Warwick Centre for Complexity Science

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MathSys Research Study Groups

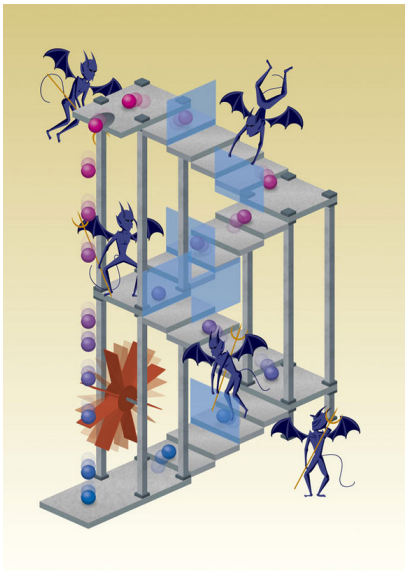
By Colm Connaughton, Director Centre for Complexity Science

The past academic year has seen significant changes to the graduate training programme in the Centre for Complexity Science with the launch of the new Mathematics of Real World Systems (MathSys) Centre for Doctoral Training. The introduction of Research Study Groups (RSGs) is one of several exciting innovations. The RSGs see MSc students work together in small teams under the supervision of a member of staff to solve research problems posed by MathSys' external partners. We hope that students will be able to further develop their team working, communication and presentation skills by working together to understand the language and motivations of our external partners. These will be among the key requirements for success in their future careers. The RSGs also give students an opportunity to translate their newly-acquired mathematical skills from the safety of the classroom to the uncharted waters of real-world research.

Four problems were proposed by our external partners: optimisation of vehicle electronics architectures (Jaguar Land Rover), mining of multi-omic cancer data to improve treatment of bladder cancer (University Hospitals Birmingham), assessing the impact of Total Loss Absorbency Capacity on systemic risk in the banking system (Sciteb) and attempting to estimate the critical community size for foot and mouth disease (the Pirbright Institute). Worries about the new style of projects quickly evaporated with the levels of energy, determination and ambition which the students showed on their chosen problems. Undeterred by the inevitable code bugs, data problems and language ambiguities at the interface of different disciplines, the students were single-minded in the pursuit of their respective research goals. **Esther Wershof**, an MSc student who worked with University Hospital Birmingham, said: "It's fair to say I had some doubts about working in a group. Having been a maths undergraduate, where almost all the work was done individually, the thought of relying on other people for such a big chunk of the year was a bit daunting. But actually it turned into a collaboration - we all had different strengths and the chances were that if one of us was stuck, someone else would know how to proceed. We were able to bounce ideas off each other and find areas that were interesting to all of us. The group project really exceeded my expectations." **Joe Hilton**, an MSc student who worked with the Pirbright Institute, said: "As part of the group co-supervised by Simon Gubbins of the Pirbright Institute, I have spent the past three months developing models for foot-and-mouth disease. I found that the concrete real-world motivation for our work was useful in providing direction and inspiring choices in our modelling. The research projects I had worked on as an undergraduate were in a similar area but were of a slightly more abstract nature, and so I learnt a great deal by spending time studying data and relating it to our results. I also gained valuable experience of scientific collaboration, both by pursuing the project as part of a group, and by working with two supervisors who were able to offer complementary perspectives on our project."

Information Thermodynamics

By Michael Maitland, 3rd year PhD student



In 1867 James Clerk Maxwell proposed a famous thought experiment challenging the validity of the 2nd law of thermodynamics. The experiment featured a sentient agent - called a `daemon' and described as a 'neat-fingered being' - able to manipulate a thermal system based on observation of thermodynamic fluctuations.

Through a procedure detailed by Maxwell, this being is capable of exploiting the thermal fluctuations to decrease the entropy of the system without doing any work on it: in essence extracting work from the environment at no cost, violating the 2nd law.

In the past century, much debate has surrounded the rationalisation of this result; from Szilard in 1929, proposing that the daemon's own measurements must produce entropy; to Landauer in 1961, highlighting that it is not the measurement but the deleting of information that creates entropy. Many thinkers have realised the importance of information in the understanding of this perceived violation of the 2nd law.

Information and Entropy are intricately linked, and by exploring their interrelationship, a more complete understanding of the 2nd law is possible.

Due to recent technological developments, it is now possible to experimentally probe the relevant time and length scales on which thermal fluctuations occur. In the pursuit of faster and smaller devices, the understanding of these thermal fluctuations has become paramount, and the possibility of exploiting those thermal fluctuations in the operation of our own devices is an exciting prospect for scientists and engineers.

The construction of real-life technological 'daemons' depends on understanding the impact of information processing on thermodynamic entropy.

By incorporating information into the thermodynamic framework, the 2nd law can be generalised for cases where feedback is employed to affect the production of entropy in a system. This framework describes the thermodynamic impact of information processing and information exchange between coupled systems (e.g. a thermal system and a 'daemon' or an 'information reservoir'). This allows the formulation of novel new thermal models such as the 'information heat engine' and 'information refrigerator' which have been shown to be more efficient than their ordinary thermal or chemical counterparts.

In our interdisciplinary research efforts, we consider models of these systems and attempt to gain insights into the interactions between coupled systems in terms of their information flow.

By incorporating ideas from a wide range of fields including large deviation theory; nonequilibrium statistical physics; control theory and information theory, we wish to formulate a physical picture of information flow and develop ideas within the information thermodynamic framework.

