme Wake**
11.10–12.30	**Graeme Hocking**
Thursday 09.30–10.50	**Tammy Lynch**
11.10–12.30	**Mark Nelson**
1.30–2.50	**Luke Fullard**

**** Mathematical modelling: what could it look like in the classroom?**
(Leader: Kerri Spooner)

Welcome to the 10th Forum "Math-for-Industry" at Massey University in Auckland

We in New Zealand are proud to host this annual event, held under the aegis of the Asia-Pacific Consortium of Mathematics for Industry (APCMfI), with a theme this year that is important to our country and indeed to many other places around the world. The Asia-Pacific region has many commonalities of interest, and this is reflected in the presentations at this meeting. We are grateful to those in the region who have come to share their own quantitatively-based efforts to address important problems, and to those who will present a New Zealand perspective on industrial matters of importance to us.

With this meeting, the Forums now have a decade-long history. Initiated by the Institute of Mathematics for Industry (IMI) at Kyushu University in Japan in 2010, the Forums have provided a meeting place for mathematical minds, and also to provide insights that enable the endeavours of industry-focussed researchers to be shared within the region.

History of the Forums "Math-for-Industry"

2010 Fukuoka Oct. 21–23
Information Security, Visualization, and Inverse Problems, on the basis of Optimization Techniques
2011 Honolulu, US Oct. 24–28
TSUNAMI - Mathematical Modelling Using Mathematics for Natural Disaster:
Prediction, Recovery and Provision for the Future
2012 Fukuoka Oct. 22–26
Information Recovery and Discovery
2013 Fukuoka Nov. 4–8
The Impact of Applications on Mathematics
2014 Fukuoka Oct. 27–31
Applications + Practical Conceptualization + Mathematics
= Fruitful Innovation

In 2014, the Asia-Pacific Consortium of Mathematics for Industry (APCMfI) was formed (see background information elsewhere in this booklet), and the forums started to move around the Consortium's member countries, with themes that reflected each country's interests.

2015 Fukuoka Oct. 26–30
The Role and Importance of Mathematics in Innovation
2016 Brisbane, AU Nov. 21–23
Agriculture as a Metaphor for Creativity in all Human Endeavours
2017 Honolulu, US Oct. 23–26
Responding to the Challenges of Climate Change: Exploiting, Harnessing and Enhancing the Opportunities of Clean Energy
2018 Shanghai, PRC Nov. 17-21
Big Data Analysis, AI, Fintech, Math in Finance and Economics
2019 Auckland, NZ Nov. 18–21
Mathematics for the Primary Industries and the Environment

It is clear that the Forums traverse a wide range of topics, and that the abilities of mathematicians to address these affirms the importance of such specialists in the increasingly-complex ways in which society operates. The value that quantitative scientists and engineers provide to all communities cannot be under-estimated. While most people appreciate effective and efficiently-operating systems, they often do not realise how these come about, and who is providing the sophisticated processes that underlie their efficiency.

While the speakers are experienced in their fields, the students who present posters and give talks about their work are the future leaders in APCMfI; they are valuable members of the "Math-for-Industry" community, and are particularly welcome at this Forum. Each student will give a brief oral presentation of their work and will provide extra comments about their their poster afterwards. There are prizes, provided by IMI, to be awarded at the closing ceremony.

We are grateful to IMI, APCMfI and Massey University for their support, and hope that all participants have an entertaining, fruitful and satisfying time at this meeting.

For the Organising and Speakers Committees,

Robert McKibbin

Organising Committee

Robert McKibbin, Massey University (Chair)
Winston Sweatman, Massey University
Luke Fullard, Massey University
Mark McGuinness, Victoria University of Wellington
Kenji Kajiwara, Kyushu University
Osamu Saeki, Kyushu University
Yasuhide Fukumoto, Kyushu University
Masato Wakayama, Kyushu University

Speakers Committee

Graeme Wake, Massey University (Chair)
Alona Ben-Tal, Massey University
Gaven Martin, Massey University
Graeme Weir, Wellington
Troy Farrell, Queensland University of Technology, Brisbane
Masato Wakayama, Kyushu University
Yasuhide Fukumoto, Kyushu University
Jin Cheng, Fudan University

Administrators

Annette Warbrooke, Massey University
Sue Di Leo, Massey University
Liz Thaisen Fitzmaurice, Massey University
Seiko Sasaguri, Kyushu University
Kumiko Nakashima, Kyushu University

FMfI2019 Registration and Social Events

Morning and afternoon tea/coffee, etc., will be provided. Information about lunch and dinner venues is provided in your conference pack.

Registration: *Sunday 17 November 2–6 pm, Round Room (and on Monday from 8:30 am)*

You can complete your registration, receive your conference pack, and meet up with colleagues and friends. During the Sunday afternoon, there will also be meetings of the APCMfI Board, an APCMfI AGM, the IMI International Advisory Board, and various journal board meetings.

For that evening, there is a good selection of restaurants in Albany Village and the nearby Mall, all within 10–15 minutes walk from the campus. A list of suggested places to eat is provided in your conference pack.

Forum Welcome Party*: Monday 5:30–6:30 pm, Round Room and ancillary space*

APCMfI and the Forum will host a "drinks, snacks and chat" reception for all participants, with a chance to talk with the local industrial representatives, who will have spoken earlier.

You may wish to wander further afield for dinner, or again take advantage of the provided list of local restaurants. You may like to use the list for dinner on Tuesday and Thursday (if you are still here). Note that Wednesday's dinner is included in the Excursion fee of NZD80.

Discussion/Workshop: *Wednesday 12:30–1:30 pm*

A Workshop on Teaching Mathematical Modelling for Industry will be held over lunchtime on Wednesday. It will be led by Kerri Spooner from AUT University (Auckland University of Technology). Lunch will be provided for participants.

Forum Excursion and Dinner: *Wednesday 20 November 1:30–5:45 pm, 6:00–9 pm*

The cost for the cruise and dinner (starting at 6:00 pm) is NZD80, to be paid at registration.

The "Excursion and Dinner" is in two parts:

A. Make your own way to downtown Auckland. There are at least two options by public transport:
   1. Take AT bus 917 from the campus to Birkenhead Wharf (fare NZD5.50). Then board a ferry to the Downtown Ferry Terminal (fare NZD7.50).
   2. Take buses from the campus to the Albany Bus Station, and then from there to Downtown Auckland (fare NZD11.00).

   You can explore the city streets, the harbour foreshore and the Wynyard Precinct. It is a 30-minute stroll from downtown through the Precinct to the Red Boats boarding pier (Pier Z) in Westhaven Marina. Be there by 5:45 pm to ensure you are on board for a 6:00 pm departure.
   See the provided bus/ferry timetables and maps.

B. The Dinner Cruise will start from Pier Z at Westhaven Marina, 31 Westhaven Drive, at 6:00 pm, and will return there around 9 pm (with transport for those who need to get back to the campus). The boat will have a bar on board (there will be a bar tab for your first drink, using your provided voucher). Bring-your-own (BYO) is not allowed, so bring some cash for further drinks.

If needed, car parking is available at Pier Z (Pay and Display); otherwise there are options for public transport from Albany (as above), as well as taxis, or arrange a ride with a colleague with a car, of course.

Tickets for the Dinner Cruise will be sold at the Registration Desk (NZD80) on Sunday and Monday. There is a limit of 60 persons. Partners are welcome, but Forum delegates will take precedence if numbers are too high.

The Asia-Pacific Consortium of Mathematics for Industry (APCMfI)

Mathematics for Industry (MfI) aims at the development of mathematics and its applications to enhance the quality of life on the planet by creating new technologies, improve industrial mathematical research and stimulate the two-way interaction between mathematics and industry. In Industrial Mathematics, it is the questions spawned by real world applications that drive the resulting two-way interaction between a particular application and the associated mathematics that is utilized and developed, and that sometimes involves, quite unexpectedly, deeper aspects and new areas of mathematics than initially anticipated.

Though its significance has often been overlooked, industrial mathematics has always been an essential aspect of the history, culture, traditions and development of mathematics, including much of modern theoretical mathematics. Directly and indirectly, developments in mathematics can be traced to the initial attempts to answer quite practical questions. The development of Galileo's telescope and the design of clocks represent early stimuli. Harmonic analysis and Fourier analysis have their origins in the study of heat transfer in metals. The conservation and minimization of energy engendered in the study of thermodynamics and fluid motion underlie much of the foundations of modern theoretical mathematics, as well as applied and industrial mathematics.

