Institution: University of Liverpool

Unit of Assessment: 11- Computer Sciences & Informatics

a. Context

Research in the Department of Computer Science has impact across economic, societal, and healthcare arenas. Beneficiaries range from UK small companies, to multinational corporations, and from groups of individuals (e.g. vulnerable children), to local authorities and healthcare services.

The Department became part of the School of Electrical Engineering and Electronics and Computer Science in 2009. The Department has four research groups, each with between 7 and 11 members. Application-driven research areas within the Agent Technology Group include data mining and software engineering. For example, a Knowledge Transfer Partnership (KTP) used Coenen's data mining research to deliver an increase of £300k in online sales at Deeside Insurance Brokers Ltd. The Group fosters longstanding relationships with non-academic users. An example of this is the development and deployment of the `In My Shoes' software tool (detailed in a case study). This tool maintained its impact over a decade, and continues to be used nationally and internationally to elicit evidence from children for care, review or court proceedings.

An example of impact in the Algorithms Group is the use of Gasieniec's algorithms to pin-point influence across the social web. It resulted in a spin-off company (Colour Text), which has Twitter and Bloomberg as customers. In the other two groups, typical examples of ongoing collaborations that have the potential to deliver impact are as follows: the Economics and Computation Group is working with Royal Bank of Scotland and Logica (funded by ESRC) to build a tool to understand the impact of financial regulation on markets; the Logic and Computation Group is working with Sellafield (funded by EPSRC) to build logically verifiable robotic systems that manipulate nuclear material.

b. Approach to impact

Over the course of the REF period we have developed an increasingly structured approach to achieving impact. The three key elements of our approach to impact have been as follows:

Building close relationships and promoting collaboration with non-academic partners.

We initiate relationships with non-academic partners through our Industrial Liaison Committee (ILC), Industrial Symposia, lecture series, and by providing training to our collaborators. Our ILC, which meets annually, currently comprises seven academics from the Department and representatives from IBM; Digital Tachograph; BAe Systems; P8 Technologies; IT Answers; Barclays; and Google. To increase awareness in industry about the Department's research, the ILC holds a regular Computer Science Industrial Symposium, involving both industrial and academic participants. The Symposium has welcomed speakers from IBM; BAe Systems; National Nuclear Labs; Altran-Praxis and Barclays. The Department has also hosted a lecture series about challenges in information technology, led by senior technologists from Barclays. Training activities include courses for Continuing Professional Development on programming delivered to company employees, and to school teachers to help them shape the new teacher-led IT curriculum. Our courses have been attended by over 100 teachers and IT professionals during the REF period.

In addition, the Department has refined and increased its mechanisms for publicity, ranging from business-facing University publications through to increased interactions with Knowledge Transfer Networks (KTNs). For example, the Financial Services KTN enabled the project with Royal Bank of Scotland and Logica by putting Savani in contact with Logica.

We have developed many collaborations with non-academic users through a range of mechanisms. A Knowledge Transfer Partnership (KTP), led by Coenen, resulted in a 15% increase in turnover for Transglobal Express Ltd, a freight-forwarding services company, through a new web-based e-

Commerce system; a KTP with Racewood Ltd developed a new product for equine simulation; and Wong's KTP with Hit Search Ltd, a digital marketing company, is developing an online-reputation monitoring service.

EPSRC and EU funding offer another important mechanism. For example, Gairing's EPSRC project on 'Efficiency and Complexity in Congestion Games' aims to discover pricing strategies which improve parking efficiency, and has Xerox's Transportation Group as a project partner. The INMA European project is a collaboration with the aerospace industry that aims to reduce aircraft development costs. Coenen leads Liverpool's project team which has used data mining techniques, developed within the Department, to provide an intelligent steel processing model for the project's industrial partners, Airbus, WSKRZ and DENN. Atkinson applies her expertise in Argumentation in the IMPACT European project, which aims to benefit government and society by developing an argumentation toolbox for supporting open, inclusive and transparent deliberations about public policy. Another mechanism is commercially-funded PhDs, one example being Savani's PhD student who is placed at trading company Arctic Lake.

Supporting and encouraging staff to realize the impact of their research.

The Department has appointed two impact facilitators (Fisher and Savani) during the REF period. They organised the industrial symposia referenced above, and advise academics on the Department's impact strategy, which aims to embed an impact culture within research groups. They also review existing research projects for the potential to lead to impact, and guide academics to take advantage of further University-level support. The University's Business Gateway team has been instrumental in connecting researchers with non-academic users, e.g., leading to several KTPs. Furthermore, the University has run a number of internal funding schemes designed to facilitate interactions between researchers and non-academics. A Knowledge Exchange voucher, for example, enabled Grasso to assist Unilever in developing a new technology (tailoring advice and information to customers) in the health sector. An Innovation Voucher enabled Lisitsa to help Cybernis, an SME that specialises in cyber security, to develop a new capability for preventing malware injections on websites. In order to provide incentives for members of staff to pursue non-academic impact, the University considers impact activities as part of promotion cases.

