Impact template (REF3a)

Institution: University of Birmingham

Unit of assessment: UoA 11 Computer Science and Informatics

a. Context

The research undertaken in the School spans a broad range of activities, from theoretical research that tackles long term fundamental issues, to applied research that addresses some of the major challenges in society. Our work has made particular impact in the following areas:

Improving digital security. Methods developed in basic theoretical research have been put to successful use in tackling problems related to trusted computing, secure protocols, access control, e-passports, e-voting, web-based malware, privacy in mobile phones and security systems in luxury cars. Our key collaborators and beneficiaries include *governmental bodies* (GCHQ, Passport Office), *standardisation organisations* (International Civil Aviation Organization: e-passports; Trusted Computing Group; 3rd Generation Partnership Project), *public transport* (Oyster card systems). Improved security benefits *the society* at large.

Effecting industrial innovation. Ideas arising from research in computational intelligence and optimisation have been employed to provide solutions to real-world problems in industries operating in constantly changing and uncertain environments. Methods for solving complex network optimization problems benefitted *transport networks*; modelling and automated fault diagnosis improved the design of *water distribution networks* in a city and of the *energy* consumption in buildings. Our software engineering research has led to the development of automated monitoring and fault detection tools for BT that *changed their internal practice*, *improved customer services* and *cut their operating costs*.

Providing new tools and services for health and disability. Our medical imaging and image interpretation research has led to patented technologies (SIAscopy, MoleMate) that improve the accuracy of *diagnosis of skin cancer* and are *more cost-effective than the best practice* in the primary care setting, benefitting both *patients and the NHS*. As a result of research combining automated reasoning and scientific document analysis, people with *visual or print impairments* can now *freely and independently access* mathematical literature via a screen-reader (ChromeVox), developed in collaboration with Google. e-Drama, a system developed from research in AI, natural language processing and distributed simulation in collaboration with charities and media companies, helps *children with difficulties in human interactions* to learn and build confidence through an interactive virtual environment.

Our work has benefitted *industry, government* and *the general public* through *improvements in security, privacy, provision of digital services, transport, the built environment, healthcare and assistive technology for the disabled and elderly*. The impact of this work extends to *the economy, public policy and services, healthcare, education, the community, and culture and creativity*.

b. Approach to impact

Our successful engagement with external users and beneficiaries is built on a foundation of strong research in areas of strategic importance to users' needs, combined with active external outreach which is integral to our research strategy and practice. We generate impact through a range of activities, from the research programmes of individual staff members, to initiation and leadership of international partnerships. Engagement with external users is actively pursued via collaborative and sponsored research projects, secondments and staff exchanges, knowledge transfer schemes, consultancies, research centres, technology and IPR transfer, open source software, and public engagement activities. Examples of the main approaches and their outcomes are given below.

Early engagement through collaborative and sponsored research projects gives beneficiaries prompt access to our research outcomes and allows them direct influence on our research directions and focus. Initial opportunities for external engagement initiated by the School, such as annual Industrial Advisory Board meetings, have led to sponsored research projects and

studentships from Honda, BT, Vodafone, and others. Our collaborations have been supported through schemes such as KTP awards, EPSRC KTS projects, EPSRC CASE studentships and Royal Academy of Engineering Industrial Secondments Scheme. Examples include Bordbar's work with BT (see case study), and Yao's work with Honda that led to a patented design of turbine blade shapes and long-term follow-up funding. Other means of early engagement are training centres (see section (c)) and EPSRC CASE studentships (regularly held with BT, Vodafone, Qinetiq, and others). A CASE award from BT to Yao resulted in a paper which won the2010 BT Gordon Radley Award for Best Author of Innovation "delivering benefits for BT's customers and shareholders".

Secondments and two-way exchange of staff. We regularly host short- and long-term research visitors from industry. Several industrial researchers have formal appointments, including Jeremy Baxter (Qinetiq, Industrial Visitor), Satnam Singh (Google, part-time Professor) and Bernhard Sendhoff (Honda, Honorary Professor). Honda's funding (continuous since 2001) led to two approved patents.

