The University of Limerick (UL) SIAM Student Chapter, together with the Mathematics Applications Consortium for Science and Industry (MACSI), hosted a Student Mathematical Modelling Workshop from June 5th-8th 2018 at UL. The event was a great success with participants, ranging from undergraduate to PhD students, from universities around Europe attending the four day residential workshop. Four diverse problems, directly motivated by industrial applications, were presented at the workshop by five experienced researchers; Dr Kevin Burke and Dr Vincent Cregan (University of Limerick), Dr Rosemary Dyson (University of Birmingham), Professor William Lee (University of Huddersfield), and Professor Mark McGuinness (Victoria University of Wellington). These problems included:

1. The calibration of a moisture analyser used to measure bauxite moisture content at an alumina manufacturer.
2. Modelling how manufacturing defects on the surface of an electrode affect the electrostatic potential generated by a component.
3. Forecasting energy demand in the Irish electricity market (together with Vayu Energy).
4. Developing a mathematical model to investigate aeration optimisation for hydroponics.

Professor James Gleeson (MACSI director) provides an opening address to the workshop.

The MI-NET COST Action TD1409 funding enabled us to be meet the bulk of the travel and accommodation costs of the non-local students as well as the costs of the instructors. The MI-NET funding also contributed to the local catering costs.

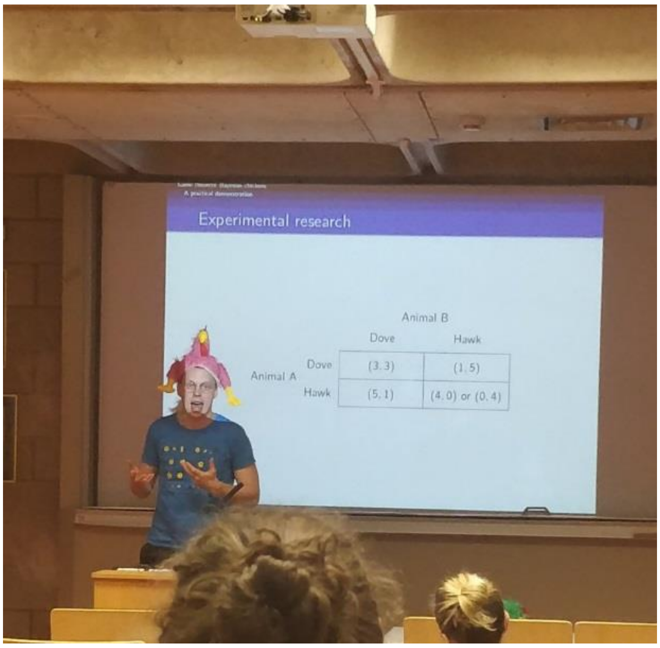
The timetable for the week is shown below.

Student Mathematical Modelling Workshop, June 5th-8th 2018, University of Limerick

	Tuesday, June 5th	Wednesday, June 6th	Thursday, June 7th	Friday, June 8th
09.00	**Registration** from 09.15	**Group work**	**Group work**	**Group work**
09.30	Main Building, C1063 (Charles Parsons)	C1059-62	C1059-62	C1059-62
10.00	**Introduction and Problem Presentations**, C1063 ***Introduction -***			
10.30	Professor James Gleeson, MACSI Director ***Problems -***			
11.00	Mark McGuinness, Victoria University of Wellington (with Vincent Cregan, University of Limerick)	**Tea/Coffee**, C1059-62 Foyer	**Tea/Coffee**, C1059-62 Foyer	**Tea/Coffee**, C1059-62 Foyer
11.30	Kevin Burke, University of Limerick Rosemary Dyson, University of Birmingham	**Group work** C1059-62	**Guest presentations**, C1063 Iain Moyles - MACSI Cameron Hall - MACSI Jimmy Hennessy - Director of Data Analytics, First Data Corporation	**Group work** C1059-62
12.00	William Lee, University of Huddersfield			
12.30	**Lunch** Eden Restaurant, Main Building, Block D, Level M			
13.00		**Lunch**	**Lunch**	**Lunch**
13.30		Eden Restaurant	Eden Restaurant	Eden Restaurant
14.00	**Group allocation**, C1059-62	**Group work**	**Group work**	**Group presentations**
14.30	**Group work**	C1059-62	C1059-62	C1063
15.00	C1059-62			
15.30	**Tea/Coffee**, C1059-62 Foyer	**Tea/Coffee**, C1059-62 Foyer	**Tea/Coffee**, C1059-62 Foyer	**Closing statement**
16.00	**Group work**	**Group work**	**Group work**	
16.30	C1059-62	C1059-62	C1059-62	
17.00				
17.30				
18.00				
20.00		**Networking Dinner**		
		Azur, George's Quay		

During the week a number of guest presentations were given by Drs. Iain Moyles and Cameron Hall (MACSI, University of Limerick), and Jimmy Hennessy (First Data). These talks were aimed to give the participants an insight firstly into some applied maths problems and approaches to solve them (Iain and Cameron) and also inform the participants about the skills that companies find desirable for those who hope to work in industry in the future (Jimmy).