The increasing sophistication of modern industry, reflected in, for example, medical measurements, game theory applications in economics, psychology, behavioural science and biology, computer-controlled instrumentation, the efficient development of geothermal energy, the microbial treatment of waste water, Ito calculus in finance, etc., has generated a need and demand for mathematical expertise to stimulate, foster and implement the associated innovations. Even the theoretical areas of algebraic geometry, abstract algebra, topology, differential geometry and group theory are playing an increasingly important role in industrial endeavours connected with entertainment (such as games and movies), architecture, analysis of protein structure and error-correcting codes.

There is general agreement and support in the Asia-Pacific region to have regular industrial mathematics exchanges, conferences, internships, etc, which build on the activities already occurring. In fact, over the years since the concept of an Asian Consortium of Mathematics for Industry was first proposed and more recently when planning to formalize possibilities, there has been strong support and encouragement from colleagues in China, Hawaii, Korea, Malaysia and Singapore as well as Australia, New Zealand and Japan.

A small group, with the encouragement of various colleagues throughout the Asia-Pacific region, met in Canberra, March 31 to April 2, 2014, to do the initial planning for the formation and launch of APCMfI, with the emphasis being fundamentally Mathematics-for-Industry. Those directly involved in the discussions in Canberra were Bob Anderssen (Australia), Zainal Aziz (Malaysia), Frank de Hoog (Australia), Yasuhide Fukumoto (Japan), Alexandra Hogan (Australia), Geoff Mercer (Australia), Masato Wakayama (Japan) and Graeme Wake (New Zealand).

In any endeavours that involve the initiation and implementation of a new opportunity, the situation is similar to planting and nurturing a seed which will grow into a strong and robust tree. The meeting and deliberations of this group represented the preparation of the ground for the planting of the seed. The subsequent planting and nurturing involves the wide distribution of this initiative throughout the Asia-Pacific region; the seeking of seed funding from various mathematics departments, societies, agencies and industry; the establishment of a website; the launch of APCMfI under the MfI banner.

Planned Activities for APCMfI

An important component of the plans for APCMfI is a number of activities through which it interacts directly with the Asia-Pacific MfI communities and indirectly with the various international industrial mathematics consortia, organizations and individuals.

The underling goal is to stimulate the development of mathematics and its applications to enhance the quality of life on the planet by creating new technologies, improve industrial mathematical research and stimulate the two-way interaction between mathematics and industry.

The planned activities include:

1. Internships for graduate students to work on industrial and governmental research projects.

   In particular, in this scheme, the student will spend several months at both their home institute and the industrial partner. Within the APCMfI framework, the goal is to make it easier for students to undertake internships with industry in other countries in the Asia Pacific region
2. Regular Mathematics-for-Industry Study Groups (MfISG) which involve a strong Asia Pacific involvement with regards to problems proposed and scientists' participation.

   . The implementation of this activity will take advantage of various study group meetings already operating in Japan, Malaysia, Australia and New Zealand.
3. Regular Math-for-Industry Forums and Workshops building on the successful annual Forums organized by the Institute of Mathematics for Industry (IMI) at Kyushu University.
4. The exchange of information and publicity material about industrial mathematics activities in the Asia-Pacific region, such as electronic news letter, publications, websites, etc.
5. The organization of joint lectures and programs such as Summer and Winter schools which foster a strong student participation which takes advantage of the similar times in the Asia Pacific region.
6. Fostering a strong two-way interaction with (i) mathematical and statistical colleagues and institutions and (ii) the needs and opportunities of industrial mathematics.

Special session on mathematical modelling in education. **Wednesday 20th November, 12:30pm.**

Kerri Spooner
(Auckland University of Technology, New Zealand, kerri.spooner@aut.ac.nz)

Mathematical Modelling, What Could it Look Like in the Classroom?

This workshop is a self-initiated consultation process with Mathematical Modellers (both academic and industry based) concerning what they think are important aspects of mathematical modelling that could or should be taught at school level.To start the discussion the modelling behaviours of a New Zealand real world modelling team and the potential authentic mathematical modelling behaviours of a secondary school student will be presented. The rest of the workshop will be a discussion session seeking feedback from you concerning what you think is important to teach at school level, why it is important and if you think it is possible to teach at school level. Discussion questions will focus on: what does mathematical modelling look like for you? What aspects of mathematical modelling do you think should be taught at school? What aspectsdo you think should be taught at Universities? What activities are possible to develop authentic modelling behaviour in a classroom? What do you see as the challenges? What support do you envisage would be needed? Your participation will be used to inform submissions I make to the NZMS education group around mathematical modelling in the New Zealand curriculum. I am also hoping to build research around this project.

Abstracts

Contributed Talks

John Burnell
(GNS Science, New Zealand, j.burnell@gns.cri.nz)

Challenges for Modelling Geothermal Systems in New Zealand.

As New Zealand moves towards a low carbon future as part of international commitments to reduce the future effects of climate change, renewable energy sources will play a key role. New Zealand is blessed with natural high-temperature geothermal resources and these are expected to be at the forefront of the renewable energy suite. Through modelling we can understand the characteristics of this resource and to predict sustainable utilization rates. To do this reliably we need methodologies that are step change beyond those used currently. In this talk we will review some of the challenges that we face and look at progress that has been made to improve the ability to predict the response of a geothermal system when developed for energy use.

Elliot Carr
(Queensland University of Technology, Australia, elliot.carr@qut.edu.au)

Coarse-Scale Simulation of Heterogeneous Flows.

Groundwater refers to water present in the pore space of soils and fractures of rock formations in aquifers located below the Earth's surface. This water comprises 98% of the world's fresh water supply and in many regional areas of Australia constitutes the only available supply of fresh water. Groundwater supplies are susceptible to problems such as *over-withdrawal* causing the water levels to dip below the reach of existing wells and *contamination* from pollutants emanating from the ground surface (e.g. hazardous industrial waste, garbage landfills, pesticides applied to crops). Mathematical and computational modelling developed to understand how water and contaminants flow through aquifers provides invaluable insight to inform decisions regarding the management of groundwater resources.

When modelling groundwater flow one encounters the challenge of dealing with a highly heterogeneous geological structure where medium properties, such as the hydraulic conductivity which controls the ease at which fluids flow through the pore spaces and fractures, vary spatially. When this variation occurs on a small scale, direct computation of the solution is computationally infeasible since one has to discretise the computational domain with a very fine mesh to accurately capture the heterogeneity. A common approach to overcome such issues is to coarse-grain the model by decomposing the domain into a number of smaller sub-domains and homogenizing the heterogeneous medium within each sub-domain. In this talk, I will present some new mathematical/computational techniques for implementing such coarse-scale models and demonstrate how these models can be used to accurately and efficiently simulate flows in heterogeneous media.

Brent Clothier
(Plant & Food Research, brent.clothier@plantandfood.co.nz)

Measuring and Mathematical Modelling of the Irrigation Requirements and Nutrient Leaching Loads from Perennial Horticultural Crops.

Our soils and their carbon stocks, our waters, our biodiversity and our climate are prime natural-capital stocks. Ecosystem services, which benefit mankind, flow from natural-capital stocks. We are dependent on natural capital, especially those of our water resources, but these stocks are finite and they are under growing pressures. Irrigation is placing pressures on the quantity of our water reserves, and nutrient

leaching is threatening the water quality of these resources. Biophysical measurements and mathematical modelling can, in tandem, lead us to new understanding that can be used to manage better water, and help develop regulations to protect our water stocks.
We describe new devices that can directly measure plant water-use, along with novel instruments that can be deployed across landscapes to monitor the leaching of nutrients from the root-zone. These new data are providing knowledge and understanding that can be included in biophysical systems-models to predict irrigation requirements for plants, and the nutrient loadings, so that more sustainable practices can be implemented to protect our soils and waters.
Joint work with Steve Green.

Conrad Edwards
(Transpower, New Zealand, conrad.edwards@transpower.co.nz)

The Power of Mathematics - Lessons from the Power Industry.

Transpower owns and operates New Zealands national electricity transmission grid. It is difficult to find a single aspect of its operations that does not have an underlay of mathematical optimisation physical, technical or economic or, increasing, some combination of these. Transpower has been a long and strong supporter of mathematics for industrial applications, and of workshops and conferences such as this. The speaker will describe many of the varied applications that Transpower has run through these events over the last 15 years to gain understanding of diverse aspects of power system operations. And a few that Transpower hasn't, too.

Brendan Florio
(University of Western Australia, brendan.florio@uwa.edu.au)

Improving Counter-Current Sugar Extraction and Other Sweet Problems in the Sugar Industry.

The Sugar Milling Research Institute is a repeat participant in the Mathematics in Industry Study Groups, South Africa. They seek innovative mathematical solutions to problems that they experience in sugar-related processing, waste disposal and energy generation.

