Report on UCNC 2016
the 15th International Conference on Unconventional Computation and Natural Computation

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The 15th International Conference on Unconventional Computation and Natural Computation (UC 2016) took place at the Manchester Metropolitan University, UK, 11–15 July 2016. Manchester is birthplace of the industrial revolution, home to Alan Turing and the first ever stored-program computer, and the driving force behind graphene. The conference was organised by the interdisciplinary Informatics Research Centre, and was held at the University's Business School. The conference received support from Manchester Metropolitan University, and Springer.

As always, the fully international complement of authors (submitted and accepted papers), and delegates came from across the globe, this year from: Austria, Brazil, Canada, China, France, Germany, India, Japan, Republic of Korea, Kuwait, Lebanon, Mexico, Republic of Moldova, Norway, Paraguay, Poland, Singapore, UK, and USA (figure 1).

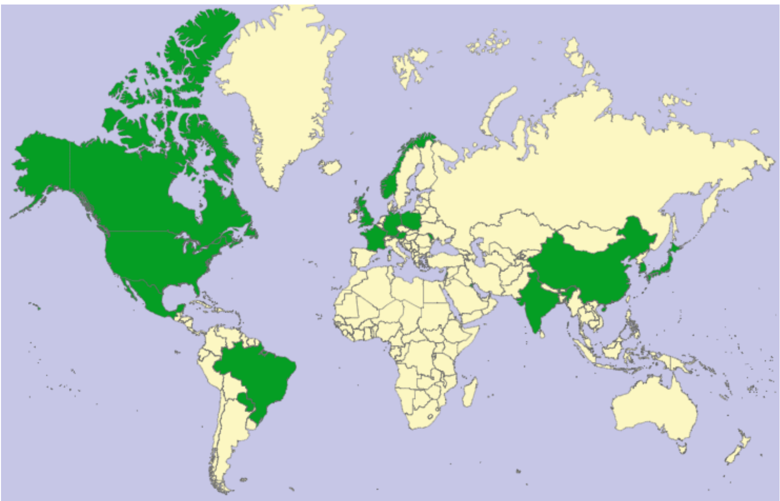

Figure 1: International participation in UCNC2016. (Map produced using www.amcharts.com/visited_countries/)

The three invited keynote speakers and their talks were

- Friedrich Simmel (Professor of Experimental Physics, Technische Universität München, Germany) "Chemical Communication Between Cell-Sized Reaction Compartments".

This was a fascinating account about a series of experiments sending signals between cells, droplets, and "genelets" (droplets containing cellular "naked" genetic machinery), based on the ideas of quorum sensing: when a high enough chemical signal concentrations is produced, because there are enough producers around, it invokes a response. We saw droplets signalling the chemicals, inducing bacteria to react, and that signal propagating through multiple droplets. There is a "bacterial Turing test": can you make a droplet that a bacterium will interact with (through chemical signals) just as if it were another bacterium? These systems pass it. Through a clever use of microfluidics, we saw videos of sheets of bacteria interacting, via fluorescent protein production. The fluorescence increases both due to the being switched on by the signalling, and due to the bacteria reproducing, two process with similar timescales. The possibilities of this approach include forming spatial and temporal patterns through reaction-diffusion systems of interacting genetically programmed droplets. Simmel then finished his talk with a description of using electron lithography to etch chips, deposit gene-length strands of DNA in a controlled manner, which could then be manipulated to stick together (condense) into linear bundles. It's early days yet; next on the agenda is using gene expression to control the condensation.

- Bob Coecke (Professor of Quantum Foundations, Logics and Structures, Department of Computer Science, University of Oxford, UK) "In Pictures: From Quantum Foundations to Natural Language Processing".

Coecke introduced us to a beautiful, formal, diagrammatic notation for quantum systems, and how the power of this notation makes many complicated quantum puzzles and proofs essentially vanish. There will soon be a book, *Picturing Quantum Processes*, from Cambridge University Press, covering this. It is 922 pages long, because pictures take a lot of space. After all this the quantum mechanics, Coecke went off in an unexpected direction, by showing how the very same notation could be used to calculate the meaning of sentences from their underlying grammar and the meaning of the individual words. Some modern meaning systems use high dimensional vectors to encapsulate word meanings. Adding the grammar via the diagrams improves the calculated meaning enormously. Then thinking about the mathematical structures needed leads to the suggestion of using density matrices rather than vectors, to cope with ambiguous meanings. This is a nice example of a deep piece of work in one domain that is not only applicable in a seemingly unrelated domain, but that suggests advances there, too.

- Steve Furber (ICL Professor of Computer Engineering, School of Computer Science, University of Manchester, UK) "The SpiNNaker Project".

After some interesting historical context, Furber told us of the SpiNNaker machine: one million processors in an asynchronous spiking architecture (SpiNNaker stands for "Spiking Neural Network Architecture"). The preliminary machine, with 500,000 cores, was launched 30 March 2016, and more cores have been added since. It can be programmed in the Python PyNN language. For example, 165 lines of Python are needed for a Sudoku solver, where the neuronal groups inhibit other groups with the same integer value in the the same row, column, or 3×3 cell. Once a solution has been found, the inhibitory links decrease, and the spiking rate goes up, solving a "diabolical" puzzle in about 10 seconds. This isn't just a toy: it is representative of complex constraint problems. So far people have only been running small programs, as they think how to scale up their ideas. Although each core is a standard processor, exploiting the asynchronous spiking communication requires a different way of thinking.