Dr. Iain Moyles presenting work on the usefulness of scaling in applied maths problems



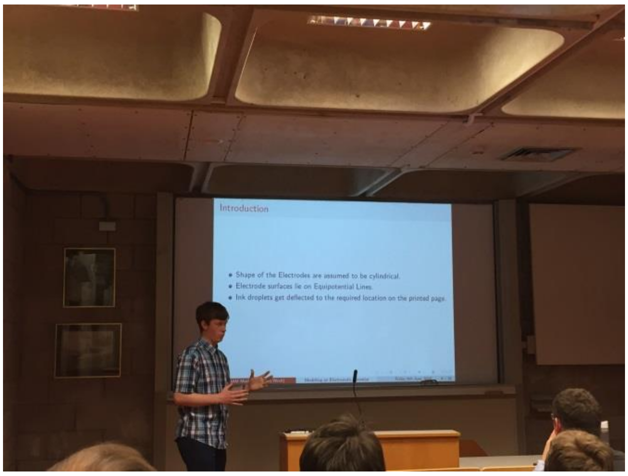
Dr. Cameron Hall talking about fighting chicken, game theory and Bayesian probability!

Problems

Title: Modelling an Electrostatic Potential.

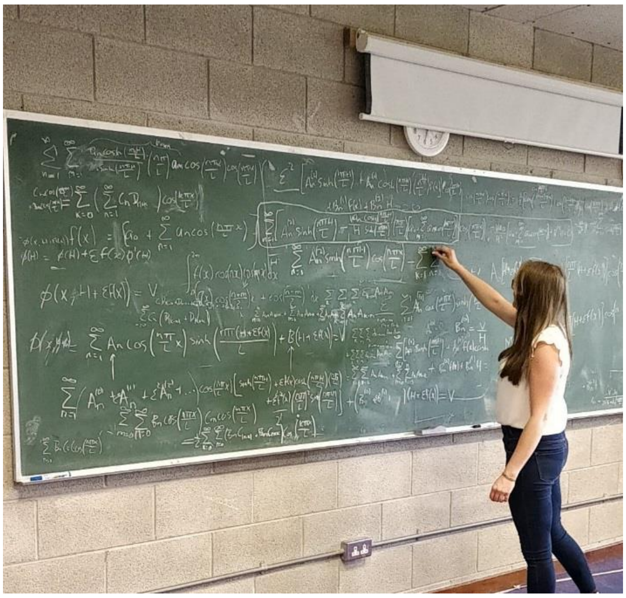
Tutor: Prof. William Lee, University of Huddersfield

Description: Company A is a precision engineering company specialising in electromechanical systems. The problem they are interested in is how does manufacturing defects on the surface of an electrode affect the electrostatic potential generated by a component. Participants will investigate the governing partial differential equation with suitable boundary conditions in an effort to gain some analytical insight into the fundamental behaviour of the component.



Thomas Keating explaining the groups approach to the problem

Prof. William Lee presenting the electrostatics problem.



Susan Fennell working out some chalkboard maths!

Aeration Optimisation for Hydroponics

From: Second Agri-Food Study Group with Industry, ICMS, Edinburgh
Original Problem Presenters: Adam Dixon, Luke Parkin (Phytoponics Ltd)
Grad Camp Presenter: Dr. Rosemary Dyson

Abstract (Technical Topics and Desired Outcomes): To optimise the design of aeration process for our Hydrosac growing module, such that oxygenation is maximised in the pool of water, and power requirements are minimised.