In the sugar extraction process, crushed cane is introduced to water in a pseudo counter-current system to maximise the yield. There are two noted problems in this process: 1) The formation of air bubbles which interferes with extraction, and 2) the perpendicular transport of dissolved sugar, which subverts the optimal counter-current design.

We present insights from the study group's mathematical models and how the problem has evolved over the years.

Graeme Hocking
(Murdoch University, Perth, Australia, G.Hocking@murdoch.edu.au)

Jet-Stripping in the Galvanization of Steel.

A problem that has arisen several times in Study Groups is that of the air-knife stripping of the coating during the galvanization of steel sheeting. The solution for an infinitely wide sheet was presented by Tuck (1984) and this provided the basic important parameters of the flow. Subsequent study groups have considered the appearance of pitting or "bananas", both defects in the coating that may have expensive consequences for the manufacturer. These may form due to pushing the limits of stable behaviour, or it may be due to non-uniformity in the process, e.g. the air-knife is not exactly uniform. In this talk I will consider other geometries to see what can be learned about variations from the "perfect" situation.

Tuck, E.O. (1983), Continuous coating with gravity and jet stripping, Phys. Fluids, **26**, (9), pp.2352-2358.

Shizuo Kaji
(Kyushu University, Japan, skaji@imi.kyushu-u.ac.jp)

Flood Prediction by Geographic Data Analysis with GANs and Tailored Loss Functions.

In recent years, Japan has suffered from severe damage caused by floods. There is an urgent need for accurate flood forecast. Flood prediction usually takes the form of time series analysis in which future water level is regressed from that of the observed past and additionally precipitation, geography, and so on. There are standard machine learning models such as ARIMAX models to perform this type of analysis. Here, we investigate the use of neural network-based models for the problem. The two key factors are (1) use of generative adversarial networks; this is to cope with the lack of data (2) a loss function which is tailored for the problem; in flood prediction, usual losses such as the mean squared error are not optimal, since, for example, undershooting in prediction is much more harmful than overshooting.

Hyun-Min Kim
(Pusan National University, South Korea, hyunmin@pusan.ac.kr)

A Model for Collaboration on Big Data Between Local Industries and Local University Math Departments.

The Applied and industrial mathematics are fields that not only Korean government, but almost all countries around the world actively and primarily support to better face the dawn of the 4th industrial revolution. Therefore, three industrial mathematics centres were established in Korea. Two are in Seoul area and the other is FFMIMC in Pusan National University. The goal of FFMIMC is to be the hub of industrial mathematics by

1. finding and solving industrial problems in finance, fishery, and manufacture based on Big Data,
2. fostering industrial mathematics experts through undergraduate course and graduate school PSM course in Pusan National University,
3. sharing performance with society.

FFMIMC is also working on finding and solving industrial mathematical problems not only in industries based in Busan but also Korean companies that have factories in overseas. In this talk, we will introduce industrial mathematics problems solved with the companies which are KOMAX (Special Printing Company), Animal and Plant Quarantine Agency, National Fisheries Research and Development Institute, Busan Bank, Korea Housing Finance Corporation and Pusan National University Hospital. We

also worked with three National Science Museums to share these industrial mathematical problems with society. So we show what three museums put on display in industrial math exhibition 2018. Finally, we will consider the direction of research on industrial mathematics in Korea and how to promote exchanges with Korea and other countries in the future. Based on this, we want to investigate what kind of desirable roles and talents mathematics, which form the basis of Big Data.

Nurul Syaza Abdul Latif
(Universiti Malaysia Kelantan, syaza@umk.edu.my)

Agriculture Management Strategies Using Simple Logistic Growth Model.

Farm management involves the development of long-term strategies to increase the profitability and competitiveness of its agricultural business. In recent years, mathematical models have been extended to the agriculture sector as a decision-making tool to ensure continuous and optimum supply. One of the well-known mathematical functions by Pierre François Verhulst, the Logistic function, has been widely used in modelling population growth rates. Many processes in biology, ecology, and other areas follow this S-shaped logistic growth. This talk explores the application of a simple logistic growth model for agriculture management strategies. The model presented here quantitatively estimates the effectiveness of the procedure used.

Yongwimon Lenbury
(Department of Mathematics, Faculty of Science, Mahidol University, Bangkok, Thailand, Yongwimon.len@mahidol.ac.th)

Complex Dynamics in Population Models in Livestock Farming and Fisheries Industries Facing Environmental Pressures.

In many agricultural countries, two major activities in the agriculture area are livestock farming and the fisheries industry. We will discuss some of our more recent results concerning dynamical systems related to these two industries. Examples will be mentioned of efforts at modelling and analyses of the swine industries in which high rates of morbidity from infectious diseases in swine farms would cause a devastating financial loss to the country as a whole. Also, the fishing industry in these countries is facing increasing environmental pressure due to climate changes. It is more crucial than ever, therefore, to carry out more detailed investigations of these systems by proposing and analyzing more complex models dealing more accurately with population distributions and spatial heterogeneity. Effects of time delays and impulsive interventions on the solutions and dynamic behavior of models of systems of interest will be discussed.

Nick Long
(Victoria University of Wellington, New Zealand, nicholas.long@vuw.ac.nz)

Alternative Energies: Is it Time for fusion?

Although many renewable technologies are growing at pace and the cost is falling below that for fossil fuels, these power sources retain the problem of intermittency. Large scale power storage which can solve the kind of problems New Zealand has with seasonal variation in availability of hydro power remains an unsolved problem. There are now about 20 companies world wide working on small scale fusion reactors, and one large scale effort in ITER. Fusion promises essentially limitless amounts of power with no carbon emissions and no long term radioactive waste problems. Ill review a select few of these efforts and discuss how viable they are as a solution to the worlds need for zero-carbon energy. A particular focus will be on compact tokamaks using high temperature superconductor coil windings. Our institute is working

with two of these companies on overcoming some of the technical challenges.

Wenlian Lu
(Fudan University, China, wenlian@fudan.edu.cn)

On an Algorithm Engineering System for Full Supply Chain Management in Manufacturing Industry.

Increasing application of AI and IoT technology in supply chain management arises such challenges in optimization and programming algorithms that should run through the full supply chain. In this work, we establish an algorithm engineering system that comprises of diverse optimization and programming modules fulfilling demands in hierarchical time-scales, including assignment, routing and scheduling of short-term, prediction, risk-warning and planning of medium term, and allocation and layout of long-term. And a hyper-heuristic scheme is utilized to integrate these modules to customize algorithms for real-world application in the Shanghai Automotive Industry Corporation.

Tammy Lynch
(Massey University, New Zealand, T.A.Lynch@massey.ac.nz)

Microbial Co-Existence and Selection in Enteric Fermentation.

In this talk I will present a mathematical model created to allow for testing of developing knowledge of enteric fermentation. The model uses concepts from chemostat modelling and enzyme kinetics and thermodynamics to model dynamic control of microbe growth. The addition of thermodynamic control that includes substrate and product inhibition and ATP formation on the rate of biochemical processes, produces substrate thresholds below which metabolism stops as has been seen experimentally. It allows for fermentation pathway selection based on rumen environment and can lead to coexistence of different species consuming the same substrate but using different fermentation pathways, providing an explanation for observed microbial diversity in the rumen that is not dependent on spatial or temporal changes in the system.

Mark McGuinness
(Victoria University of Wellington, New Zealand, Mark.McGuinness@vuw.ac.nz)

Microwaves Measure Moisture in Bauxite.

Moisture measurement in bauxite as it is being offloaded from a ship is a challenge that was brought to a European Study Group with Industry at the University of Limerick in 2017. A refinery asked us to confirm that it is possible to calculate the moisture content once every second, in real time, by passing microwaves through the ore as it is being unloaded at about 2 m/s. The microwaves experience a phase shift and signal attenuation, depending on the amount of moisture present. We review the theory of microwave transmission through a polarising medium, and we study the data produced by the microwave analyser. We explore the consequences of the method for measuring phase change, and the effects of noise on the phase shifts observed. We provide an algorithm for lifting the measured phase shifts from their restricted range to an unlimited range for the true phase shift, by using concurrent measurements of ore height. And despite initial indications that this method is very promising, we reveal that there may be issues at very high moisture levels.

Mark Nelson
(University of Wollongong, Australia, mnelson@uow.edu.au)

Modelling Wastewater Treatment by Activated Sludge: A Review.

Wastewaters from both the municipal and domestic sectors contain a wide variety of complex organic materials. As a consequence of stringent effluent discharge limits, they must be cleaned before the processed water can be discharged into the aquatic environment. One way to do this is to use biological treatment, in which microorganisms feast upon soluble organic molecules.

