Institution: University of Sheffield

Unit of Assessment: 11 – Computer Science and Informatics

a. Context

The main types of impact the Department's research has given rise to are:

- Economic impact, specifically via the creation of new spinouts (Organisations, Information and Knowledge (OAK) and Speech and Hearing (SpandH) groups) and the performance improvement of existing business (Machine Learning (ML), Natural Language Processing (NLP), SpandH, Verification and Testing (VT) and Virtual Reality and Graphics (VRGraphics) groups).
- Impact on Public Policy, specifically the stimulation of policy debate (see *Ethics* case study)
- Impact on Society and Culture, specifically the stimulation and informing of public discourse, the informing of public attitudes and understanding (Computational Biology (CompBio), NLP, ML)
- Health impacts, specifically the development of new diagnostic technology (CompBio)

The principal beneficiaries are spin-out companies, industrial collaborators and the Open Source community. The general public has benefitted from research that has informed public policy and discourse and from research that positively affects health outcomes.

b. Approach to impact

Our overall vision (see REF5) is to advance basic understanding of computational methods and models and *to apply the insights gained in this process as widely as possible.* Here we describe our approaches to impact and evidence them through examples (*ICS* = Impact Case Study).

1. Industrial Collaboration in Funded Projects: A major source of our research funding for over 20 years has been the EU Framework Programmes, in particular via Specific Targeted Research Projects (STREP) and IP grants. These **require** the participation of commercial partners, particularly SMEs, and have a strong emphasis on commercial exploitation of IP created in the project. Since 2008 we have had 33 EU projects; in many cases research carried out by our staff has been exploited by commercial partners. For example:

- The GATE text analytics platform, developed via EPSRC and multiple EU projects, has been exploited by a number of non-academic partners: our Prestospace project partner, the BBC, now uses GATE to power its on-line sports site and EU SEKT project partner, Ontotext, markets GATE-powered semantic annotation tools to customers such as the Press Association, CNN and the UK National Archives (see *ICS GATE*).
- The OAK group's Knowledge Management (KM) technology was first developed in an EPSRC project, which had Rolls-Royce on its industrial steering committee. It was then further refined and exploited with Rolls-Royce as a partner in DTI- and EU-funded projects. It is now heavily used in Rolls-Royce, saving them millions of pounds (see *ICS OAK*).
- SpandH automatic speech recognition technology was significantly enhanced via two EU-funded projects and several industrial participants in the projects have exploited the technology in new or ongoing ventures (see *ICS ASR*).
- The StateChum tool, developed by VT in EPSRC and EU funded projects, has been commercialized by QuviqAB and released as part of their QuickCheck testing tool.

Other government-funded collaborative work with industry includes KTP awards, such as Stevenson's KTP award to work with TDX Group, Nottingham.

Work directly funded by industry has also led to impact. Matrixware invested £1M directly in the GATE platform in 2007-10. The resulting advances were included in the open source version (3. below) and have been exploited by many other non-academic users. Rolls-Royce directly funded further development of the OAK KM tools and an iCASE studentship. These tools form the core component of a data mining programme that Rolls-Royce estimates saves £6M pa.

2. Spin-Out Companies: During 2008-13 five successful spin-out companies have been created.

- In 2008 **K-Now** was spun out to provide OAK's mature KM technologies to Rolls-Royce. K-Now now has a range of other clients. The OAK group attracted further direct funding for another spin off – **the Floow** (2012), which has generated over £1M in its first year. Our ability to respond in a very agile fashion was key to realising this opportunity: time from initial contact by funder to first large contract with DirectLine was just 11 months (*ICS OAK*).
- Stemming from research on Agile software engineering methodologies, **Epigenesys** was created in 2008 to deliver software consultancy. It has had over £1M turnover since then, now has

9 staff and over the past year engaged in 52 projects.