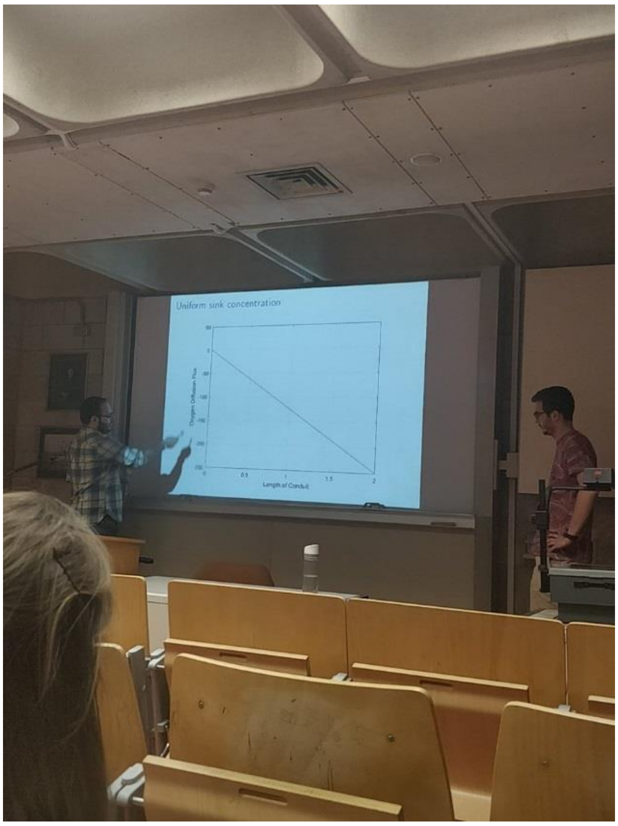
Objectives: Hydroponics involves growing plants in a water based nutrient solution for higher growth rates. However, in a water environment, a significant constraint is the dissolved oxygen level, as plant roots respire using this dissolved oxygen as their primary source in this environment. Having adequate dissolved oxygen levels is essential for healthy roots due to maintaining pathogen defence systems and nutrient uptake apparatus; therefore it is an item of design for a hydroponic growing system.

The Hydrosac is a hydroponic growing system module that holds a body of water to grow plants in, subject to a previous study with the Innovate UK mathematics group which concerned the form of the modules for plant support. At the base of the module is an integrated aerator, which consists of a perforated strip of material that receives external air input from an air compressor, and emits bubbles to the body of water such that oxygenation of the water occurs.

This air compression service requires power and is a significant power requirement for the system, therefore reducing the cost of oxygenation is highly desired to reduce overall operating costs or make available higher levels of oxygenation for the same cost. The level of oxygenation passed to the water will be based upon the temperature and constitution of the supplied air and body of water, but also the aerator strip pore diameter, size and spacing throughout the body, as smaller bubble size is linked to greater oxygen transfer.

Therefore, the scope of this project is to develop a mathematical model of the aeration system of the Hydrosac, including volumetric flow rate, input pressures, aerator strip material design parameters and costs therein, such that Phytoponics can use this model to improve the aeration of the Hydrosac design and select supporting ancillary air supply services or system parameters. The benefit to the project could be a major improvement in the performance of the Hydrosac growing modules and future produce developments thereafter, and is a critical element of our product design.