The activated sludge process has proven to be a very reliable and flexible process, which is capable of producing high quality effluents. Consequently it has become the most widely used biological treatment process for the treatment of both domestic and industrial effluents. The distinguishing features of it are the use of aeration and a settling tank. Aeration is required as the organic materials are oxidised by the microorganisms present in the reactor. The effluent stream leaving the aerated reactor contains a mixture of microorganisms and unconsumed organic material in the form of biological flocs. These flocs are colloquially referred to as 'sludge'.

The job of the settling unit is to separate, under the action of gravity, the 'sludge' from the clear treated water. A fraction of the settled solids, i.e. the sludge, are recycled in the form of a concentrated slurry back into the aerated reactor. The remaining activated sludge has to be disposed of whilst the cleaned wastewater is discharged into the environment. It is the return of the sludge that is the key to making the process efficient. Early researchers quickly realised that the sludge contained some 'magical' ingredient that greatly increased the efficiency of the process. Hence the name 'activated sludge'. We now know that that the magical ingredients that puts the activated into 'activated sludge' are the microorganisms. The recycling of the microorganisms in this way allows them to adapt to the local environment.

Historically the activated sludge process was developed to remove biodegradable organic material from wastewaters — it has proven to be highly efficient at this. The removal of nitrogenous matter or phosphate can also be achieved, by including additional steps involving the use of anoxic conditions; i.e. there is no dissolved oxygen. The main disadvantage of the activated sludge process are the high costs associated with the disposal of the excess sludge. Secondary disadvantages include its relatively complex operation, it requires qualified and experienced operators, and its capital and operating costs.

Mathematical models for the activated sludge process contains two components: a mechanistic model for the biochemistry and a process model. The process model specifies the number of reactors and ancillary units such as recycle units and settling units.

In this presentation I give an overview of common biochemical models, process models, and settling unit models.

In 2007 the British Medical Journal posed the question: what has been the greatest medical advance since 1840?
Was it the introductions of antibiotics? No!
Was it the introduction of anaesthesic drugs? No!
Was it the introduction of vaccines? No!
Was it the discovery of the structure of DNA? No!

The greatest medical advance in the period 1840–2007 was judged to be the development of sanitation. Perhaps you won't think more of this whilst you are going about your daily business. At least not until it is time for you to do your business!

Takashi Okayasu
(Faculty of Agriculture, Kyushu University, Japan, okayasu@bpes.kyushu-u.ac.jp)

Plant Phenotyping for Smart Agriculture Utilizing Affordable IoT Devices.

Agricultural management strongly depends on climate, weather, soil conditions, plant type, and so on. Thus, farmers have tried to modify cultivation skills for a long time so as to fit the ambient environmental conditions and nutritional status for crops. The average age of the core persons mainly engaged in farming in Japan reaches 70 years old. We encounter a very serious problem because their knowledge and skills cannot be easily passed down to posterity and/or new farmers. Therefore, we must consider and built how to collect information and utilize it to improve agriculture in Japan and train new farmers. Additionally, consumers' demands have shifted to fresh, high-quality, and high-security fruits and vegetables. In response to these issues, various researches and developments have been well investigated in order to establish next agriculture including sustainability up to present. These studies are expected to advance the use of Information and Communication Technologies (ICT) in Japanese agriculture. We also study about a sustainable agricultural production and food supply chain system (Nugroho et al., 2016, Okayasu et al., 2017) as shown in Figure 1.

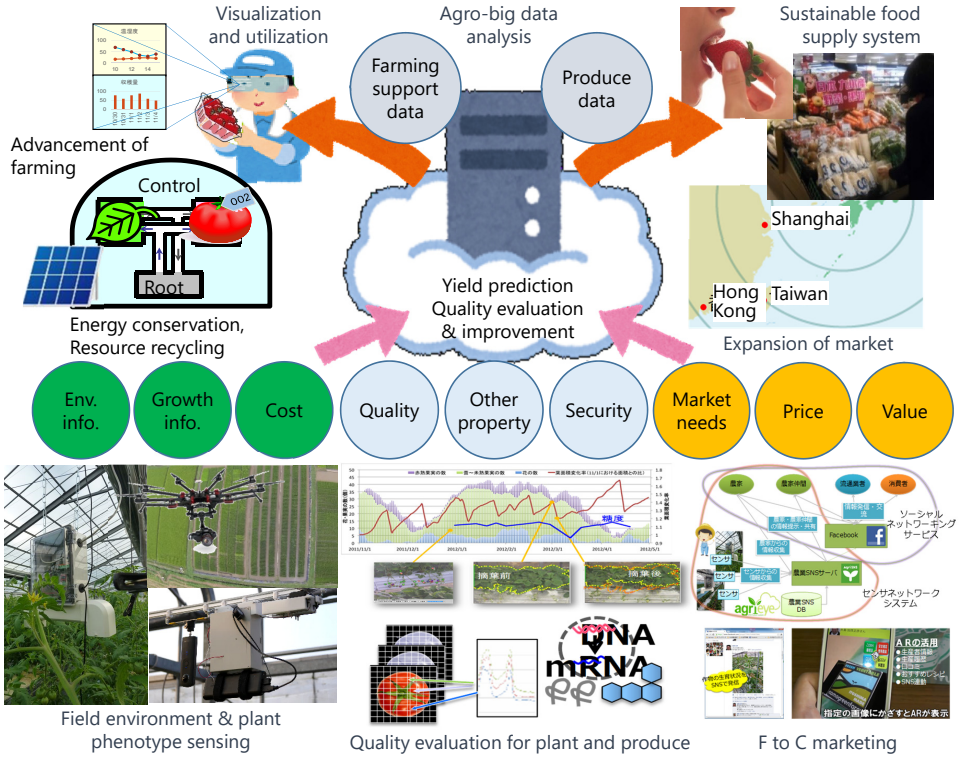

Figure 1: Overview on sustainable agriculture and food value chain system.

On the other hand, plant growth characteristics are influenced not only by the gene property but also by the ambient environmental condition and the nutritional status in general. Thus, a lot of methods and devices have been developed in order to measure the field environmental information and the plant growth behavior. Among them, image processing and analyzing methods based on visible (RGB), hyper (multi) spectrum, and IR images are used to extract plant growth features. Due to rapid expansion of recent IoT (Internet of Things) and AI (Artificial Intelligence) technologies, they are utilized to measure plant phenotyping, which are focused on the comprehensive assessment of complex plant features such as growth, physical property, and yield (Roberto et al., 2015). Therefore, high-throughput plant phenotyping technologies are being actively investigated in the world and contribute to solve problems related

to food and biomass production under drastic climate change, global warming, and the increase in the global population. However, typical systems are very expensive. Thus, development of the affordable system is needed to improve smart agriculture. Some examples on our plant phenotyping studies are introduced below.

Figure 2 shows a plant feature measurement system using RGB-D sensor, which is possible to obtain a RGB (visible) color image and a depth image. For the depth image sensing, several methods such as stereo mapping, Light Coding, and ToF (Time of Flight) have been developed up to present, and these depth image sensors are available as a reasonable price. They are very useful technologies in the plant phenotyping research field. The plant growth features such as leaf area, leaf surface direction, and plant height are able to be obtained directly. We used this method for counting number of the leaves and for performing the leaf segmentation. Figure 3 shows the number of leaves and dry matter weight of the spinach estimated by the RGB-D sensor. As the results, linear relationship between the measured and estimated number of leaves is obtained. However, the small leaves could not distinguish from the captured image. In order to improve the accuracy, more effective estimation method should be considered. On the other hand, the estimated volume index, which is defined by multiplication of the leaf height and leaf area had almost same tendency as the dry matter weight. Thus, these results could be a promising sensor to establish smart agriculture. Another examples will be introduced on the day of the conference.

Acknowledgement This work was supported by the Japan Society for the Promotion of Science of KAKENHI Grant No.17H01768 and 18K05906, and the Project of the NARO Bio-oriented Technology Research Advancement Institution(the special scheme project on regional developing strategy, No.16822352), and a collaborative research with the Fujitsu LTD. We would like to express a lot of thanks for the valuable support.
Joint work with Daisuke YASUTAKE (Kyushu University), Daisaku ARITA (University of Nagasaki), Yasuhiro TANAKA (Canon IT Solutions Inc.), Koichi NOMURA (Kyushu University), Yukio OZAKI (Kyushu University), Tadashige IWAO (Fujitsu Ltd.)