Several academic staff spent substantial periods of time in industry, bringing tangible benefits to the host companies and their clients. Ryan's secondment to HP led to the discovery and later fix of TPM protocol flaws. During his secondment to BT, Bordbar developed important software tools that changed the company's practice and cut operating costs. Cova's secondment to Lastline has led to the commercialization of his research at Birmingham in fighting the malicious web. Sorge's secondment to Google has enabled him to incorporate his research on mathematical document analysis into the latest version of ChromeVox for web accessibility. The success of this approach to impact can be seen from the case studies.

Knowledge transfer secondments (KTS). Many research fellows who work on projects with industrial involvement move afterwards to a collaborating company. Recent examples of research fellows working on Yao's EPSRC KTS projects with multi-national companies include: SAIC (where Schnier contributed to a successful EPSRC bid for car engine management using dynamic multi-objective evolutionary algorithms and later recruited by Vector); The Supply Guys (where Robinson developed data analysis and mining methods which led to significant cost-saving for the company). The long-term impact of such skilled people in industry is significant as it facilitates the transfer of both research outcomes and the skills and expertise of the researchers themselves into industry. They will be the engine for the continuous generation of further impact in the future.

Research centres provide a focal point for external users to access specialist expertise in specific research areas.

The Centre of Excellence for Research in Computational Intelligence and Applications (CERCIA) has worked with more than 100 companies since its inception and has made impact internationally in areas such as warehouse management, financial planning for companies, education, fleet management and e-commerce. As an example, research on robust design of vehicle fleets funded by the Defence Science and Technology Organisation (DSTO) Australia in 2010, was said by a DSTO official to "counteract[s] Australian politicians' "efficiency thinking" that currently tries to reengineer Australia's defence force". Further funding followed.

The USTC-Birmingham Joint Research Institute in Intelligent Computation and Its Applications, co-established with a substantial School involvement, has attracted collaboration requests from United Technologies, Unilever, Baidu, and other companies. Its impact was noted by the British Consulate in Shanghai who offered support, including funding, to further strengthen the collaboration.

The School is an active partner in *the Manufacturing Technology Centre (MTC)* in the areas of intelligent automation, and modelling and simulation for computerised engineering. MTC, established to bridge the gap between academia and industry, has over 50 members from a broad range of industrial sectors including Aero Engine Controls, Airbus and Rolls Royce.

An *EPSRC/GCHQ Academic Centre of Excellence in Cyber Security Research* award to the School is a result of our "strengths in analysis and verification of systems, privacy and security, malware, intrusion detection, web security, botnets, and secure software engineering".

Technology transfer and IP. In the REF period, 11 international patents were filed and/or approved. Ryan and Beale launched a start-up company *CloudTomo* (cloud security) that has raised over £0.5m in TSB and SMART awards and gained official recognition and support from the Scottish government Hi-tech growth team.

Open-source software has proved to be an effective route leading into impact generation and commercial uptake. The School has produced several widely downloaded software packages including PRISM for probabilistic model checking (Parker), MaxTract for PDF to LaTeX/MathML/text conversion (Sorge and Sexton), and UML2Alloy for bridging the gap between the popular but semi-formal UML and formal Alloy Analyzer (Bordbar). These tools have had significant impact in academia, industry and society. Sorge's and Bordbar's work is described in the impact case studies.

Engagement with the public and society. School members are active in many local and national initiatives aimed at *improving computer science education in Schools.*

Jung is involved in the national "*Computing at School*" (CAS) working group whose work led to the announcement by the government of the new computer science curriculum for Schools. We host the annual CAS national conference which brings hundreds of teachers to the School for CPD activities. Examples of best practice, resources and ideas disseminated at the conference make impact on teaching of computer science in schools.

Our academic staff undertake a large number of *public engagement activities*. Notable events include the "Robotville" exhibition at the Science Museum in London (Hawes, 2011) the Lord Kelvin Award Lecture at the 2013 British Science Association meeting (Hawes), "Meet the Scientist" event at the Birmingham ThinkTank (Deghani, 2013). Musolesi's work on human mobility prediction has received wide coverage in mainstream media, and won the Nokia Mobile Data Challenge in 2012.