Dr. Rosemary Dyson introducing her problem



Some group members present their results from the weeks work

The group hard at work trying to solve their problem

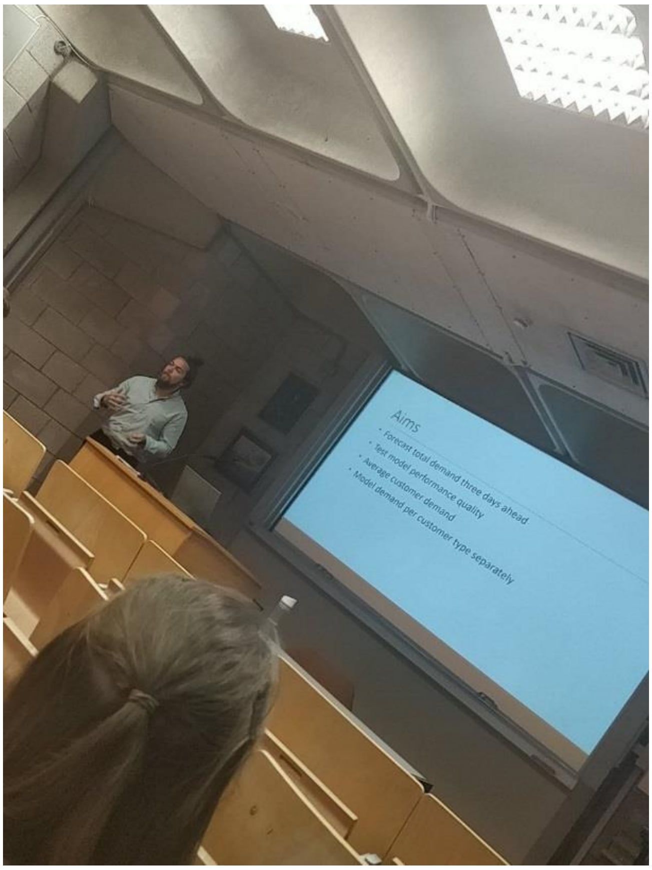
Energy Demand Forecasting – Vayu

Mentor: Dr. Kevin Burke

From May 2018, the Irish electricity market moved from SEM to I-SEM (Integrated Single Energy Market) in which energy can be traded with a wider European market. The aim of this change is to produce a more dynamic energy market in which energy can flow freely across the EU, with the aim of reducing costs to customers and increasing supply stability. A primary feature of I-SEM is that energy suppliers are now "balance responsible" – which means that they are legally obliged to supply as much electricity as is demanded. If a given supplier does not meet the balance at a given point in time, then they are required to buy energy from the market to meet their customers' demand. Similarly, if there is an oversupply of energy, this can be sold to another supplier within the EU market. Within this new I-SEM framework, it is important for a supplier to accurately forecast energy demand to reduce the risk of incurring balancing costs.

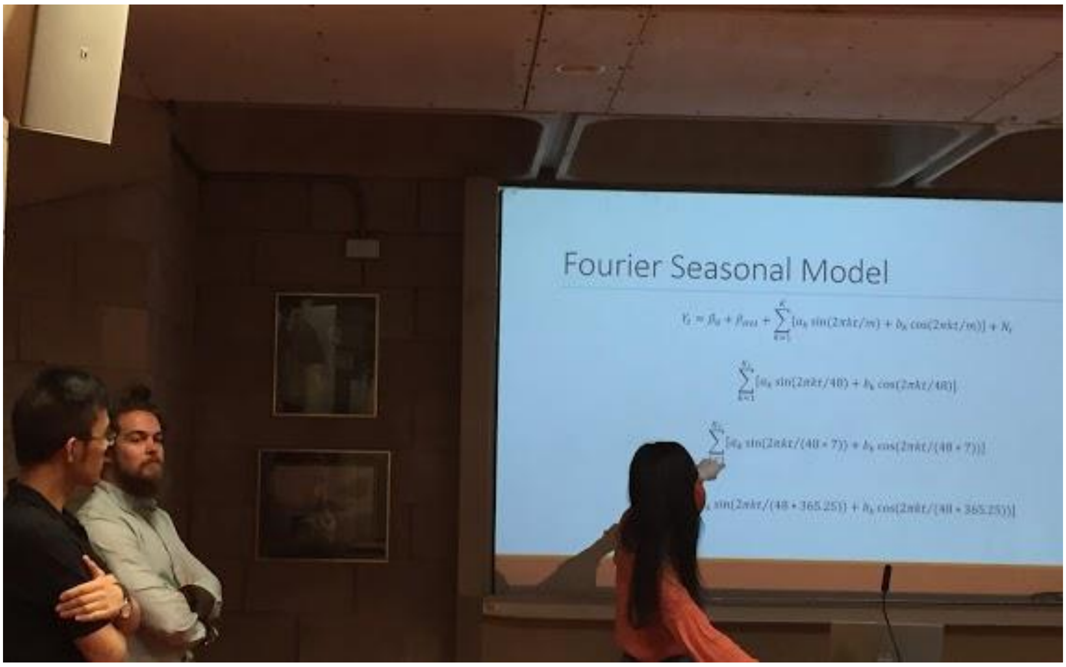
This project aims to build a model for forecasting energy demand which is an essential requirement within the new energy market. These forecasts must be made several days ahead of time and must also cover intraday patterns, i.e., the forecast must be "dynamic" over time (e.g., demand on a half-hourly basis) rather than simply producing a forecast for overall demand for a given day. Some challenges to overcome are modelling demand patterns within a day (day and night schedules), a week (weekday/weekend), or a year (summer/winter), as well as the effects of regular holiday periods such as Christmas, or moving holidays such as bank holidays. Further considerations are trends over longer time horizons (say, over multiple years), and any additional correlation between sequential demand measurements which, for example, cannot be captured by modelling various trends and seasonal patterns.

In order to build models described above, an energy supplier has provided energy consumption for a large number of customers over time. The individual customer demand curves can be aggregated to look at overall demand or average demand per customer. Such forecasting models are important as, ultimately, an energy supplier is interested in the total amount of energy they need to produce. However, models for individual customers separately or groups of customers are also of interest. These groups may be based on the customer features such as private or commercial customers, or could be constructed by clustering the demand curves themselves (i.e., grouping customers with similar demand profiles). Indeed it may be useful to identify customers which are easy to predict and those which have more variable demand profiles.