- **Koemei** and **Quorate Technologies** are spin-outs created to exploit speech recognition advances made in the two EU-funded projects referred to above. Koemei (founded 2010) has generated revenue of ~600k CHF to date, has 6 full time employees and has received 500k CHF investment as well as 1m CHF in subventions from Swiss/EU project funding agencies (*ICS ASR*).

In addition, research in CompBio (Walker) has helped optimise the design of a probe for detecting cervical cancer. It has passed clinical trials and is being marketed in the UK and EU by existing University spin-out **Zilico**, leading to both economic and health impact.

3. Open source (OS) software allows publicly funded research to reach beyond direct collaborators and facilitates non-exclusive exploitation at low cost**.** For example, **GATE** is an OS code base (50k+ annual downloads), which has enabled the formation of SMEs including Fizzback (founded 2004, sold 2011 for £58M), Text Mining Solutions and Foodity. It has been extended for cloud-based services and crowd-sourced annotation via consultancies. **SimMetrics** is the most widely used OS library of string similarity measures (*ICS OAK*). **Flame GPU**, a simulation framework for massive real-time complex systems, is being used by Costain and the Dubai Police. Patents referencing Sheffield OS include 54 in the US that refer to GATE and 12 referring to GPLVM developed by Lawrence.

4. Consultancies/secondments: We have generous **consulting** and **shared IP arrangements**. The Faculty's *Sheffield Engineering Gateway* provides a portal for our services, and contract negotiation support. The ML group have consulted to a major F1 racing team; Ciravegna to Lycos Brain; the GATE group to clients in the Medical/Clinical area, including the South London and Maudsley NHS Trust, eClinicalWorks and the Health Protection Agency. Cunningham was seconded part-time to Internet Memory Research in 2011-12 and Romano to Costain in 2012-13.

5. Engagement with Policy Makers and NGOs: Sharkey's work on the ethics of autonomous weapon systems in war has had significant impact on policy makers and NGOs in the UK and internationally, including the UK parliament, the UN, the French MOD, Human Rights Watch (*ICS Ethics*). Holcombe is Chair of the Creative and Digital Industries Sector of the Sheffield City Region Local Enterprise Partnership. Clayton and Ciravegna have been members of international expert panels reviewing the European Space Agency ELIPS programme and the Irish Government's investment in Alcatel-Lucent Labs.

6. Public Discourse and Understanding: Mechanisms include media fellowships, media appearances and public road-shows. For example, Sharkey used two Media Fellowships to inform debate on autonomous robotic weapons via print, radio and TV. Marshall discussed modelling bees on local, national and international radio and the Discovery Science channel. Moore took a Speech Technology road-show throughout Yorkshire.

Supporting Impact: Impact is an integral part of staff review and promotion. It is recognised alongside teaching and research as a core element of staff duties. We have reinforced our ability to deliver our impact agenda by appointing staff with a track record that matches our strategy.

c. Strategy and plans

Our strategy is based on an analysis of our current position from which we identified a set of strategic objectives, to be annually reviewed. While top-down strategic plans to direct impact are important, we also remain committed to being agile, moving rapidly to exploit new opportunities.

Current Situation: We have achieved significant economic impact with industrial partners, especially from (1) EU-funded projects (see (b) above and ICS GATE, OAK, ASR) and (2) via OS (see above), typically initiated in RCUK-funded projects, then refined in subsequent collaborative ventures. Such OS has been core to business developments in several companies and has led to many consultancies. OS impact has been achieved by (1) an initial good idea, and (2) long-term commitment to develop and maintain a robust and fully featured codebase. These two routes to impact remain a core part of our strategy. We have new opportunities that stem from the fit of our research profile to wider trends in the ICT/knowledge industries, specifically, in big data/data analytics, testing/agent-based simulation and personalized healthcare. The University has invested in new cross-disciplinary institutes bringing together researchers and research users, creating unique opportunities for impact (see below). In July 2013 we won a £3M HEFCE award to set up an ***Advanced Computing Research Centre*** (ACRC) to engage with regional industrial partners.

