Warwick Centre for Complexity Science
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The Dynamics of Complex Systems: A meeting in honour of the 60th birthday of Robert MacKay FRS

by Colm Connaughton, Director Centre for Complexity Science, and Ellen Webborn, 4th year PhD student

For younger staff and students at Warwick Prof. Robert MacKay, FRS has been a constant driving force behind the development of applied mathematics and complexity science at the university. He co-founded the Warwick Complexity Complex in the early 2000's which subsequently evolved into the Centre for Complexity Science in 2007. During his tenure as the director of the centre and its associated Centres for Doctoral Training in Complexity Science and Mathematics of Real World Systems, Robert's inexhaustible energy and formidable intellectual leadership has facilitated the growth of the thriving academic community which we see in the Centre for Complexity Science today.

In June, Warwick Mathematics Institute hosted a 3-day meeting in honour of Prof. MacKay's 60th birthday. Current and former scientific collaborators, Ph.D. students, post-docs and friends, many of them leading international researchers in their own right, visited Warwick from all over the world for this meeting. They discussed scientific progress under the umbrella theme ``Dynamics of Complex Systems'', enjoyed sharing their memories of time spent with Robert in the past and ventured their guesses as to what the future may hold.

The scientific scope of the meeting was eclectic. It reflected Robert's broad intellectual curiosity and innate ability to see the underlying mathematical structures in a broad range of phenomena, regardless of academic discipline. Around sixty talks and posters were presented on a wide variety of topics, ranging from the underlying theory of nonlinear dynamical systems to the mathematical foundations of complexity science. A diverse range of applications were discussed including black holes, social networks in ancient myths, and the science of sleep. Robert himself surprised everyone by presenting recent work he has been doing on a novel approach to the Riemann Hypothesis.

Robert has been on sabbatical for the past year but we look forward to welcoming him back in October. While he has passed on his roles as director of the Centre for Complexity Science and director of the MathSys CDT to younger staff, he will remain actively involved in the intellectual life of both through his membership of our steering committees. Having spent a few days in June reflecting on Robert's scientific contributions over the past 30 years, we now look forward to his future contributions. We wish him well.

We also have an impact outside academia!

Written by: Peter De Ford, MSc student

Our department is developing projects that are changing the world.
Here we present a few of them!

Transportation

Ayman Boustati, Álvaro Cabrejas, Peter De Ford, Laura Guzmán, Guillem Mosquera, Colm Connaughton and Stephen Hilditch (Thales UK)
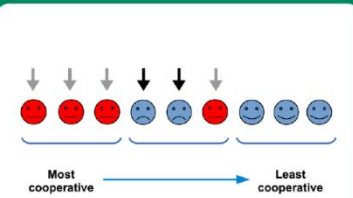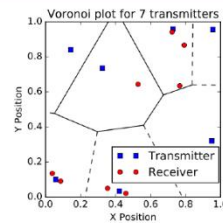
In partnership with Thales UK, we designed algorithms to predict traffic jam duration in England's motorways.

Wireless communication

Sami Al-Izzi, Robert Gowers, Roger Hill, Tim Pollington, Samuel Johnson and Keith Briggs (BT)

We used convex optimisation techniques to solve a BT wireless communication problem.

Medical electronics

Jim Skinner, Richard Savage (WSB), James Covington (School of Engineering)

Using a machine called the Electronic Nose, along with statistical and machine learning techniques, we have correctly diagnosed UHCW hospital patients using urine smell alone.

Cancer

Simon Graham, Maxim Smilovitskiy, Luke Whincop and David Rand (WSB)

We worked with the IARC* in developing a cellular automaton model to optimize immunotherapy treatment in cancer.

International Agency for the Research on Cancer.

Climate change

Samuel Johnson

We proposed a game theory approach to promote cooperation among nations against climate change.
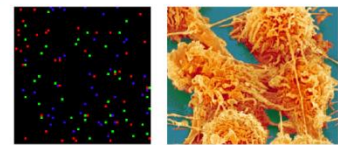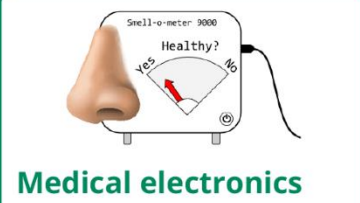
Crowds

Federico Botta, Suzy Moat (Data Science Lab) and Tobias Preis (Data Science Lab)

We created a method for quantifying crowd size with mobile phone and Twitter data. Our project was featured by BBC World News and Science.

Infectious diseases

Christopher Davis, Emma Davis, Cameron Lack, Sophie Meakin, Matt Keeling (WIDER) and Ian Hall (PHE)

In collaboration with Public Health England, we created a multiscale model of intracellular bacterial infections. It will be used for predicting the dynamics of infections with strong dose-dependent responses.

Electrical grid
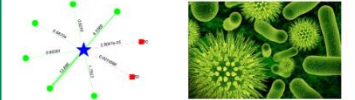
Ellen Webborn, Robert MacKay, Michael Waterson (School of Economics)

We are modeling how domestic appliances like fridge-freezers could be used to provide stability to the electricity grid.