David Alexander Robinson describing some of the groups work

Dr.Kevin Burke introducing the Energy Forecasting problem



Fatima-Zahra Jaouimaa explaining a Fourier seasonal model approach

Calibration of a Moisture Analyser

Mentor: Dr. Vincent Cregan and Prof. Mark McGuinness

Rusal Aughinish Alumina Ltd. (RAAL), located on the Shannon Estuary, are producers of a white sandy type material called aluminium oxide (or alumina) which is a critical component in the production of aluminium. The Bayer process is used to extract the alumina from a reddish brown ore called bauxite.

Figure 1: Overview of RAAL plant

Figure 2: Moisture analyser on conveyor belt

One of the key concerns of RAAL is the precise moisture content of the bauxite before it is processed at the plant. To date RAAL have used the loss on drying technique to determine the moisture content. RAAL collect several bauxite samples per day from the conveyor belt that carries the bauxite from the ships to the refinery. These samples are taken to the laboratory where the moisture content is measured. Whilst, this method gives accurate measurements, the method is tedious and time-consuming.

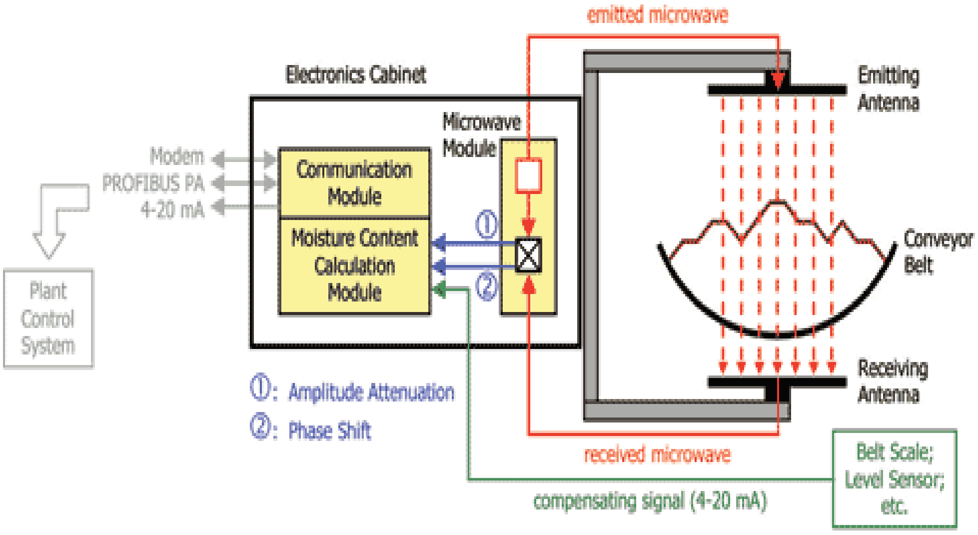


Figure 3: Moisture analyser schematic

To improve the frequency of the moisture content measuring process, RAAL recently installed a moisture analyser, which records measurements every second. The device uses microwaves to measure the moisture content. In theory, the online analyser should measure the moisture content of a ship in real time. However, at present there are discrepancies between the moisture content of the samples and the measurements from the analyser.

Key questions for the Workshop

- Is the analyser capable of measuring moisture accurately?
- If so, what is the optimal calibration?
- Additional questions:
  - What is the best way to use the data output by the analyser?
  - Is the measurement from the analyser bauxite-dependent? RAAL currently import four different types of bauxite. Will the analyser need to be reconfigured for a particular type of bauxite?

Data: RAAL have 1 second interval data from the analyser for a few months. The data includes measurements for:

- Attenuation
- Phase shift 1
- Phase shift 2
- Depth of bauxite
- Bauxite tonnage

They also have corresponding moisture data as measured in the lab with 3 to 4 (approximately) daily measurements.

Background reading

- F. Gao – On-line measurement of moisture content of iron ore slurries
- M.S. McKeown et al. – Microwave sensing of moisture in flowing biomass
- S.A.A. Viana – Microwave-based moisture measurement of bauxite ore on conveyor belts
- P. Lorrain and D. Corson – Electromagnetic Fields and Waves

Confidentiality

The analyser vendor has given us full access to the data but it should not be shared outside the workshop. The conclusions can be shared.

James Fannon outlining the problem and their approach to solving it

Some of the workings from the week

The participants and mentors from the week

More details about the workshop can be found on our chapter website (https://sites.google.com/view/ulssc/home).

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