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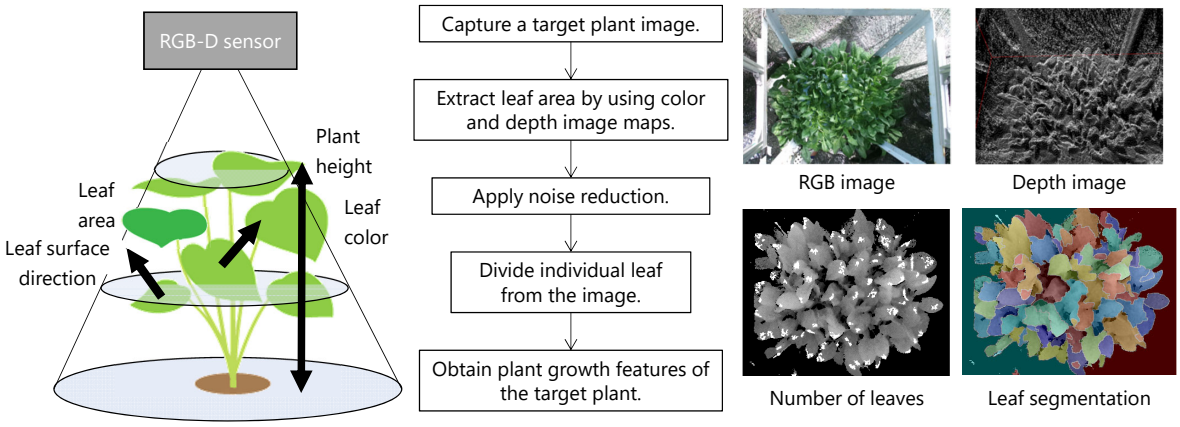

Figure 2: Plant feature measurement system using RGB-D sensor.

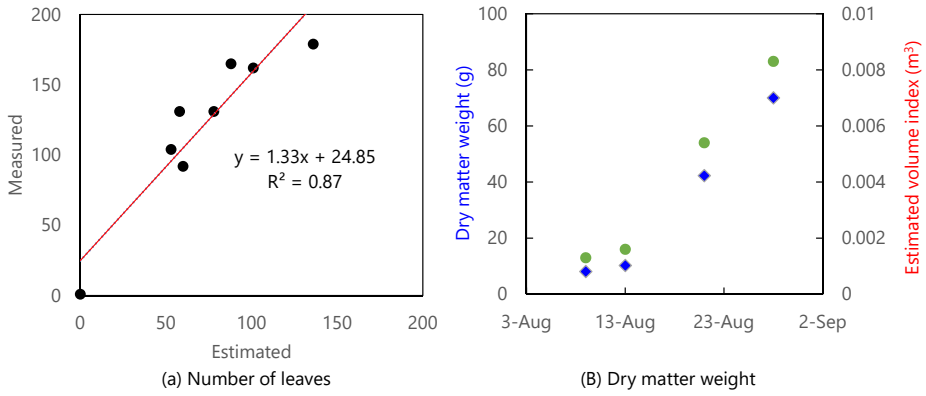

Figure 3: Estimated plant feature values.

Aroon Parshotam
(Aqualinc Research Ltd., aroon@aqualinc.co.nz)

Mathematical Modelling for Catchment Management.

Catchment models are useful tools to help describe and quantify the sources, transport, and fate of sediment, nutrients, and other constituents in a landscape. Results from catchment models are used to quantify and understand existing conditions, and used in restoration efforts by defining areas with highest contributions (hotspots, where actions would be most beneficial) and describing the relative importance of various sources (what types of actions would be most beneficial).

In practice, a continuum of mathematical models is used in New Zealand (see Figure 4) from simple empirical models to complex process-driven models, each requiring different types and amounts of information. Each of these models has its strengths and weaknesses, which should be considered when deciding which model to apply to a specific area. In many applications, a combination of models can be either coupled or run in series to help describe how nutrients and sediment are transported from the field to downstream receiving water bodies. This work gives a brief overview of this catchment modelling continuum with a focus on the Soil and Water Assessment Tool (SWAT), used to develop a national New Zealand sediment model (Parshotam, 2018a).

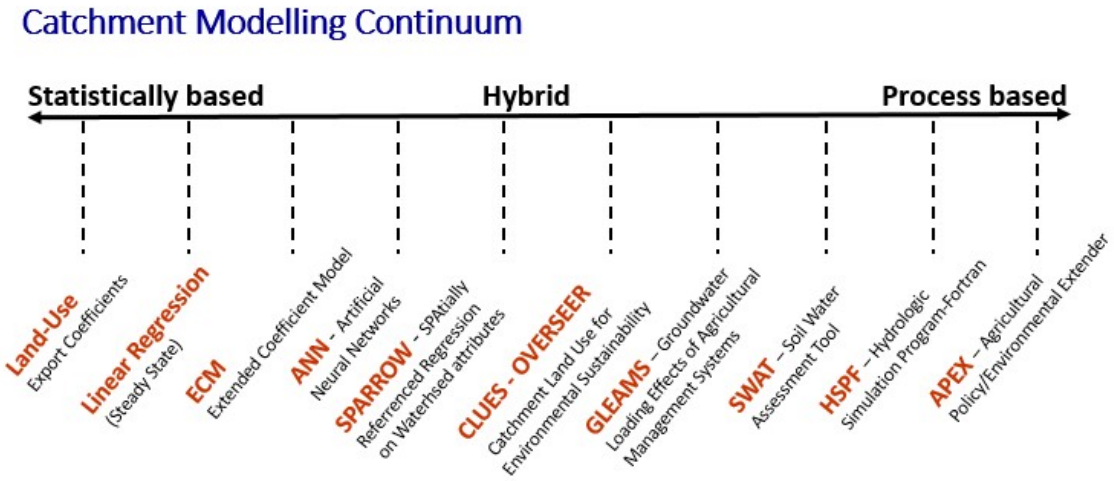

Figure 4: Catchment modelling continuum (from Parshotam and Robertson, 2018)

The Soil & Water Assessment Tool is a small catchment to river basin-scale model used to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds. There are over 3800 peer-reviewed journal articles in the SWAT literature database (https://www.card.iastate.edu/swat_articles/). Model inputs include spatial data such as land use, soils, topography, meteorological station data as well as cropping and land management information.

In the absence of suitable and freely available soils input data, a national soil map was created from the Fundamental Soils Layers and the New Zealand National Soils Database (NZ-NSD) (Parshotam, 2018b). In the absence of suitable long-term meteorological station databases, long-term Climate Forecast System Reanalysis (CFSR) data was acquired and spot checked for quality assurance. Stochastic weather generators used for climate-change studies were developed and used to fill missing data. A stream network is defined, and sub-catchments delineated using a hydrologically corrected digital elevation model (DEM), for a region, and with a given area threshold value. Hydrological response units were created from land use, soils and topography data layers. The model is run and output results imported to databases,

summarised and presented graphically. The model is calibrated and validated using measurement data and SWAT-CUP.

The methodology developed allows the SWAT model to be applied to any sub-catchment in New Zealand and nutrient and sediment concentrations estimated in every stream reach.

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Michael Plank

(University of Canterbury, New Zealand, michael.plank@canterbury.ac.nz)

Size-Based Models of Harvesting and Fisheries Management.

Many marine fish species can grow in body mass more than seven orders of magnitude over their lifetime. As fish grow, their target prey and their growth, mortality and reproduction rates change drastically with body mass. This means that body mass is a crucial variable in any mathematical model. Size-spectrum models put body mass foremost by doing a bookkeeping of biomass as it flows from prey to predator, and from parent to offspring. This is a different paradigm from the classical species-based predator-prey model.

This talk will give an overview of size-spectrum models and the insights they have given us into marine community dynamics. Size-spectrum models are based on a generalisation of the McKendrick-von Foerster equation to a nonlinear, partial integro-differential equation. I will show some theoretical results about the equilibrium size structure and stability, as well as applications in fisheries management and fisheries-induced evolution. Size-spectrum models are particularly suited to investigating the effects of different distributions of fishing mortality over body mass and species, which is a key question for ecosystem-based fisheries management.

Tony Pleasants

(The AL Rae Centre for Breeding and Genetics, Massey University, Hamilton, New Zealand, tony@pleasantsanalytics.co.nz)

Modelling Large Complex Interacting Systems. Developing Regulatory Tools for Managing Environmental Processes.

Consider the issues of modelling large dynamical complex biological systems arising in particular in environmental management and regulation. The task of building these models has been captured by disciplines which have applied quantitative tools familiar to the discipline practitioners. In biology these tools are characteristically kinds of regression analysis, typically inappropriately applied to nonlinear dynamical situations. Contestable funding is to blame for the failure to reach out to other disciplines.