This centre affords a tremendous opportunity for impact.
Improvement is possible: specifically, there is potential for wider staff engagement in impact-related activities. Our health care impacts are fewer than we would like given our strengths in comp. bio. Furthermore, we need to be sensitive to threats to impact including: (1) vulnerability to staff departure; (2) dependency on EU funding (R&D funding could decline; funding priorities could change); (3) overlap with industrial research agendas leading to competition for ideas and staff.
We have thus developed a strategic plan addressing: **what** areas of research could lead to impact; **how** impact can be facilitated; **who** will generate the impact, i.e., how to engage and support staff.
What: Areas of potential engagement and impact. Significant opportunities exist in areas of our research strengths. (1) *Big data/data analytics*. Massive volumes of data, particularly unstructured data, are being generated by sensors/organizations /individuals. Our expertise in machine learning, speech and language enables us to exploit opportunities to make sense of this data deluge. (2) *Testing/agent-based simulation*. Building and understanding complex systems is increasingly important. Our expertise in testing and simulating systems, from economies to cell complexes, has huge impact potential. (3) *Personalised Healthcare.* From the level of the genome to design of assistive technologies, the trend in healthcare is towards personalisation. Our expertise in CompBio, machine learning, haptic/speech technologies puts us in a strong position to exploit developments at all levels.
How: Enhanced Mechanisms. The increasing importance of impact has led to institution-wide impact strategies and new mechanisms to assist staff in realising impact. The latter include: a Research Partnerships and Engagement team, Faculty and Departmental Business Development Managers (BDMs), the Sheffield Engineering Gateway (SEG), a shop front for industry to identify engineering expertise in the University. We will take advantage of these enablers. In our department we will focus on: **(1)** HEFCE ***ACRC***. This new Centre will address Software Testing, Data Analytics and Agent-based Simulation. It will support specialist researchers, managed by academic staff, who will actively engage with industrial partners to carry out short term industry-driven R&D projects. **(2) *EU/Horizon 2020***. Continuing to collaborate with industrial partners via EU grants will remain a core part of our impact strategy. We are well positioned to exploit the priorities set for the upcoming programme; in addition, several senior staff (Cunningham, Gaizauskas, Moore) are members of EU Expert Panels helping to set the agenda for the first calls. **(3) *Cross-disciplinary institutes***. The Institute for Translational Neuroscience (SiTran), the Institute for in-silico Medicine (INSIGNEO) and the Centre for Assistive Technology and Connected Healthcare (CATCH) will bring together clinicians, medical researchers, computer scientists and NHS and industry partners, affording unique opportunities for health impacts. These institutes form the core of our strategy to achieve impacts in personalised healthcare. **(4) *Open source***. We are committed to maintaining our successful OS bases, which will be further exploited, e.g. through the ACRC. The virtues of this model will be promoted to all staff. **(5) *Industry-facing funding***. To mitigate the risks of a drop in EU funding and to more directly engage with UK industry we aim to increase TSB and KTP funding, as well as to secure more direct funding from industry. The ACRC will be one route to this and Faculty/Dept BDMs another.
Who: Staff Involvement. To broaden our impact and mitigate the threat of key staff leaving we will encourage more staff to engage in impact-related activities. To raise the profile of impact, monitor impact related activities and disseminate best practice we have created an open *impact register*, which staff update regularly. Staff have an impact section in their CV which is reviewed in their annual appraisal, serving as a criterion for promotion. We have just created the role of *Impact Officer,* to be held by a senior academic with significant experience of research exploitation, who will be responsible for bringing impact-related opportunities to the attention of staff, mentoring junior academics in relation to impact, monitoring Faculty and University level impact initiatives, etc. We have created *impact sabbaticals* to enable staff to work exclusively with non-academic beneficiaries. Our new BDM has a specific role to work with staff to increase consultancies.

d. Relationship to case studies

These have been indicated in section b. above. ICS GATE, OAK and ASR are examples of impact arising from industrial collaboration via funded projects and from Open Source; Ethics ICS is an example of engagement with policy makers and NGOs.