Institution: University of St Andrews

Unit of Assessment: 11 – Computer Science and Informatics

a. Context

The School of Computer Science investigates the theoretical and practical aspects of building effective software and systems, organised around five broad research themes: artificial intelligence, computer systems, programming languages, human-computer interaction, and systems engineering. All our themes achieve impact, tailored to what their research can bring to different external stakeholders. During the REF period:

- NHS doctors have used methods developed by our artificial intelligence research to more accurately model and assess human fertility and cancer treatments;
- Leading multinational organisations have adopted technology from our computer systems theme providing robust distributed systems middleware, and have taken-up network technology to develop emerging internet standards;
- Several companies now provide "swipe" keyboards for mobile phones and tablets based on techniques developed within our human-computer interaction theme;
- Companies including BAe Systems, Selex, and Rolls Royce, have used our programming language theme's Hume technology to improve analysis of embedded real-time systems;
- Adopting cloud computing often poses unquantifiable risks, but our systems engineering research has provided a web-based cross-provider tool for cost estimation; and
- Our researchers delivered the specification and architecture for a Scotland-wide digital learning system used by over one million students.

We place impact in the context of using technology to improve quality of life; gaining access to real-world problems and non-academic approaches; and developing collaborations to facilitate future research. We perform these activities as a leading partner in the Scottish Informatics and Computer Science Alliance (SICSA), for whom we direct the Knowledge Exchange programme.

b. Approach to impact

Strategy. The School embeds impact as an intrinsic part of the research process, rather than an activity performed separately or at the ends of projects. We focus on three classes of impact:

- Direct commercialisation of software and techniques, achieved by licensing technology to established and spin-out companies (e.g., CloudSoft, PlanForCloud);
- Indirect exploitation of our research experience by industry and the public sector through consultancy and advice (e.g., critical infrastructure protection with Strathclyde Police); and
- Societal engagement and knowledge exchange, making tools, technology, and knowledge available not-for-profit for the public good, e.g. as open-source codebases and datasets.

By becoming more proactive as well continuing to react to individual opportunities, over the REF period we have delivered a significant improvement in our ability to attract interest from outside organisations; to initiate, encourage and manage the impact deriving from our research; and in using the results and contacts obtained to further our research activities and goals. Mechanisms have included improving the breadth of our funding portfolio with direct engagements with multi-nationals and SMEs, charities, and government agencies, delivering an average of 7% of our research funding over the REF period. We have invested to identify appropriate approaches to impact across the lifetime of a research interest, for example through dedicated business-development support for projects, and by using our staff experience in translating research.

Growing staff expertise and engagement. The School fully supports the different aspirations of our staff in assessing and delivering on the most appropriate ways to exploit their work, including through collaboration, standards, community projects, and starting companies. Overall:

- 10% of the School's staff have founded and run start-up companies from inception through growth phase (and to trade sale in one case);
- 80% are involved in collaborative research projects involving industry, and/or have received direct funding for research from industry;
- 20% perform research-driven strategy consultancy for external companies; and
- 20% co-ordinate open-source projects and standards development.

For example, staff have worked with SMEs and MNCs to help identify opportunities for further commercial opportunities in sensor networking, advanced interfaces (e.g., Paywizard, Interface3, Advanced Display Solutions), embedded computing (e.g., Selex, BAe Systems), and distributed computing (e.g., Cloudsoft, Thales), as well as with social stakeholders (e.g., Historic Scotland)—all positioning the School for future joint proposals. Staff engage internationally on industry and advisory panels including the Scottish Enterprise Informatics and Computing Technology group (Sommerville), and the Finnish Academy of Sciences research roadmap (Dearle).

Leveraging funding initiatives. The School has taken a leading role in funded Scottish and UK knowledge exchange activities, which have delivered funds in excess of £500K. These include leadership roles in three "Horizons" translational grants to engage directly with the SME sector in digital tourism (Quigley, Dearle), cloud computing through the Scottish Cloud Computing Network (Sommerville), and sensor systems through the Scottish Sensor Systems Centre S^{3}C (Bhatti, Dobson), which engage directly with companies to deliver high-value software and services. The School also received £100K through EPSRC Institutional Sponsorship and Small Equipment schemes to support research in cloud computing, virtual reality, and large-scale data handling.