ESGI 116 – working on real-world problems

The European Study Group with Industry is a five-day long workshop where mathematicians and industry professionals work together to solve some of the important issues that companies are facing nowadays. A large group of PhD students and academics from the Complexity Centre and the MathSys CDT took part in the 116th ESGI which was held at the University of Durham in April.

During the first day, the industrial partners presented the problems and we had to decide which one to work on for the rest of the week. We were impressed by the variety of problems ranging from finding better ways to plan field trials to improving the accuracy of pre-symptomatic diagnosis of sepsis. Over the next three days we worked with the industrialists towards practical solutions, and presented our progress on the problems on the final day.

It was a great experience to be part of this study group, where we got a glimpse of the broad range of mathematical problems that can have a real impact on industry and society. We had the amazing opportunity to meet and work with academics and PhD students from all over the world, and found that getting out of the comfort zone of your PhD can be fun and motivating.

We look forward to hosting ESGI at the University of Warwick next year!

The Centre's Annual Retreat

by Neil Jenkins, 3rd year PhD student

This year the Centre went to Ironbridge for its annual retreat. The format of the scientific content was changed significantly - instead of the traditional 15 minutes talks by the PhD students, there were 3 minute 'lightning' talks. This new talk format required students to communicate their wide variety of research topics clearly and concisely and the group rose to the challenge brilliantly.

Also new to this year's retreat were the Warwick Annual Retreat Projects (WARPs) which saw the students break out into small groups to work on projects which had been suggested beforehand. These were a great chance for the students to work together on topics possibly outside their usual research and may potentially turn into longer lived collaborations.

3MT final

by Elizabeth Buckingham – Jeffery, 3rd year PhD student

A large group of students from the centre entered the University of Warwick's Three Minute Thesis competition this year. Myself, Federico Botta (on the photo), Jonathan Skipp and Diana Khoromskaia, all third year PhD students, were amazingly chosen to be part of the group of 11 students from across the University to be in the final of this competition! This took place on the 9th of June, as part of the University's Research Showcase. The afternoon of the final was very enjoyable. I think all our hard work paid off, and the standard of talks was exceptionally high.

Unfortunately, none of the Complexity finalists were chosen as the winner, but it was still a great achievement to be in the final. Our congratulations go to Melissa Colloff of the Psychology Department who was chosen as the winner!

Recent publications from our staff and students:

- **Machon T, Alexander GP.** Umbilic Lines in Orienational Order, Physical Review X 6, 011033, (2016)
- **Klaise J, Johnson S.** From neurons to epidemics: How trophic coherence affects spreading processes, Chaos 26, 065310, (2016)
- Dominguez – Garcia V, **Johnson S,** Munoz MA. Intervality and Coherence in complex networks, Chaos 26, 065308, (2016)
- **Timofeeva Y,** Lu Y. Response functions for electronically coupled neural network: a method for local point matching and its applications, Biological Cybernetics, 1-77 (2016)
- Brand SPC, Rock KS, **Keeling MJ.** The Interaction between vector life history and short vector life in vector-borne disease transmission and control, PLoS Computational Biology 12(4), e1004837 (2016)
- Irvine MA, Jackson EL, Kenyon EJ, Cook KJ, **Keeling MJ,** Bull JC. Fractal measures of spatial pattern as a heuristic for return rate in vegetative systems, Royal Society Open Science 2(2), 150519 (2016)

Faculty of Science PhD Prizes

Congratulations to **Tom Machon** and **Davide Michieletto** who have been awarded the 2016 Faculty of Science PhD Thesis Prizes for their research on *Aspects of Geometry and Topology in Liquid Crystalline Phases*, and *Topological Interactions in Ring Polymers*, respectively. Tom is now a postdoc at University of Pennsylvania and Davide is a postdoc at University of Edinburgh. We wish them all the best in their careers!

Optimising wireless communications using Python

by Tim Pollington, MSc student

Our research study group worked with Keith Briggs from BT, to solve wireless communication problems using convex optimisation. Our team consisted of Robert Gowers, Sami Al-Izzi, Roger Hill and Tim Pollington; we affectionately called ourselves "RSTaR" in e-mails with Keith and Sam Johnson.

The field of convex optimisation was initially daunting and we relied on Boyd and Vandenberghe's book and watched their excellent YouTube lectures. Keith helpfully gave us some study problems to start on; our task was to implement them using cvxpy – a recent Python package built on a symbolic programming language that chooses the appropriate interior-point method. Our approach was to show the problem was convex (usually easy) and then formulate it into a format that cvxpy could understand (much harder). The strength of convex optimisation is that if (i) the objective function and its constraint functions are convex and (ii) it can be formulated in a standard format that cvxpy can understand, then the solution is globally optimal.

Our research found many optimisation benefits in wireless and digital subscriber line systems, which were substantial compared to the unoptimised setting, with either significant reductions to the transmit power or signal quality improvements.

At the end we drove to BT's research and innovation HQ in Suffolk, where we presented our findings to their experts. Their feedback was really positive and gave us an indication of its applicability. To top it off, our code examples were accepted by cvxpy.org to inspire the community in future problems.