Impact case study (REF3b)

Institution: University of Southampton

Unit of Assessment: 11 Computer Science and Informatics

Title of case study: 11-02 Intelligent Energy Management

1. Summary of the impact

Research at the University of Southampton, into the engineering of complex socio-technical systems, has underpinned new technologies in the area of intelligent energy management, and made Professors Nick Jennings and Alex Rogers trusted sources of advice for energy policymakers, key stakeholders and industrial researchers. The work has had an economic, environmental and societal impact: it has shaped R&D strategies of leading British companies like BAE Systems and Secure Meters; the launch of iPhone apps and websites have supplied private and industrial users with personalised data regarding their energy use, resulting in cost savings and reductions in carbon emissions; it has enabled charities to provide energy-saving advice to households directly; and has won an international technology showcase competition leading to a spinout and commercialisation of research.

2. Underpinning research

Department of Energy and Climate Change findings showed UK emissions of greenhouse gases covered by the Kyoto Protocol rose by 3.5 % between 2011 and 2012 - primarily resulting from greater use of coal for electricity generation at power stations and an increase in residential gas use. Research conducted within the 'energy' domain of the University of Southampton's Agents, Interaction and Complexity Group (AICG) has focused on the development of key tools for energy management that will allow users to defer use of electricity to off-peak times, to use energy more effectively and to reduce their carbon footprint. The programme was led by Professors Nick Jennings, Professor of Computer Science (since 1999), and Alex Rogers, Professor of Computer Science (since 2013, Lecturer since 2006).

The starting point for this research was the development of key technologies as part of two projects led by Jennings in conjunction with the University of Oxford: ARGUS II (2003-2008, A) and ALADDIN (2005-2011, B). This work was concerned with the development of software agents that act on the behalf of humans with minimal intervention. Researchers addressed fundamental questions regarding the engineering of systems composed of multiple autonomous agents and how individual agents should make effective decisions in the face of uncertain and dynamic environments. Key findings included the development of software that uses local message-passing algorithms to allow agents to communicate with each other, to solve complex problems involving uncertainty **[3.1]** and the use of Gaussian processes to extend the use of independent agents, and uncertainty-based reasoning and prediction, into areas where resources are limited and continually shifting **[3.2]**.

Three further interconnected AICG projects have focussed on the specific requirements of 'intelligent energy management': 'Intelligent Decentralised Energy-Aware Systems' (iDEaS) project (2009-ongoing, C), 'Intelligent Agents for Home Energy' (IAHEM) (2010-2013, D) and ORCHID (2011-ongoing, E), in which researchers built and applied agent approaches to real-world applications in the critical domains of the smart grid and citizen science in conjunction with the Universities of Oxford and Nottingham.

Through the development of novel machine-learning algorithms, using Gaussian processes to estimate and predict energy use, both in the form of electricity-demand within the grid and the thermal characteristics of building and homes, researchers designed a tool through which heating and electrical loads can be optimised and deferred. This allows users to reduce energy and carbon emissions without impacting on comfort **[3.3, 3.6]**. Researchers also developed novel optimisation routines that allow users to make optimal use of energy storage devices, by enabling cheap and low-carbon electricity to be stored and loads to be deferred, resulting in minimised carbon emissions **[3.4]**. Researchers' application of techniques from game theory and mechanism design resulted in the development of a range of novel online auction mechanisms that can automatically allocate and price electric vehicle charging. This ensures that individual users get the best deal possible while satisfying the constraints of the distribution network **[3.5]**.

3. References to the research (best three are starred)

3.1 *A. Rogers, A. Farinelli, R. Stranders and N. R. Jennings (2011) "**Bounded approximate decentralised coordination via the max-sum algorithm**" *Artificial Intelligence* **175** (2) 730-759.

3.2 M. A. Osborne, S. J. Roberts, A. Rogers and N. R. Jennings (2012) "**Real-time information processing of environmental sensor network data using Bayesian Gaussian processes**" *ACM Trans on Sensor Networks* **9** (1).

3.3 S. Ramchurn, P. Vytelingum, A. Rogers and N. R. Jennings (2011) **Agent-based homeostatic control for green energy in the smart grid.** ACM Transactions on Intelligent Systems and Technology, 2 (4).

3.4 *P. Vytelingum, T. Voice, S. Ramchurn, A. Rogers and N. R. Jennings (2011) **Theoretical and Practical Foundations of Agent-Based Micro-Storage in the Smart Grid.** Journal of Artificial Intelligence Research, 42, 765-813.

