Institution: Keele University

Unit of Assessment: B11 – Computer Science and Informatics

a. Context

The Computing Research Cluster is subdivided into two research groups.

Software Engineering (B. Kitchenham, P. Brereton, S. Linkman)
The principal non-academic beneficiaries of our research in software engineering (SE) are organisations that develop software (i.e. SE practitioners and decision-makers) as well as teachers of SE. Software products and services have a major impact on almost all aspects of our daily lives including our environment, our health services, our leisure activities and on the broad economic success of the UK.

Computational Intelligence and Cognitive Science (A. Channon, C. Day, K.P. Lam, D. Collins)
This group's main impacts and non-academic user groups are in medical applications, forensics, and the built environment (with economic and public safety factors). We plan to add the environment (preventing extinction events, and arboreal health monitoring) and computer security (for the large-scale management of virtual machines, with economic and societal factors).

b. Approach to impact
The two research groups take different approaches to impact. The Software Engineering group has impact embedded as an established stage of its research process, made possible due to the known target group (software engineering practitioners and decision-makers). The Computational Intelligence and Cognitive Science group evaluates the potential for each new research finding to have a marked benefit to any target group or aspect of life beyond academia (be that to the economy, society, culture, public policy or services, health, the environment or quality of life) and, where such potential exists, progresses basic-research findings to applied research projects and applied-research findings to impact.

Software Engineering
The substantial body of research on evidence-based software engineering (EBSE) undertaken at Keele (and elsewhere) has established a firm basis from which to carry out knowledge translation (KT) to SE organisations and to teachers of SE (Brereton output 4). KT is the 4th step ('integrate the critical appraisal of evidence with SE expertise and stakeholder values') in the 5-step EBSE process. KT can be defined as "the exchange, synthesis and ethically sound application of knowledge – within a complex system of interactions between researchers and users – to accelerate the capture of the benefits of research through better quality software and software development processes".

Over the last two years, we have been investigating the process of KT in relation to the outcomes of EBSE research. In April 2012, we held a workshop with members of industry and commerce to examine how evidence-informed software development might be facilitated. The workshop identified a wide range of mechanisms that could be used to communicate the outcomes from systematic reviews and also a set of SE topics that are of particular interest to practitioners. The practitioners who took part in the workshop are providing support for our continuing work on KT. The use of guidelines for performing KT in order to produce recommendations for practice has been investigated extensively for both clinical medicine and education. We have examined some of the models used in these other disciplines, and suggested a possible interpretation for software engineering ('The Case for Knowledge Translation', Budgen, Kitchenham and Brereton, Proceedings of 2013 International Symposium on Empirical Software Engineering and Measurement, Baltimore, October 2013).

Computational Intelligence and Cognitive Science
Our research in multiscale object recognition (Impact Case Study 1, including Lam output 1) has led to key breakthroughs in the automated identification of tissue boundaries in computer tomographic (CT) scans, enabling the latest generation of radiotherapy linear accelerators to more accurately target diseased tissues (with their multiple highly focussed low-power beams) rather

than neighbouring healthy organs: essential for the roll-out of this life-saving equipment for the treatment of cancer. Our research in this area has also led to new fractal algorithms to characterise the quality of transplanted cell growth from post-operative biopsies, essential for the development of a medical capability for large-scale patient-specific generation of cartilage growth for the treatment of arthritis; and to algorithms that improve the tracking of cells and the auto-focus method used in high throughput phase contrast microscopy.

The group's research into classification within forensic datasets (Impact Case Study 2, including Lam outputs 3 & 4 and Day output 1) has led to novel algorithms capable of isolating subtle patterns in complex data. This has been applied first to enabling images captured by mobile phone cameras to be reliably and evidentially linked to source devices, with huge applicability to those fighting terrorism, paedophile rings and civil unrest, by extending detection capabilities to mobile phones in an era in which they are rapidly replacing dedicated cameras. This research is now embodied in the products of a leading producer of forensic software. Second, it has enabled criminal record checks to be carried out securely online where previous paper-based systems were both too slow for purpose (taking weeks or months) and inherently insecure, leaving key posts unfilled in the health care industries and education sector; so benefitting the public by solving a problem that was having a negative impact on the running of these public services.
Another neural project applied self-organising map neural networks to the practical problem of determining a post-mortem interval from scene-of-crime samples, with great success (Day output 3); this has lead to collaboration requests from the UK Natural History Museum and applied researchers in Germany and the US.