This means that models are being developed that cannot address the variety of outcomes that a natural system can express, stochasticity, multiple equilibria, bifurcations, etc. Models of pasture grazing systems demonstrate how critical phenomena can be missed if the correct mathematical framework is not used. This shows the need for mathematicians to be better integrated into applied science teams.

Stochastic analyses are useful where the system interactions are poorly understood. Specifying elements with probability distributions with some variance and covariance structure can express the uncertainties

typically inherent when modelling large complex systems but needs interaction with experts in the field. This approach also prepares the model to be linked to data and/or experimental design through the construction of a likelihood. Formulating a model as a stochastic system also allows the application of updating methodologies.

When addressing large complex systems, a flexible modelling approach is needed where outcomes from multiple models are reviewed to come to a decision. In addition, data assimilation methods based on Bayesian parameter updating methods are useful in defining a model that continuously conforms to the knowledge evolving from the system of interest. Data assimilation is useful when data for parameter estimation is sparse. Historical analyses of the time variation of updating models can be used to improve model structure by showing up subtleties not apparent in the initial construction, and which can continuously test the model against reality and cope with the incorporation of new knowledge.

Dealing with the complex dynamical systems associated with environmental management is necessarily multidisciplinary. Trained mathematicians are key personnel in such a team that are often missing. The mathematical community needs to pay more attention to ensure that rigorous science is employed.

Steven Psaltis
(School of Mathematical Sciences, ARC Centre of Excellence for Mathematical and Statistical Frontiers, Queensland University of Technology, Brisbane, Australia, steven.psaltis@qut.edu.au)

Computational Modelling for the Timber Industry.

The QUT porous media modelling group has developed a long and fruitful research collaboration with the Queensland Department of Agriculture and Fisheries, Forest Products Innovation team (DAF). I will discuss outcomes of a recent collaborative project with the forestry industry that focused on developing models to better understand the Southern Pine resource, which covers an area of approximately 156,000 ha in southeast Queensland and northern New South Wales. The significant amount of data collected at the plantation, stand and tree levels, together with the data obtained from destructive sampling of a selected number of trees, was used to develop analytic tools capable of forecasting the future development and value of this resource.

I will also highlight on-going collaborative work between the QUT team and DAF on using computational techniques for optimising transport processes in wood.

Brief Biography: Steven Psaltis is a research fellow in the Australian Research Council (ARC) Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) at Queensland University of Technology (QUT). His research interests lie in the mathematical modelling and numerical simulation of multiscale, multiphase, and multicomponent systems, with applications in electrochemistry and porous media flow, and his multidisciplinary research demonstrates a strong interaction with industry.

Akiko Satake
(Kyushu University, Fukuoka, Japan, akiko.satake@kyudai.jp)

Phase Response of Plant Circadian Clocks Leads to Robust Metabolic Rhythms Under Seasonal Variations in Day Length.

Growth and maintenance processes requiring carbon must be maintained despite daily fluctuations in light and dark conditions. Buffering against daily fluctuations in the carbon supply is achieved through a diel turnover of starch. Starch accumulates in the day and decreases in the night with almost linearly. Moreover, starch accumulates rapidly and decreases slowly as night-period decreases, which allows plants to maintain the same amount of starch at the end of the night regardless of photoperiod. Recent studies reported the importance of feedbacks between circadian clocks and carbon metabolism for optimal growth. However how plants adjust starch metabolism in response to changing photoperiod remains elusive.

To investigate the mechanism of flexible coordination of starch metabolism, we modeled the interplay of carbon metabolism and circadian clocks. We first showed that the linearity of starch metabolism is an emergent property of sucrose homeostasis. We next demonstrated that hyperbolic function of starch degradation rate that has a peak at dawn is necessary for sucrose homeostasis. We then showed that a phase response curve to sucrose signals that realizes sucrose homeostasis is the same as the one determined by the experiment, which shows phase advance in the morning and delay in the night. We finally showed that the phase response to sucrose signals leads to appropriate adjustment of starch accumulation and degradation rates. These results indicate that the responsiveness of plant circadian clocks to sucrose signals has an adaptive significance for optimal growth under diel and seasonal fluctuations in environments.

Tanya Soboleva
(New Zealand Food safety, tanya.soboleva@mpi.govt.nz)

Mathematics behind Food Risk Assessments.

For food safety and health protection authorities risk assessment is an important tool used for making informed decisions in presence of inevitable and often irreducible uncertainty. Designed to address different issues risk assessments vary from qualitative to fully quantitative and from explanatory to predictive. This presentation will focus on quantitative risk assessments that heavily rely on mathematical models. In contract to chemical risk assessment quantitative microbiological risk assessment (QMRA) usually involves a set of stochastic dynamical mathematical models as number of pathogens in food may increase and decrease because of a range of random and controlled bacterial events (i.e. growth, survival, death, physical removal and cross-contamination) when the food moves through the supply chain. Another set of models in QMRA designed to establish probability and severity of disease as a function of type and amount of pathogen ingested. The dose-response relationship is subject to both variability and uncertainty.

Examples of OMRAs and associated probabilistic models will be given in the presentation.

Toshihiko Takemura
(Kyushu University, Japan, toshi@riam.kyushu-u.ac.jp)

Numerical Simulation of Air Pollutants for Analyzing Climate Change.

Suspended particle matters in the atmosphere, aerosols, and tropospheric ozone are known as major air pollutants. They also cause climate change although it is not well-known. Some principal gaseous air pollutants and their precursors absorb the infrared radiation at specific wavelengths for each composition, i.e., greenhouse gases. Aerosols, on the other hand, scatter and absorb the solar radiation and additional infrared radiation over wide wavelengths. They also change cloud characteristics through their acts as cloud condensation and ice nuclei. Therefore, changes in atmospheric aerosol concentrations bring about changes in energy budget and consequent hydrological cycle. To quantitatively analyze climate change due to aerosols, I have developed a global aerosol climate model, SPRINTARS that calculates the transport process which includes emission, advection, diffusion, chemical reaction, and deposition, and their effects on the radiation and cloud processes. The simulated results have been used in activities of the Intergovernmental Panel on Climate Change (IPCC) under the United Nations, for example. The SPRINTARS also provides information on PM2.5 and dust concentrations to the public every day as its additional use (http://sprintars.net/forecastj.html), which is cited in TV and radio programs, newspapers, environmental administration in local governments, etc.

Lisa Thomasen
(Fonterra Co-Operative Group Ltd, Lisa.Thomasen@fonterra.com)

Using Mathematics to Model Milk.

Milk is a complex liquid. The Fonterra Research & Development Centre has been based in Palmerston North for over 90 years. In that time, there have been many advances in our understanding of the building blocks of milk. Unsurprisingly, mathematics and statistics play an important role in developing new techniques and insights which help us to be world leaders in dairy expertise. This talk will outline three interesting applications of using mathematics to model milk which occur prior to products hitting the supermarket shelves.

In the same way that each of us have unique fingerprints, raw milk from a specific farm is unique. Milk fingerprinting relies on Fourier transform infrared spectroscopy (FTIR) to rapidly analyse the composition of milk at a detailed level. This technique earned an Innovation Excellence in Research Award at the NZ Innovation Awards in 2015. Its application has resulted in significant cost savings and many potential benefits, including improved product quality and supply chain optimisation.

Dealing with variability comes with the territory in large scale manufacturing. Each product that is produced has associated specification limits to meet quality standards and customer expectations. Regular in-process sampling is designed to detect non-conforming product. Measurement error introduces uncertainty which complicates product release decisions. The technique of fractional non-conformance involves generating probabilities of conformance associated with each sample measurement to bring more rigour to the decision to accept or reject a batch.

On the occasion products don't meet their desired functional or sensory characteristics, a troubleshooting process begins. This may lead to an exploration of the product at the chemical bond level. Data produced from the Raman confocal microscope has highlighted differences in the micro structure of different cheeses. This is an area of ongoing work which involves clustering millions of pixels to understand the behaviour of fats, proteins and other key compounds. Currently this results in lots of information dense spectral images, but over time we aim to be able to correlate these clusters with the sensory experience of product consumption.

Eloise Claire Tredenick
(Queensland University of Technology, Brisbane, Australia, e.tredenick@connect.qut.edu.au)

Agrochemical Droplet Evaporation and Diffusion Through Plant Cuticles: Surfactant Effects.

The agricultural industry requires improved efficacy of sprays being applied to crops and weeds to reduce their environmental impact and increase financial returns. One way to improve efficacy is by enhancing foliar penetration. A mechanistic partial differential model has been developed, focusing on plant cuticle diffusion of calcium chloride through tomato fruit cuticles. The mechanistic model includes adsorption and desorption, hygroscopic water absorption and droplet evaporation of the ionic active ingredient and surfactant on the surface, along with the ability to vary the active ingredient concentration and type, relative humidity and plant species. The sensitivity analysis indicates surfactants increase diffusion by promoting active ingredient desorption, changing the point of deliquescence of a solution, water absorption, initial contact angle and number of pores under the droplet. The results of the validation and sensitivity analysis imply that this model accounts for many of the mechanisms governing penetration in plant cuticles. We also discuss current work creating a mathematical model and conducting experiments for droplet evaporation on inclined wheat and capsicum leaves.