Leveraging SICSA investment. The School has used its position within SICSA to focus on delivering impact, and through SICSA we have access to a range of knowledge exchange mechanisms. In 2012—2015, SICSA committed £410K funding to encourage exchange between researchers and business, targeting PhD students and other early-stage researchers. The SICSA Postgraduate Industry Internship Programme funds for research students to undertake an industrial internship of up to 9 months, including a period of preparation or return transfer activity, as part of their research programme, supporting placement of a St Andrews student at Microsoft Research (£9K). The SICSA Postdoctoral and Early-Career Research Exchanges scheme has supported two visits by St Andrews staff (£10K) to work on cloud computing with UC Berkeley. The School uses the facilities of Informatics Ventures, SICSA's Edinburgh-based accelerator that supports globally ambitious software start-ups across Scotland via a range of activities and events.

The School has contributed to each of the annual "Demofest" industrial showcases of student work, each of which attracted over 50 companies. (St Andrews provided 20% of the presentations in 2013.) Staff and students in the School have engaged strongly with SICSA's programme of entrepreneurial workshops. This approach has been very effective, leading to two spin-out companies led by the School's graduate students (one in high-performance databases, one in cloud migration services) over the REF period.

Public demonstration and open source. The licencing of software is a complex area, and often achieves most impact by being given away. The School's research software is typically made available under an open source licence, generally not precluding simultaneous commercial exploitation. The School maintains eight open-source code bases, the two most significant being:

- GAP (computer algebra, used for teaching and research in over 2,000 institutions worldwide and integrated into the world-leading Sage computer algebra system); and
- Minion (constraint solving, over 10,000 downloads, embedded into several products including a commercial protein analyser).

The School is deeply engaged with the local community, including a long-term engagement with the Fife Schools' Science Fair (Baxter), using virtual reality to engage students with heritage (Miller, Dow, and Allison), and science-based stand-up comedy at the Bright Club (Jefferson).

c. Strategy and plans

The School's future strategy for impact involves two strands of continuing and deepening engagements with partners:

- Improving the embedding of non-academic impact within the research process; and
- Providing support to staff seeking exploit their work by whatever appropriate means.

We have begun a long-term plan to extend our academic environment to provide a culture that includes engagement with the wider community alongside research excellence, encouraging entrepreneurship as a part of the graduate experience through provision of workshops and involvement in coding competitions, start-up boot camps and so forth provided through SICSA. Given the School's emphasis on research-led teaching, we are embedding entrepreneurship into the undergraduate curriculum through the use of industrially relevant problem-based learning in project modules, together with targeted development and exploitation workshops and training.

To support specific activities, we have begun to provide a "drop-in" centre (staffed by a dedicated business development manager provided by the University) for discussing exploitation and monitoring collaboration opportunities and non-traditional funding sources. We provide rolling audits of the impact potential of on-going and proposed projects. That 25% of our staff have start-up and/or consulting experience provides significant value in helping other staff in similar activities.

Furthermore, we have realised that many of our collaborators could potentially be engaged in other joint activities within other themes. To support this we have created a single "industry club" (with a member of staff assigned to manage it), to whom we provide improved access to our on-going and proposed activities. This improves our ability to get attention for our work within companies, and provides a route for staff to exploit the contacts already made and avoid unproductive cold-calls.

d. Relationship to case studies

Our approach to a commercial impact can be illustrated by Dearle's work on distributed mediation, where an academic spin-out company would have struggled to penetrate the enterprise marketplace, and so licencing to an existing company with an existing route to market dramatically improved the impact achieved. Conversely, Sommerville's cloud migration toolkit was perfect for a spin-out, but the company offers a service based on the technology rather than the technology itself. These impact activities have taught us that the appropriate route to impact depends critically on the fine detail of the technology being exploited, and to make use of the commercial experience of staff in making these strategic decisions.

Miller, Dow, and Allison's public engagement has enormously increased the visibility of computer science and virtual world technology in Scotland, as well as being used to bring alive work in archaeology, history, and the humanities. These experiences have reassured us that our broad approach to impact is correct, to leverage our research so as to maximise its wider significance without being constrained by narrow commercial considerations.