Developing research themes and hiring staff with the potential to deliver impact.

As part of our internal review, we looked at existing research competencies, commercial contacts and impact successes, and identified the following themes based on their potential for impact: **Autonomous Systems**, **Network Science**, and **Data Science**. In contrast to our research groups, which are defined by research areas within the academic community, these themes are application-driven and public-facing. They utilise the Department's fundamental research (as detailed in the Environment Section REF5), and additionally match areas of national importance, e.g., 'autonomous systems' and 'big data' are highlighted within the 'Eight Great Technologies' defined by Willets.

In 2013, the Department hired five new staff to develop critical mass and leadership in these areas. Professors Parsons and Tuyls bring expertise in robotics to the autonomous systems theme. Professor Spirakis is a renowned researcher in networks algorithms. For the data science theme, Bollegala brings expertise in knowledge engineering for the web, and has built a successful startup (www.spysee.jp) using technologies based on his research, and Hernich is an expert in databases. Further details on our plans for these research themes are outlined in Section c.

c.   Strategy and plans

There are three parts to our strategy:
1. To support and develop existing collaborations with non-academic partners;
2. To promote and support impact initiatives by individual academics;
3. To focus the efforts of groups of academics around our three research themes.

For 1. and 2., our Impact Facilitators will engage with academics across the Department to ensure that appropriate advice and resources are provided. We will continue to use the mechanisms outlined in detail in Section b. Our main vehicle to provide resources and leadership to the research themes is through research centres.

The **Centre for Autonomous Systems Technology**, founded in 2012 is led by Fisher and connects the Department with Engineering, EEE, Law, and Psychology. A key focus of the Centre is the safety and effectiveness of autonomous vehicles and robots. The Centre closely interacts with the Virtual Engineering Centre (VEC), which is a joint venture between the University of Liverpool and the Hartree Centre, and provides a mechanism for the exploitation of our research, particularly in the aerospace and robotics sectors. The VEC is part of the GAMMA programme which funds university collaborations with SMEs to open up opportunities in new markets (http://gammaprogramme.co.uk/). To support new arrival Professor Tuyls an additional lectureship has been allocated to this theme.

The newly formed **Network Science and Technologies Centre** (NeST) brings together research on multi-agent systems, game theory, network algorithms and efficiency. Professor Spirakis was hired to lead NeST, which was given £30,000 as initial funding. Spirakis is an experienced advisor both to the Greek government and EU on major IT projects, and research and innovation. Taking as an example Gasieniec's work on social networks that led to the spin-off Colour Text (see Section a), the Centre will apply computational methods to other commercially-relevant settings, such as global manufacturing networks, smart power grids, and biological networks.

Data Science brings together our expertise in data mining (Coenen), information retrieval (new arrival Bollega), and data-integration and ontology-based data access (Payne, Wolter, and new arrival Hernich). It targets an area that will be ever more applicable as organisations strive to capitalise on the vast amounts of data that are generated and stored. Data Science is not yet supported by a centre. During the next period we will develop a clear business plan, and form an advisory board and a centre for this theme.

For each of these themes, a key goal is to develop a *technology pipeline*, with our theoretical research leading to practical applications and then commercial deployment. To facilitate this, at Department level, we aim to provide increased support for sabbaticals and secondments within industry. We will draw further on expertise in Business Gateway and the University's commercial partner (Impact Science) to assist with IP issues and spin-offs. An advisory board will carefully monitor the success of each Centre with respect to clearly defined targets in terms of funding and impact. In the medium term, we are flexible and open to evolve or change themes as required.

d. Relationship to case studies

Our case studies have both benefited from, and informed, our approach to impact. The 'In-My-Shoes' impact case study is an archetypal example of how we would like the Department to bring together research and long-term collaborations with non-academic partners. 'In-My-Shoes' has a dedicated staff member (Jimmieson) who has contributed to the research, develops the software, and delivers in-house-training, which has been instrumental in its widespread adoption. The importance of long-term collaborations and dedicated resources has informed our approach and impact strategy. The Whitestein impact case study based on the agent-based Gaia methodology developed in the Department demonstrates our strategic choice to invest in areas with the potential for impact (in this case Agent Technologies). The National Grid impact case is based on the research of Henry Wu from EEE, and demonstrates the synergies between CS and EEE, which form the foundation of the newly formed School of EEE&CS. We will leverage these synergies going forward, by sharing expertise and non-academic contacts.