Posters. **Tuesday 19th November, 3:10pm.**

1. Linh Thi Hoai Nguyen

(Institute of Mathematics for Industry, Kyushu University, Japan, linh@imi.kyushu-u.ac.jp)

Sustainability Conditions for a Stochastic Forest Model.

A stochastic forest model of mono-species with young and old aged classes of trees is investigated. The existence, uniqueness and boundedness of the global non-negative solutions are proven. The asymptotic behavior of the solutions is given by means of a sufficient condition for the sustainability of the forest. Under this condition, we show the existence of a non-trivial Borel invariant measure. Besides, some sufficient conditions for decline of the forest are presented. The conditions for the sustainability or decline of the forest suggest that the mortality rate of the old aged tree can be considered as a control parameter. It may give us some information on how to effectively exploit the forest resource while ensuring the sustainability of the forest. Numerical simulations that match the theoretical results are shown.
Joint work with Ton Viet Ta and Atsushi Yagi.

2. Takumi Imamura

(Kyushu University, Japan, imamura.takumi.279@s.kyushu-u.ac.jp)

Order Selection Test for LAQ Models.

The main aim of our study is to propose a data-driven model selection method for non-ergodic dependent data models. Our study has three keywords: dependent data, non-ergodic model, and likelihood misspecification. Dependent data is observed in various fields such that medical, weather, financial, and economic fields. When we analyze dependent data, it is important to consider non-ergodic statistical problems.
In this study, we focus on the locally asymptotically quadratic (LAQ) models. Many model families have the LAQ structure. Furthermore, we deal with the quasi-likelihood function, where quasi means that the data-generating true model may not be included in the candidate model family.
Information criteria or statistical hypothesis tests are used as model selection method. Above all, the Akaikes information criterion (AIC) is used in application fields. However, classical AICs bias term can not be computed from data for non-ergodic models. Therefore, we focus on a statistical hypothesis test method. We propose the so-called order selection test for checking the fit of a prescribed parameter form for a function of interest. The order selection test utilizes the omnibus non-parametric method, but it is free from smoothing parameters. Our main results are three theorems about convergence destinations of the proposed test statistic under the null hypothesis, alternative hypothesis, and local alternative hypothesis. These theorems give the framework, which is necessary for the statistical hypothesis test.
Joint work with Professor Hiroki Masuda, Faculty of Mathematics, Kyushu University.

3. Naoto Agawa

(Kyushu University, Japan, agawa.naoto.557@s.kyushu-u.ac.jp)

Theories of relational algebra for a monad and their formal proofs.

A network structure, a relation between two objects, is frequently used in applied mathematics, such as telecommunications field, transportation network, data structures and computational algorithms. Relational theory has really developed for a long while. In this poster, we review this theory from a viewpoint of formal verifications. Further, we introduce theory of relational algebra for a monad introduced by M.Barr in 1970. We refine this theory and introduce a formal proof using relational calculus.

4. Hiroaki Kurihara

(Kyushu University, Japan, h-kurihara@math.kyushu-u.ac.jp)

An Invariant of Surfaces in the 3-Sphere.

A closed connected orientable surface F embedded in the 3-sphere S^3 splits the exterior $S^3 \setminus int(N(F))$ into two submanifolds of S^3. By considering a Heegaard splitting of each submanifold, we obtain two handlebody-knots. In this poster, the author will explain an invariant of such surfaces w.r.t. a quandle invariant defined for handlebody-knots.

5. Kazuhiro Araki

(Kyushu University, Japan, araki.kazuhiro.903@s.kyushu-u.ac.jp)

Mathematical Model of Angiogenesis in Retina Assuming Intracellular Oxygen Diffusion.

Angiogenesis is a formation of new blood vessels. It occurs not only in infant body, but also during the wound healing process and when cancer cells develop. To elucidate its mechanism mathematically contributes to the discovery of new cancer treatments.
Tero (Institute of Mathematics for Industry, Kyushu University) has created a mathematical model in which vascular network is formed spontaneously by applying an adaptive transport network. And then, Yamada added to the model an effect of oxygen flowing in blood vessels. This model can reproduce the physical phenomenon that few capillaries are formed around arteries because of the high oxygen concentration.
In the physical phenomenon, it is known that few capillaries appear around also the optic disc, the part behind the eyeball where blood vessels gather, for the same reason as around arteries. We focused on the intracellular diffusion of oxygen and made new model. In conclusion, this model can capture the physical phenomenon. I introduce the dynamics of this model and numerical simulation result in our poster.
Joint work with Atsushi Tero.

6. Yuta Doi

(Kyushu University, Japan, doi.yuta.668@s.kyushu-u.ac.jp)

Mathematical Model of Human Auditory Information.

When humans hear sounds, eardrums vibrate and convey sound waves to inner ears. Sound waves are converted to electronic signals there. After that, auditory nerves convey the information to our brains and our brains perceive the sounds. In the process, humans approximately estimate the direction of sounds by Interaural Time Delay (ITD) and Interaural Intensity Difference (IID). Brains distinguish subtle difference of information from right ear and left ear, and estimate the direction of sounds.
Oscillators with the same frequency synchronize when receiving periodic stimulation of similar frequency. We regarded brain waves as oscillators. We thought if they synchronize to sound waves, we can think that humans perceive the sound stimuli. In order to analyze brain waves, we assumed that they are independent oscillators. Under this assumption, we made the mathematical model of human auditory information and showed the result of simulations.
In this poster, we assumed that we hear a single sound, and the direction we estimate is 2D. However, we hear composed sounds and estimate the 3D direction in reality. We are planning to integrate these complex scenarios into our work.
Joint work with Atsushi Tero.

7. Mori Yuta

(Kyushu University, Japan, ma218043@math.kyushu-u.ac.jp)

Mathematical Model of Pill Bugs Turn Alternation Considering Elevation Differences.

There are a lot of things that the phenomena of nature and the properties of animals are used. In particular, it could be helpful to understand the complex phenomena like the human brain by remarking the properties of simple creatures.
Turn alternation (TA) is a behavioral pattern characterized by the tendency to alternate the direction of movement when the subjects are forced to turn. TA can be observed in many kinds of animals including pill bugs. And the mathematical model of TA is proposed by Yamaguchi et al. Also, there are reports that pill bugs behave according to landform information. In addition, it is revealed that pill bugs integrate TA and landform information by the experiment that we conduct.
This poster presents experimental results about the pill bugs TA on slopes, our mathematical model of pill bugs TA considering elevation differences, and some numerical results about the proposed model. We expect that the formalization of pill bugs TA on slopes will enable the development of robots that make decisions based on landform information.

8. Yasuaki Kamada

(Kyushu University, Japan, ma219008@math.kyushu-u.ac.jp)

Numerical Simulation of Kyushu Railway Network based on Mathematical Model of True Slime Mold.

Kyushu railway has a cost-efficiency problem. Kyushu Railway Company must discuss necessity of each route. We suggest which routes they should preserve or abolish by comparing simulation result with actual Kyushu railway network.
Human build railway networks by repeatedly extending or abolishing routes according to the number of passengers. True slime mold Physarm polycephalum build transport networks with the same mechanism as human build railway networks. Previously, a mathematical model of Physarm network is proposed by Tero et al. and it was applied to Tokyo area railway network. We applied same algorithm to Kyushu railway network.
We could reproduce roughly Kyushu railway network including the number of passengers in this simulation. By comparing simulation result with actual Kyushu railway network, we could suggest paths which should be abolished to improve cost-efficiency.
Joint work with Atsushi Tero.

9. Sebastiá Elías Graiff Zurita

(Kyushu University, Japan, s-graiff@math.kyushu-u.ac.jp)

Integrable Discrete Eulers Elastica? Explicit Expression for the Curvature.

In a previous work we have seen that an integrable discretization of the Eulers elastica can be parameterized via a potential function, which is a quantity that comes from the isoperimetric discrete deformation theory, and also it can be completely characterized by seven parameters.
In this work, we will study an integrable discrete Eulers elastica defined in terms of the discrete curvature. As the main result, we will see that an analytic solution can be obtained in terms of the Jacobi elliptic functions. Furthermore, we will see that both definitions of the discrete Eulers elastica are equivalent.
In this presentation there will be an emphasis on explaining the procedure needed to construct the analytic solution, trying to provide a general framework that can applied in other circumstances.