3.5 *V. Robu, E. H. Gerding, S. Stein, D. C. Parkes, A. Rogers and N. R. Jennings (2013) **An Online Mechanism for Multi-Unit Demand and its Application to Plug-in Hybrid Electric Vehicle Charging.** *Journal of Artificial Intelligence Research* (In Press).

3.6 Ramchurn, S., Vytelingum, P., Rogers, A. and Jennings, N. (2011) **Putting the "Smarts" into the Smart Grid: A Grand Challenge for Artificial Intelligence.** Communications of the ACM, 55 (4), 86-97.

A. ARGUS: PI Jennings; "Decentralised Data Fusion"; EPSRC/MoD/DTI (GR/S20727/01); 2003-2008; £1m.

B. ALADDIN: PI Jennings; CoIs: Rogers, Ramchurn, Polukarov; "Autonomous Learning Agents for Decentralised Data and Information Systems"; BAE SYSTEMS/EPSRC (EP/C548051/1); 2005-2011; £5.4m.

C. iDEaS: PI Jennings & Rogers; "Intelligent Decentralised Energy-Aware System"; Industrially funded by Secure Meters; 2009-2014; £1.6m.

D. IAHEM: PI Rogers; CoI Jennings; "Intelligent Agents for Home Energy Management"; EPSRC (EP/I000143/1); 2010-2013; £0.8m.

E. ORCHID: PI Jennings; CoIs: Rogers, Ramchurn; "Human-Agent Collectives"; EPSRC Programme Grant (EP/I011587/1); 2011-2016; £5.5m.

4. Details of the impact

AICG research has resulted in a range of algorithms and technological strategies that allow individual energy consumers and suppliers to coordinate their actions within electricity networks and electricity markets to make better use of limited or constrained resources. This has led to economic savings in energy expenditure and has contributed to the reduction of carbon emissions through work on "smart meters", which the Government aims to have in 26 million homes by 2020.

An early key output of this work was *GridCarbon:* an iPhone application for monitoring the UK electricity grid's carbon intensity and generation mix, launched in January 2010. *GridCarbon* was the first smartphone app aimed at electricity distribution professionals, to provide real-time information on a national electricity grid. The last update in October 2013 currently has over 2,000 users **[5.1]**. In July 2013, *GridCarbon* was cited during the House of Lords' Grand Committee on the Energy Bill, in the context of the need for the Government to develop a gold-standard methodology for providing real time grid information to users **[5.2]**.

During 2012/13, live energy displays using data derived from *GridCarbon* were used during a six-month trial at a Federal Mogul (automotive and aerospace product supplier) factory in Chapel-en-le-Frith. During the trial, live energy usage data was combined with live production data to generate per component energy feedback to factory workers, as part of a company wide initiative to pinpoint where energy was being wasted. The trial reduced energy waste by up to 20%, and in June 2013 the approach was rolled out across the whole factory, with a view to extending it to other Federal Mogul sites. **[5.3, 5.8]**

In December 2012, AICG launched *MyJoulo*, a free online energy advice system. Drawing on AICG research, *MyJoulo* uses intelligent algorithms to analyse data collected from an AICG-designed USB temperature logger, to build a thermal model of the home and to infer the operational settings of the heating system. This model is then used to calculate the impact, in terms of percentage reduction in heating costs, of various interventions such as adjusting timer settings. In its first four months of operation, *MyJoulo* provided advice to over 750 private households, identifying over £50k in annual heating bill savings. Feedback from public users includes: "Geekery at its best." **[5.4]**. In September 2013, *MyJoulo* won first place in the British Gas Connecting Homes competition, and was named as the UK's brightest home tech startup, at an event which saw 25 companies from around the world pitch innovative products and services in the home energy sector to British Gas. *MyJoulo* won £30k in seed funding at the event, was spun-out of University of Southampton in November 2013, and plans are progressing for a trial with British Gas customers in January 2014 **[5.5]**.

In June 2011, Rogers participated in an industry workshop organised by the UK Energy Research Centre, to discuss how smart meter research can reduce customers' energy demands **[5.6]**. Subsequently, in March 2013, AICG began work with the Centre for Sustainable Energy, a charity that provides energy advice to individuals and organisations, to extend intelligent energy applications to electricity monitoring, using a bespoke electricity logger developed at AICG **[5.9]**. In March 2013, AICG was also invited by the Department of Energy and Climate Change to participate in the next stage of its 'Smart Heating Control Trial' providing sets of three *MyJoulo* loggers to 21 households, and providing customised energy and heating system use analysis to the customer experience team, in the first stage of the trial **[5.10]**.