Support and rewards for impact.
The University supports interaction and engagement with external users through its commercial arm, Alta Innovations Ltd.*,* who assist in the commercial exploitation of research.

The College-level Business Development Managers (BDMs) identify and support strategic industrial partnerships, sponsored research and development, and were instrumental in a number of the initiatives described above.

The School's *flexible approach to managing staff time* contributed to generating impact through supporting sabbaticals, secondments and fellowships, including Medici Fellowships awarded by the University for training in the commercial exploitation of research which has benefitted Sorge's, Sexton's and Bordbar's work (see case studies). Academic staff, research fellows and students are encouraged and given time to attend training courses provided by the University's Research and Commercial Services unit. Research impact is rewarded and recognised via both formal and informal means. It is explicitly included in the University guidelines for senior promotions (recently Ryan and Beale), and in the award of sabbaticals and secondments by the School.

c. Strategy and plans
The key aspects of our strategy to generating impact are:

Proactively seeking external partnerships. This is pursued on an individual level, through sponsored schemes (by research councils, charities, industry), and via School- or university-based centres of excellence that were established specifically to engage with external partners. We actively pursue open-source software as a route towards sustainable impact generation and commercial exploitation.

Early engagement with external users. This ensures that the research directly addresses users' needs; consequently the outcomes are likely to generate impact as the users act as champions for our research.

Fostering high-level long-term strategic partnerships. Such partnerships create infrastructure and enabling mechanisms for impact generation. We make use of University support to appoint senior industrialists to academic positions, establish joint institutes with industry and with overseas partners, and use these to reach out to global companies.

Strategic and flexible management of staff time. The support schemes to release staff time through sabbaticals, secondments and funded fellowships enable us to rapidly take advantage of any collaborative opportunities.

Embedding impact generation, knowledge transfer, and an entrepreneurial culture into all aspects of the School's work. External partners engage with the School via advisory boards (curriculum development, industrial liaison), School committees, learning and teaching (e.g. the "Commercial Programming" module delivered by our industrial partners), project supervision, honorary appointments and seminars, becoming champions for us within their companies and industrial sectors.

Our **strategy for the future** is to continue to develop these successful approaches. Furthermore, we plan to take explicit steps to *increase the transfer of both the research outcomes and the researchers themselves to industry*; the importance of this strategy is seen in the impact of the work presented in the case studies. An important role in this respect can also be played by spin-off companies (such as recently established CloudTomo). We shall capitalise on *the involvement of the industrial sponsors and beneficiaries of research carried out by training programmes* that we co-lead. For example, the PSIBS CDT has over twenty industrial partners, including Smith & Nephew, GlaxoSmithKline, Perkin Elmer, Nikon, Diamond Light Source and NPL, creating significant potential for impact in imaging sciences and biomedical industrial research. Our MRes programme, with funding from Honda for studentships) opens further impact opportunities in the area of intelligent systems which, according to Honda, "will shape our future in a variety of forms, ranging from accident-free mobility to cognitive robotics and from smart process management to the efficient use of resources". *Further areas* where the School's impact is currently developing include human-computer interaction research that aims to embed digital technologies and computing devices seamlessly into society; and robotics, focused on developing autonomous robots that can work with or for humans, e.g. to support elderly people in the home.

d. Relationship to case studies

Four of our case studies are *the direct result of our strategy of releasing time for knowledge transfer and impact generation activities*. Ryan's secondment to HP Labs has led to the discovery of a flaw in TPM protocols and a subsequent fix which has been adopted by the industry. Through his secondment to BT Bordbar has developed an automatic diagnosis tool that is now widely used by BT. Cova's secondment to Lastline has led to the commercialization of Wepawet technologies for web security. Sorge's Medici Fellowship award enabled him to devote his time to the development of MaxTract for visually challenged people. The technology behind MaxTract was later transferred to Google's ChromeVox through his sabbatical at Google. Claridge's SIAScopy work is *an example of the effectiveness of our strategy of proactively seeking early engagement with industry*. This case also illustrates the value of the transfer of highly skilled staff as well as research outcomes into industry. The company established to commercialise this research employed the student who worked on the project which facilitated the rapid market deployment and impact of this work.