Impact template (REF3a)

Institution: University of Kent

Unit of Assessment: UoA 11, Computer Science

a. Context The School of Computing has five research groups:
- *Computational Intelligence* (Group I): machine learning, knowledge discovery, cognitive science, computational biology and visualization;
- *Computing Education* (E): pedagogy and tools for learning programming;
- *Future Computing* (F): new computational paradigms, new approaches to computational economics and agent-based systems;
- *Programming Languages and Systems* (P): the theory and practice of building systems, including verification, analysis and tool building;
- *Security* (S): multi-disciplinary information security, verification, formal methods, communications and distributed systems security.

The School's research has impact on the products, services and practice of the software industry, on the use of computing systems in a range of industrial and social sectors, and on the education and training of programmers in schools, HEIs and business.

The School's target sectors for impact include: *software and system developers*: (groups F, P, S); *educators in secondary and tertiary education*: (E); *system builders and integrators*: (P, S); *application areas, including bioinformatics, health, traffic management and business*: (F, I, P, S).

b. Approach to impact

The School aims to produce research of the highest international standard, and to disseminate it through the highest impact journals and conferences. Building on this foundation, we aim to maximise the impact of our work in a number of ways.
- Open source (OS) release of research results and contribution to international OS projects.
- Building and maintaining strategic, long-term collaborations.
- Targeting follow-through activities and funding designed to maximise industrial impact.
- Interdisciplinary activity: computing having an impact in a variety of application domains.
- The widest possible dissemination and public engagement with our work.

Open Source Software Release. The school aims to give its research results the greatest reach by making them available as open source software. This includes all of the impact case studies – Greenfoot, PERMIS, Wrangler in the refactoring case study and JCSP and other systems in Communicating Process Architectures (CPA) – as well as contribution to the OpenStack initiative. Open source (OS) gives high visibility: BlueJ, for example, has 10 million downloads per year. OS projects also become sustainable through drawing in outside contributors (as discussed in the refactoring impact case study) to support a project long-term. The school has its CSProjects repository (*projects.cs.kent.ac.uk*) specifically intended to support OS and collaborative work. During the REF period, 61 of 244 projects have attracted external participation. (To protect the IP and interests of industrial collaborators, some of these projects are visible only to the participants.)

Strategic, long-term collaborations. The School's most successful industrial collaborations are strategic and long-term, and each is built and sustained through a breadth of activities:

- **Sun Microsystems** (**Oracle**) has supported the development of the Greenfoot and BlueJ open source systems for teaching programming in schools and universities since 1997 ($1.21m during the REF period). This is a highly successful collaboration: e.g. BlueJ is used in 2,000+ universities across the world, and is downloaded 10 million times per year. As well as this, 100+ Kent computing students have spent a 'sandwich' year with Sun in the USA, and Sun/Oracle has also supported research and teaching in multicore systems. Cisco Systems have recently inaugurated a similar USA 'sandwich' programme, taking 20 Kent students per year.
- **Erlang Solutions Ltd (ESL),** an SME software consultancy, has worked together with the school in three Knowledge Transfer Partnerships (KTPs) involving software components, e-learning and embedded systems, and three EU Framework7 projects. Two staff from ESL and Kent have also co-authored a practitioner text on Erlang Programming (O'Reilly, 2009).
- **IBM** work with the school in research, student placements and support for the Kent IT

Consultancy, a student-led IT consultancy based in the School (*www.kitclinic.com*).
- **The Kent IT Alliance**, of which the School is a founding partner, brings together HEIs and public sector organisations across Kent to promote interactions between the members. Current activities include prototyping (via student projects), placements, and masterclasses (e.g big data, security). Work with Sun and ESL is highlighted in two Impact Case Studies: on transforming the way that programming is taught (Greenfoot) and on improving programming practice (Wrangler).

Targeting follow-through for impact. The School of Computing encourages and rewards staff for working closely with industry, to follow through their research. For example, the two staff members who have held Royal Society Industrial Fellowships (King: Portcullis Computer Security 2008-12; Rodgers: INRIX media Ltd. 2010-13) have been promoted during their fellowships. In King's case the fellowship followed an EPSRC *Collaborating for Success Through People* award, and results of the fellowship led in 2013 to collaboration with GCHQ. Other follow-through activity is supported by direct industrial funding (Oracle, Agilent, Bergen Software Services), support for patent applications (NCR), KTPs (ESL), and UK public sector support (Jisc, NHS, HEFCE, HEA).

Interdisciplinarity. A distinctive aspect of much of the school's research is its interdisciplinarity. The Centre for Cyber Security involves researchers from computing, engineering, sociology, law and psychology as well as industrial partners (RIM, DSTL). In that area, Chadwick has worked with healthcare professionals, legal experts and e-Scientists to examine how security can be embedded into their electronic systems from the design phase onwards. Building on King's fellowship the centre has recently gained two grants within the GCHQ/EPSRC Research Institute in Automated Program Analysis and Verification. Freitas, D. Barnes and Chu work on applications in pharmacy and biosciences, generating impact in those fields, rather than simply in core computer science.