Throughout the course of this research, AICG researchers have collaborated with industrial partners, influencing their funding decisions and shaping their business strategies in the intelligent energy sector. Having secured a £1.6 million grant from Secure Meters (market leader in supply of intelligent electronic meters) in 2009, they worked with the company's engineers to use Gaussian process prediction algorithms to predict aggregate electricity demand in the UK and Indian electricity grid. Utilita, an energy retailer and Secure Meters subsidiary, applied AICG clustering algorithms to the problem of clustering UK consumers according to their electricity and gas consumption. Secure Meters engineers incorporated both novel algorithms into their standard toolset **[5.11]**.

AICG has worked alongside developers from Horstmann Controls (the UK's leading home heating controller manufacturer and a wholly-owned subsidiary of Secure Meters) to demonstrate the application of intelligent learning algorithms within Horstmann's heating controllers. Horstmann says the on-going trials will inform the design of its next-generation home heating controllers **[5.12]**. The Southampton researchers are also working with BAE Systems within an EPSRC Impact Acceleration Account-funded knowledge transfer secondment, to deploy advanced load recognition algorithms within their DEMS (Deployed Energy Management System), and with Microsoft Research to deploy algorithms to learn the thermal performance of homes within their HomeLab smart home infrastructure.

AICG researchers have proactively disseminated their research findings to increase awareness among the general public and industry of the value of smart meters. The research has appeared in BBC News, *The Economist, New Scientist*, *The Engineer* (monthly e-magazine, 138,000 subscribers) and *Science Daily* (3 million monthly visitors online). Alex Rogers wrote about *MyJoulo* in the *Huffington Post's* Tech section (28/3/13). Academics delivered presentations at Autonomous Agents and Multi-Agent Systems (AAMAS) conferences in 2010, 2011 and in 2012 (where Rogers gave the keynote address 'Delivering the Smart Grid'). Each conference attracted several hundred leading researchers and practitioners of agent technology **[5.7]**.

5. Sources to corroborate the impact

[5.1] GridCarbon. http://itunes.apple.com/gb/app/gridcarbon/id346832866/.

[5.2] http://www.publications.parliament.uk/pa/ld201314/ldhansrd/text/130702-gc0002.htm
GridCarbon is cited by Lord Grantchester in Column GC398

[5.3] Building Banter.

http://www.epsrc.ac.uk/newsevents/news/2013/Pages/cuttingworkplaceenergycosts.aspx

[5.4] MyJoulo. http://www.myjoulo.com.

[5.5] MyJoulo is named the UK's brightest home tech startup.
http://britishgas.presscentre.com/Press-releases/MyJoulo-is-named-the-UK-s-brightest-home-tech-startup-2a4.aspx

[5.6] www.ukerc.ac.uk/support/tiki-download_file.php?fileId=1839

[5.7] Public and industry engagement:
Huffington Post (28/03/13) http://www.huffingtonpost.co.uk/dr-alex-rogers/artificial-intelligence-ai_b_2969797.html
BBC News 8/12/12 http://www.bbc.co.uk/news/technology-20173641 and 05/10/09:
http://news.bbc.co.uk/1/hi/sci/tech/8287130.stm
The Economist 06/09/11: http://www.economist.com/blogs/babbage/2011/09/recharging-electric-cars
The Engineer 06/05/2011: http://www.theengineer.co.uk/sectors/automotive/news/computerised-scheduling-for-electric-vehicle-charging/1008558.article
New Scientist 07/03/2011: http://www.newscientist.com/article/mg20928025.700-smartgrid-stockbrokers-to-manage-your-power.html
Science Daily 05/06/2010: http://www.sciencedaily.com/releases/2010/05/100505092527.htm
AAMAS 2012 conference:
http://aamas2012.upv.es/index.php?option=com_content&view=article&id=38&Itemid=36

[5.8] Chief Technical Officer, Moixa Technology Ltd.
Web: http://www.moixatechnology.com

[5.9] Senior Development Manager, Centre for Sustainable Energy
Web: http://www.cse.org.uk

[5.10] Head of Consumer Insight, Energy Technologies Institute
Web: www.eti.co.uk

[5.11] Managing Director, Secure Meters
Web: http://www.securetogether.com/

[5.12] Product & Market Development Director, Horstmann Controls.
Web: http://www.horstmann.co.uk/