There were also three invited tutorials:

- "Many Hands Make Light Work: A Case Study in Swarm Robotics", by Jon Timmis (Professor of Intelligent and Adaptive Systems, Department of Electronics, University of York, UK), on XXX.

This subject has multiple simple automomous robots working together with no global control, to produce an emergent behaviour and capability that none has individually. The tutorial covered the history of the subject, showing how some of the original constraints have become irrelevant: today's "simple" robots are actually quite sophisticated compared to those at the discipline's inception; and the original "nature inspiration" is no longer so prominent: use it if it helps, ignore it if it doesn't. There are a couple of issues that make the subject difficult. The first is, how to design the local, individual robot rules that produce the desired emergent behaviour (and doesn't produce undesired behaviours also)? This often reduces to an iterative design: suggest, test, refine, which can be automated in a search algorithm, such as an evolutionary search. This leads to the second issue: this search is most efficiently done in simulation, but there is a "reality gap" in simulation: the simulated physics is often too simplistic, leading to "overfitting" to the simulation and the solution then not working on the embodied physical robots. There are lots of fascinating results addressing these issues: the next challenge is moving this research out of the lab into the real world.

- "Gellular Automata", Masami Hagiya (Professor, Department of Computer Science, University of Tokyo, Japan).

Gellular Automata are a form of cellular automata implemented using gels and chemical reactions. The walls between cells can be "decomposed" or "composed" using chemical reactions, or instead can "swell" or "unswell", forming a valve. This allows chemicals to move between cells. There are theoretical results demonstrating these systems can in principle implement certain kinds of CAs. The tutorial moved on to talking about implementations. Most of the manipulations involve a form of DNA chemical computing: using complementary strands to form networks of polymers, or to control diffusion by attaching anchors. These processes can be controlled by the DNA technique of "strand displacement" that breaks the bonds between the complementary strands. There are some initial prototype implementations. These are still rather complicated, needing multiple chemical species to implement relatively simple state transitions. However, it is early days yet, and more efficient approaches may well be discovered.

- "Self-Assembling Adaptive Structures with DNA", Rebecca Schulman (Assistant Professor of Chemical and Biomolecular Engineering and Computer Science, Johns Hopkins University, USA).

Schulman's philosophy is, rather than trying to assemble arbitrary structures, let's just look at what can be done with 1D systems: filaments of DNA nanotubes than can controllably be built into strings, trees, and network structures. She pointed out that it doesn't make sense to build every structure from weaving pure DNA: a human-size object would need about 3 light years of it. But smaller things can sensibly be built this way. This approach doesn't include only static structures: movement can be achieved by growing at the front and dissolving at the back. This is the way the cytoskeleton in cells works to move them around. DNA nanotube growth can be controlled by a variety of chemical processes, but it's hard to design different systems: there's no good enough model or simulation of how it all works. Currently things are a mixture of approximate yet expensive simulations, and lab experiments. But this is clearly a very powerful and rich area.

The full conference comprised these keynotes and tutorials, together with the scientific programme of technical presentations of the published papers, and a poster session.

Proceedings of UCNC 2016 are published in the Springer series as LNCS volume 9726 (ISBN 978-3-319-41312-9). The volume contains abstracts from the six keynote speakers and tutorial presenters, and 15 refereed contributed papers.

There were also two workshops on related unconventional topics run in association with the main technical conference:

- Workshop on Membrane Computing (WMC 2016)
- The 7th International Workshop on Physics and Computation; electronic proceedings available at arxiv.org/html/1606.06513v1

There were some particular highlights of the conference for me, in addition to the excellent keynotes and tutorials. Ella Gale talked on "Analysis of Boolean Logic Gates Logical Complexity for use with Spiking Memristor Gates", demonstrating that analysing the gates natural to memristor systems leads to a ternary logic formulation. Raul Rojas talked on "Babbage meets Zuse: a Minimal Mechanical Computer", starting with a description of Zuse's mechanical computer, and gradually paring down the system to produce a universal computer comprising three cog wheels and one gate. Gilles Dowek, an invited speaker at the Physics and Computation workshop, formalised a simple concept across Newtonian mechanics, Special Relativity, and General Relativity, in a cellular automaton. On the way he introduced a particular set of units familiar to astrophysicists, setting $c = G = 1$; in these units Planck's constant has dimensions of area, with a value closely related to the area of one bit in the Bekenstein bound.

These examples just help illustrate the broad interdisciplinary diversity of material covered by Unconventional Computation and Natural Computation. Further information can be found at the conference website: www.ucnc2016.org

Many thanks for another very well organised event go to: Martyn Amos and Anne Condon (Co-chairs), James Charnock, Matthew Crossley, René Doursat, and Emma Norling (organising committee).

Next year's UCNC moves west: 5–9 June 2017 in Fayetteville, Arkansas, USA. UCNC 2018 will be in Fontainebleu, France.