Dissemination and public engagement. The School ensures that its research work receives the widest possible exposure beyond the purely academic routes of publication and conferences.
- **Research monographs** (on data mining, garbage collection, dependable systems, program refinement) and practitioner guides (to modelling in biosciences, Java, Erlang, Haskell) give their authors' research work higher visibility, particularly with non-academic readers.
- **YouTube videos** give an immediate 'hands on' introduction to a tool (Wrangler) or system (Greenfoot) that is impossible to achieve through printed manuals. Social networking media (Twitter, discussion forums for Greenfoot) support a community around the research results.
- **Training.** To maximise impact for Greenfoot, the school has provided residential training and written a textbook to equip teachers with suitable classroom resources. Other research results have been presented at practitioner conferences (e.g. ACCU). The Computing Education group has had impact on HE practice through the *Bootstrapping Research in CS Education* project, which trained HE staff in research techniques for CS, supported by the US National Science Foundation.
- **Public engagement** with our work is also promoted. Staff from Computing have set up and run the university's Café Scientifique (*www.cs.kent.ac.uk/~cgj/site/CS*). Through nationally-reported surveys of the public, the Centre for Cyber Security has highlighted its work in real-world security (*http://www.cybersec.kent.ac.uk/Survey1.pdf*).

Managing impact. Advice on strategy is provided by the School's Stakeholder Panel, with members from industrial and public sector organisations. The Director of Research and Enterprise and Heads of research Groups actively monitor activity to identify impact-generating opportunities. They ensure that staff are supported in seeking funding to generate and sustain impact (e.g. KTP) and exploit results (e.g. NCR patent application.) Kent Innovation and Enterprise (KIE), the University's organisation that promotes industrial engagement and exploitation, assist in this.

c. Strategy and plans

Impact planning and strategy are seen by the school as part of the overall school research and enterprise strategy. On a yearly cycle, research groups and individuals plan their activity (general direction, publications, grant applications, impact). The School's Stakeholder Panel has the role of promoting interaction with its various stakeholders. Members of the panel come from corporates (IBM, Oracle, Barclays), SMEs, the public sector (Kent County Council), education and alumni, and it is chaired by Ian Penny, Head of Distributed Technology & Operations at Barclays.

As noted in Section b, the school's strategy for maximising the impact of its research has the following goals:

- **Actively to target funding** that supports impact-raising activity, particularly schemes where the school has a record of success, including industrial fellowships, KTP, EPSRC Discipline Hopping and FP7 / Horizon 2020. Previously successful applicants in the school mentor these applications, and further support is provided by KIE and Research Services, through its Grants Factory and Early Career Research Network activities.

- **To deploy research results as open source software**, and open access publication of basic research. This is particularly successful when research results are incorporated into larger systems (e.g. components of PERMIS are being incorporated into OpenStack, an IaaS cloud computing project). This gives research results, like computing systems and tools, the widest possible reach, as well as ensuring their sustainability through attracting collaborators to contribute to the projects

- **To capitalise on existing links with industrial enterprises**, including long-standing links with Oracle, IBM and ESL, as well as Royal Society Fellowship links. Some 75% of undergraduates take a placement year, and so we are well placed to develop new links through placement contacts, as well as through research dissemination. Building on earlier joint work (e.g. in FP6 and FP7), BT links are being strengthened by the appointment of Dimitriakos to a 20% position in the school: his remaining 80% is as Chief Security Researcher in BT's Security Research Centre.

- **Interdisciplinarity**. Through participation in and funding of research centres in the university, to encourage interdisciplinary research which can lead to practical impact. As well as supporting research, these centres provide contact with stakeholders through whom impact can be delivered.

During the period 2014-20 the school will particularly support impact-generating activities coming from four different areas of activity:

- activity that has already been supported by Royal Society Industrial Fellowships and is now feeding through into further research and development activities;
- 'discipline hopping' activity by staff, and other interdisciplinary research in biosciences, cognitive science and cyber security;
- research results of academic/industrial research consortia, e.g. FP7 and Horizon 2020; and
- the activities of recently-appointed staff, many of whom are early-career researchers, and who are currently developing collaborations with other researchers and industry; other recent recruits are more experienced, and will develop and strengthen links with existing partners.

In all these domains the school will disseminate research results as widely as possible. The school will ensure that impact-generating activities are encouraged and rewarded through its workload allocation and appraisal processes, and feed this into the university's promotions process.

In summary, the school will build on its research and follow-through activities in five ways:

- maximising the impact of its software through open source release,
- targeting funding that enables research impact generation,
- sustaining its existing long-term collaborations, and building new ones,
- supporting interdisciplinary research in the university and beyond, and
- disseminating its research as broadly and accessibly as possible.

d. Relationship to case studies

Case studies 1 (Greenfoot) and 3 (Refactoring) reflect long-standing, multi-faceted relationships between the school and a company. These relationships are mutually beneficial, and the school will sustain these relationships and build others (e.g. with BT). Valuable interactions can also emerge in an *ad hoc* way as a result of an approach from a company. Case studies 2 (PERMIS) and 4 (CPA) show this, and how the school was able effectively to respond to the approach.

In three cases, the research that has had impact has received industrially-related funding: in case 1 with direct industrial funding, in 2 and 3 with Framework 7 funding for industrial/academic research consortia. The results of all four are available as open source projects, and therefore can be sustained by the community as well as the originating researchers.