10. Mako Sato

(Kyushu University, Japan, sato.mako.682@s.kyushu-u.ac.jp)

Effect of Magnetic Fields on Darrieus-Landau Instability of a Flame Front.

Combustions are phenomena commonly occurring not only on the earth but also on astrophysical objects. We explore the effect of magnetic field on the Darrieus-Landau instability (DLI), the linear instability of a planar front of a premixed flame, to pursue a possibility for suppressing the DLI. An externally imposed magnetic field is parallel to the flame front. We find that the magnetic field acts to reduce the growth rate of the DLI and even could suppress it when the wavenumber-vector of disturbance field is parallel and near-parallel to the external magnetic field, but that this is not the case for disturbances with their wavenumber-vectors perpendicular to the magnetic field. Although, for astrophysical plasmas, the value of the magnetic permeability is usually taken to be uniform, with the value of the vacuum, we take account of the discrepancy of their values between the unburned and the burned regions. We show that the discrepancy has a significant influence on the DLI, depending on paramagnetism or diamagnetism of the fuel material. For instance, the supernova is thought to be diamagnetic.
Joint work with Yasuhide Fukumoto.

11. Yuya Miyata

(Graduate school of Mathematics, Kyushu University, Japan, y-miyata@math.kyushu-u.ac.jp)

On the topological complexity of S^3/Q_8.

Topological complexity was first introduced in 2003 by Farber as a homotopy invariant for a connected topological space X, denoted by $\mathrm{TC}(X)$. Although the invariant is defined in terms of elementary homotopy theory using well-known Serre path fibration, not many examples are known to be determined concretely by now, except for works done by authors especially Grant and Farber. In 2010, Iwase and Sakai showed that the topological complexity of a space is a fibrewise version of a L-S category for a fibrewise space over the space. In this poster, we introduce how to determine the topological complexity of S^3/Q_8 using a method produced from the fibrewise view point.

12. Ye Yuan

(Graduate School of Mathematics, Kyushu University, Japan, y-yuan@math.kyushu-u.ac.jp)

Experimental Studies of Distributed Energy Resources Control via Quantum Secure IEC 61850 based Communication.

As the energy industry shifts toward cleaner and more sustainable models, the control of distributed energy resources (DERs), including renewable energy sources such as solar, wind, or geothermal power, becomes increasingly important for power distribution system operations. However, introducing DERs owned by individuals has potential concerns not only in grid reliability but also in messages confidentiality. The standard IEC 61850 proposes a unified solution to the communication aspect of the substation. It can provide an approach of direct, intelligent, and effective monitoring and control of DERs for aggregators. Hence, the secure IEC 61850 communication must be ensured for direct DERs control.
In this poster, we focus on the performance investigation of the feasibility of post-quantum cryptographic (PQC) algorithm for secure IEC 61850 communication.

13. Kento Okuda

(Kyushu University, Japan, k-okuda@math.kyushu-u.ac.jp)

Bifurcation and stability for surfaces with constant mean curvature bounded by two coaxial circles

It is important to analyze a shape and stability of a surface with constant mean curvature (CMC) in interface phenomena and geometric flow. In this poster, we deal with unduloids bounded by two given circles with the same radius on two parallel planes in order to find out the shape of interface that can appear in interface phenomena. We analyze bifurcation around both one period of an unduloid between two necks and two bulges.
This is a joint work with Prof. Miyuki Koiso.

14. Jagir R. Hussan

(Auckland Bioengineering Institute, University of Auckland, New Zealand, r.jagir@auckland.ac.nz)

Bioengineering for Primary Industries.

Animal farming in the future must navigate many conflicting demands due to climate change, resource constraints and consumer expectations on animal welfare. Farmers have to maintain a product that can command top price in the market, grow animals efficiently on whatever sustainable feedstuffs that are available, effectively manage diseases and provide high standards of animal welfare. This will require strategies for rapid adjustment of animal diet constrained by prevalent market conditions, rapidly respond to novel diseases, and in developing novel animal husbandry practices. Such flexibility requires predictive, quantitative models based on integrated knowledge of animal physiology.

Currently, statistical associations and selective breeding are widely used to manage livestock. We acknowledge that these approaches are likely to be sufficient for tackling several important issues in the years to come, but they are limited by the availability of existing genetic variation in the target animal population. Given that disease outbreaks that severely decimate populations are now common, the industry must develop robust methods that causally relate the genotype to the phenotype in the context of the environment and the biotechnology necessary to enact those observations.

Based on our endeavours in human health, we argue that digital animal models that encompass mathematical descriptions of animal physiology, advanced instrumentation and high-dimensional data analysis are necessary. Such models will be instrumental in adapting farm animals to new diets, for understanding complex diseases, developing novel biotechnologies, and in preserving ecology.

The Physiome Project (www.physiomeproject.org), provides a framework for modelling the human body using biochemical, biophysical and anatomical information on cells, tissues and organs. A functioning organ relies on an interplay between fast and slow processes on multiple spatial scales. To address this challenge, models are developed to describe processes on different levels of organization from single cells to tissues to the whole organ, which are then coupled to describe the whole human— the Digital Patient. Efforts are also underway to tailor the generic human model to represent variation between individuals and deliver personalised care.

The poster presents our efforts to replicate the Physiome Project to cattle to create digital animal models. Joint work with Peter J. Hunter.

15. Neelum Bashir

(School of Natural and Computational Sciences, Massey University, New Zealand, N.Bashir@massey.ac.nz)

The Triangular Symmetric Six-body Problem.

The N-body problem is the problem of predicting the individual motions of a group of celestial objects interacting with each other gravitationally. In astrophysics N-body simulations are used to study the dynamics of few-body systems such as the Earth-Moon-Sun system. The goal of the present study is to investigate the triangular symmetric six-body system. We are interested in the different possible orbits resulting as a consequence of encounters of these six bodies. One specific aim is to find a special periodic orbit: the Schubart orbit and to explore its stability.
Joint work with Winston Sweatman, and Alona Ben-Tal

16. Shumaila Noreen

(School of Natural & Computational Sciences, Massey University, New Zealand, s.noreen@massey.ac.nz)

Mathematical Modelling of the Cardiovascular System to Study the Effects of Respiratory Sinus Arrhythmia on Cardiac Output.

Respiratory sinus arrhythmia (RSA) is a phenomenon where heart-rate (HR) increases during inhalation and decreases during exhalation. A strong RSA indicates a healthy cardiac system but its physiological benefits are still debatable. We have developed a mathematical model for the cardiovascular system of a sheep that considers RSA. Using this model, we explored the hypothesis that RSA increases the mean cardiac output. The model includes two sources of RSA: one that originates in the brainstem and one that is due to changes in the thoracic (chest) cavity volume during breathing. We found that RSA does not affect the mean cardiac output (but it does change the beat-by-beat cardiac output).
Joint work with Alona Ben-Tal, Maja Elstad, Winston Sweatman, Rohit Ramchandra, and Julian Paton.

17. Seyed Mohsen Hashemi

(New Zealand Institute for Advanced Study, Massey University, New Zealand, s.m.hashemi@massey.ac.nz)

Linear Distortion and Its Application in Material Science.

This poster is primarily concerned with the convexity properties of distortion functionals (particularly the linear distortion) defined on quasiconformal homeomorphisms of domains in Euclidean n-spaces, though we will mainly stick to three-dimensions. The principal application is in identifying the lower semi-continuity of distortion on uniformly convergent limits of sequences of quasiconformal mappings. For example, given the curve family or analytic definitions of quasiconformality - discussed in this poster - it is known that if $\{\mathbf{f_n}\}_{n=1}^{\infty}$ is a sequence of K-quasiconformal mappings (and here K depends on the particular distortion but is the same for every element of the sequence) which converges to a function $\mathbf{f}$, then the limit function is also K-quasiconformal.
Despite a widespread belief that this was also true for the geometric definition of quasiconformality (via the linear distortion $H(\mathbf{f})$ defined below) Tadeusz Iwaniec gave a specific surprising example to show that the linear distortion function is not lower semicontinuous. The main aim of my research is to show that this failure of lower semicontinuity is actually far more common, perhaps even generic in the sense that it might be true that under mild restrictions on a quasiconformal $\mathbf{f}$, there may be a sequence $\{\mathbf{f_n}\}_{n=1}^{\infty}$ with $\mathbf{f_n} \to \mathbf{f}$ uniformly and with $\limsup_{n\to\infty} H(\mathbf{f_n}) < H(\mathbf{f})$. The main result of my research is to show this is true for a wide class of linear mappings.