A third applied neural project progressed our basic research in reservoir computing and extreme learning machines (Day output 2) to the high-impact problem of automatically detecting corrosion defects in ageing reinforced concrete. Structural collapse has already resulted in many fatalities globally and today very many structures are reaching an age that causes concern. The method developed has demonstrated its effectiveness in the field (Day output 4) and subsequent developments have been well received by leading industrialists and staff at the UK National Physical Laboratory's (NPL's) bridge monitoring project. In addition to merely detecting the emergence of defects for more effective structural health monitoring, recent further developments of techniques allied to those reported in Day outputs 1 & 2 are allowing us to identify whether the disposition of the affected structure has been significantly altered by the detected defect(s). These findings will be presented at the forthcoming European Symposium on Artificial Neural Networks (ESANN 2014) and as part of the NPL's ongoing longitudinal bridge monitoring project.
In addition, our research in security assurance architectures for cloud computing is mid-way to impact: it has already demonstrated that our approach can address key security problems for the large-scale (secure) management of virtual machines (Lam output 2).

c. Strategy and plans

Our approach to impact (section b) is working well and aligns closely to Keele's Research Strategy (2011-15), which prioritises our (University) aims to "have significant social, cultural, environmental and economic impact, working with external partners and collaborators to benefit society" and to "foster relationships with research users and external stakeholders to facilitate the dissemination, impact and promotion of research outcomes". Our strategy is therefore to build on our current approaches and to ensure that early-stage researchers fully engage with these. What has changed, however, is that we now have a systematic set of procedures, supported by expertise and resources from the wider University, that builds in planning to maximise impact as integral to all research (through regular review of the plans of individuals, the Computing Research Cluster and the Research Institute), and recognises work with non-academic groups and impact as elements in calculating time for research, annual research plans and appraisals and is explicit in promotion criteria. The PGR training programme has recently been strengthened to provide explicit training on researcher development and impact). In addition we strongly support the sector's move toward increased open access as a means to effectively disseminate research outcomes to their users and external stakeholders. The following are our more specific plans within each group.

Software Engineering

We are continuing to work towards KT of the outcomes of EBSE research and have recently submitted a research proposal (2nd stage, Leverhulme Trust) with the aim of producing and evaluating guidelines for undertaking KT in SE. The guidelines will include the specific involvement of practitioners at various stages of the KT process. The research will involve close collaboration with industry (both practitioners and decision-makers) who will contribute to a survey (to prioritise the SE topics that will form our case studies), with expert panels (for example for the development of an initial set of guidelines and for evaluating the recommendations that result from the use of the guidelines for specific cases or SE topics) and through dissemination workshops.

Computational Intelligence and Cognitive Science

Given that it is working well, the group intends to continue its strategy of evaluating the potential impact of each new research finding and to progresses basic-research findings to applied research projects and applied-research findings to impact.

With regard to progressing basic-research findings to applied research projects, we have developed a draft work programme to progress our EPSRC-funded basic research findings on extinction factors (Channon output 1) by bringing computational modelling and biological laboratory experiments closer together to verify and refine the theory (grant proposal planned for submission in 2014) with a view to subsequent impact through aiding population management and slowing the world's unnaturally high rate of species extinction: arguably today's most important global challenge. In a second example, we have recently been awarded a BBSRC grant (01/2014-12/2016) to progress our EPSRC-funded basic research on mutation rate control (Channon output 3) to advance knowledge of how bacteria evolve antibiotic resistance, with a view to subsequent impact through helping prevent the spread of antibiotic resistant 'superbugs': a global challenge which the UK Chief Medical Officer has warned poses a 'catastrophic threat' to humanity and which the UK Science Minister put top of the agenda at the 2013 G8 meeting of science ministers.

With regard to progressing applied-research findings to impact, our structural health monitoring work is now being carried forward as part of an interdisciplinary (Computer Science and Physics) programme partially supported by ongoing consultancy work with SciCorr Scientific Detection Systems (a Keele University spin-out company). The promise here is that Electro Magnetic Anomaly Detector (EMAD) data streams can be fused with multi-sensor real-time structural health monitoring data to give better estimates of structural safety and maintenance cycle revisions.
As a result of the work reported in Day output 3, collaborators from Germany and the UK have been identified for a planned application for support from the European Commission's Horizon 2020 funding programme. The aim of this work will be to see if abiotic (for example environmental or meteorological) factors can be incorporated to deliver more accurate forensic entomology post mortem interval estimates.

Research and development work to progress our medical impact from Case Study 1 is continuing through a collaborative project with The Robert Jones & Agnes Hunt Orthopaedic Hospital and CM Technologies Ltd (formerly Chip-Man Technologies Ltd), funded by industry and the BBSRC (01/2013-01/2017). The project's main objective is to construct new engineering toolsets for the quantification of cell characteristics in vitro, using computationally tractable and biologically meaningful metrics extracted via automated high throughput screening. In addition, we are preparing a KTP proposal in cloud security/privacy with a new industrial partner, following on from Lam output 2.

d. Relationship to case studies

Both of our case studies arose directly from the approach to impact taken within the Computational Intelligence and Cognitive Science group (section b) and are summarised in the first two paragraphs on page 2. The success of these and our other impact projects has given us the confidence to form our ongoing and future plans (section c) around these same approaches.