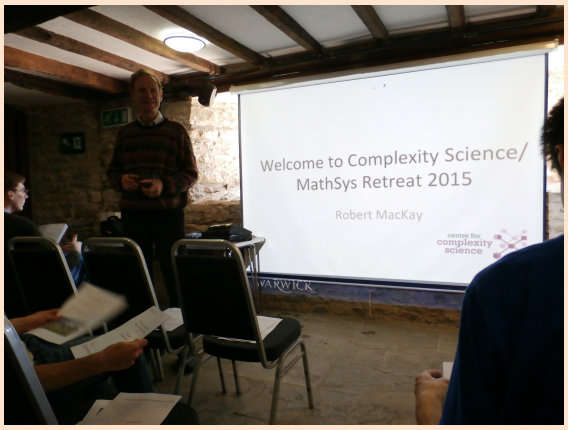
New director and welcome to the new students

In September 2015, Robert MacKay is passing Directorship of the Centre for Complexity Science to Colm Connaughton. He wishes the Centre continuing success under Colm's leadership. The MathSys CDT, which is a collaboration between the Centre for Complexity Science, Warwick Systems Biology Centre and Warwick Infectious Disease Epidemiology Research will be directed by Matt Keeling for the academic year 2015/6 while Robert MacKay is on study leave.

The second MathSys intake of students will start in September 2015. For the first time, this will see a Chevening scholar from Costa Rica and a government-sponsored student from Thailand. The Centre looks forward to welcoming them and the rest of the cohort!

Complexity Annual Retreat

By Neil Jenkins, 2nd year PhD student



This year the Centre went to the Shropshire hills for its annual retreat. This once again provided a great opportunity for the various members of our community both to speak about their own work, and to learn more about the work being done by others within the Centre. This year marked the first retreat since the start of the MathSys CDT. The MSc students from the new CDT presented posters about their group projects with MathSys' External Partners which led to many interesting discussions and highlighted the diversity in the projects that the new links with the external partners are producing. In addition to the scientific content, the retreat was also enjoyed for the opportunity it provides for the members of the Centre to socialise. In particular, as in previous years, a group walk was arranged on one of the afternoons. Many people joined for the walk and although it was possibly longer than some had expected, the good weather and picturesque scenery ensured that spirits remained high.

Recent publications from our staff and students:

- **Botta F**, Moat HS, Preis T. Quantifying crowd size with mobile phone and *Twitter* data, Royal Society Open Science 2, 150162 (2015)
- **Papavassiliou D**, **Alexander GP**. The many-body reciprocal theorem and swimmer hydrodynamics, Europhysics Letters 110, 44001 (2015)
- **Hill EM**, Griffiths Fe, House T. Spreading of healthy mood in adolescent social networks, Proceeding Royal Society B, 282, 20151180 (2015)
- **Pellis L,** House T, **Keeling MJ**. Exact and approximate moment closures for non-Markovian network epidemics, Journal of Theoretical Biology 382, 160-177 (2015)
- **Dawson PM**, Werkman M, Brooks-Pollock E, Tildesley MJ. Epidemic predictions in an imperfect world: modelling disease spread with partial data, Proceedings of the Royal Society B 282, 1808 (2015)
- **Chleboun P, Grosskinsky S**. A dynamical transition and metastability in a size-dependent zero-range process, Journal of Physics A: Mathematical and Theoretical 48, 055001 (2015)
- Trevino S, Nyberg A, **Del Genio CI**, Bassler KE. Fast and accurate determination of modularity and its effect size, Journal of Statistical Mechanics – Theory and Experiment P02003 (2015)

Ian Macmillan Ward Prize

Congratulations to Davide Michieletto! The Polymer Physics Group of the Institute of Physics has decided to award the Ian Macmillan Ward Prize to 3rd year PhD student Davide Michieletto. The prize "recognises the most outstanding publication by a PhD student on a subject within Polymer Physics Group's remit". The committee was impressed by the quality of Davide's publications and, as part of the award, Davide will be giving a Prize lecture at the Polymer Physics Group. Congratulations to him from the Centre!

Postgraduate Research Showcase

Congratulations to Elizabeth Buckingham-Jeffery! Each year the University of Warwick organises an annual Postgraduate Research Showcase to recognise the excellence of Warwick's postgraduate research and to allow postgraduate researchers to engage with the University community. The Showcase event includes a Research Poster Competition and 2nd year PhD student Elizabeth, with her poster "Syndromic Surveillance" in collaboration with Public Health England, was one of the runners up in this competition! Congratulations to her from the Centre!

Summer Graduation

Congratulations to Marcus Ong, Michael Irvine, Jonathan Mascie-Taylor, Anthony Woolcock, Matthew Graham and Rebecca Cotton-Barratt for graduating in this summer's graduation ceremonies! The Centre organised reception drinks to celebrate all the graduates and wish them luck in their future careers!

Events coming soon:

Some upcoming Warwick events that may be of interest:

- 07th-09th September 2015, Centre for Research in Statistical Methodology, Non-likelihood based statistical modelling
- 14th-16th September 2015, Centre for Research in Statistical Methodology, Models and Inference in Population Genetics
- 21st-25th September 2015, Warwick Mathematics Institute, Fluctuation driven phenomena in non-equilibrium statistical mechanics
- 6th October 2015, Department of Computer Science, The Smart City Built by Citizens
- 9th December 2015, MathSys Open Day
- 14th-17th December 2015, Warwick Mathematics Institute, Numerical methods for large deviations and efficient sampling of rare events

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