Institution: University of the West of England, Bristol (UWE)

Unit of Assessment: Computer Science & Informatics (11)

a. Context

The research undertaken by the four groups within the Unit ranges from basic science to knowledge transfer. The groups are: 1) the Unconventional Computing Group (UCG); 2) the Bristol Robotics Laboratory (BRL); 3) the Artificial Intelligence Group (AIG); and 4) the Centre for Complex Cooperative Systems (C3S). The Unit's research has involved a broad variety of non-academic entities over the reporting period: multi-national corporations (e.g., Hewlett Packard), European companies (e.g., Airbus), European organisations (e.g., CERN), large UK companies (e.g., Wessex Water), UK companies (e.g., via five Knowledge Transfer Partnerships), and the many companies involved as partners in European Union and UK Research Council projects.

The actual non-academic impacts over the reporting period have primarily been economic and made by C3S, with contributions to science policy (via the Department for Innovation, Universities & Skills) and the societal benefits of improved data security (via the Office for National Statistics) also being made by the BRL and AIG respectively. Each of the groups seeks to maintain a balance between fundamental and applied research in pursuit of impact, with recognition that the timescales to its achievement will necessarily vary according to its nature and maturity. For example, economic impact in the areas of microbial fuel cells and memristors, by BRL and UCG respectively, are anticipated in future and with relevant relationships establishing.

b. Approach to impact

UWE has an increasing reputation nationally and internationally, as one of the leading and fastest growing post-92 universities for research, with an emphasis on interdisciplinary and collaborative research that makes a positive difference to our economy and society. The Unit's approach to impact is closely aligned to this, with a tradition of fostering pathways to impact through collaboration with industry, typically focused on economic gain. The origins of this approach can be traced back over twenty years to such initiatives as the DTI and Inmos co-funded Bristol Transputer Centre hosted in the Unit's Faculty.

The aim is to build long-term, multi-dimensional relationships with an ever-widening set of partners to achieve impact. These are typically initiated through **enquiries**, e.g., to/from UWE's Research, Business & Innovation (RBI) unit, **personal networks**, e.g., via ex-students/researchers, or **academic networks**, e.g., via discipline communities, project collaborators. The next step is **consultancy agreements**, **student co-supervision**, or to become **partners on small/medium sized funded projects** thereby establishing trust, respect, and an interchange of technical know-how and appreciation of mutual competences. The aim is then to obtain **larger projects**, potentially leading to the development of **adopted/exploitable product(s)** or **policy change(s)**. In short, impact is through partnership.

Groups in the Unit have long-established track records of participating in schemes to encourage impact, often identified by RBI. For example, following a period of consultancy work won under tender 2006-07, the AIG (**Smith**) undertook a CASE Award with the Office for National Statistics (ONS) 2007-10, in collaboration with UWE's Engineering Modelling and Simulation Group (EMS, UoA15). National and other data providers release information which decision makers in Government, business and health services use to improve the economic and physical well-being of the nation. When publishing such statistical tables, data providers have a duty to preserve respondent anonymity and ensure that individual respondents' data cannot be calculable. The CASE Award led to a PhD completion and went well beyond its original objectives after the discovery of a serious flaw in existing protection methods. To minimise the risk that a well-publicised incident of disclosure would pose to data collection agencies, the AIG and EMS undertook a further study and risk analysis, funded by and in collaboration with ONS. This also involved liaising with Stats-Netherlands and Statistics-Germany, who maintain the eurostat tool "Tau-argus". Recognition of the seriousness of the findings from this work has led to the adoption of the AIG/EMS methodology at ONS and additional ONS funding to integrate it into existing

systems under licence from UWE, via its RBI unit. As of summer 2013, AIG/EMS auditing and protection tools are now also becoming integrated into the Tau-argus which is used by national statistics agencies and others. The work is on-going through consultancy and contract research agreements, supported by RBI. This work has already had impact upon UK Government policy (Case Study by EMS, UoA15) and impact upon methodology is anticipated in the near future.

Special interest groups or communities of users that can realise tangible benefit from UWE research can be engaged directly through joint participation in appropriately designed EU projects. For example, C3S's component of the EU FP7 project N4U (**McClatchey,** 2007-13, following on from neuGRID) conducted an extensive study of the software engineering requirements of the worldwide community of neuroscientific researchers involved with Alzheimer's disease and has instantiated what is quickly becoming the standard infrastructure for the study of complex 3D MRI images across the neuroimaging discipline. This is evidenced by adoption by the CBRAIN users in Canada, the BIRN/Loni researchers in the USA, along with a growing European community of researchers: use has grown from scores of researchers in 2008 to over 1500 in 2013. The C3S software enhances the sharing of data and analyses, thereby improving aspects of disease discovery, drug therapy and prescriptive treatment.

The Unit increasingly collaborates with UWE's Science Communication Unit (SCU) which is advancing the science of public engagement. For example, led by BRL (**Winfield**) jointly with SCU, the EPSRC Stage Award Walking with Robots (WWR) (EP/D05656X/1) and subsequent related projects (EP/E06308X/1, EP/F026080/1, EP/G06895X/1) created significant impact in terms of raising public awareness of intelligent robotics among a wide range of audiences, including policymakers. WWR brought together leading researchers in intelligent robotics with science communication experts. In three years this grew into a national network of researchers, at all levels, from sixteen universities together with engineers from a wide range of companies. Together they showcased robotics research at over 100 events across the UK, attended by around 80,000 people. BRL robotics research strongly featured in WWR events. WWR raised the profile, and promoted the potential of intelligent robotics with policymakers by co-organising, with the Department for Innovation, Universities & Skills, a Westminster briefing with live robot demonstrators; the event was chaired by Lord Strathclyde and attended by 130 parliamentarians. WWR raised the level of public debate on the likely societal impact of robotics; for instance WWR co-investigators held a press conference to challenge a report on 'robot rights', which resulted in significant media coverage, and brought a more considered approach to the discourse on robot futures. WWR was recognised by the RAEng with the award of the Rooke Medal for the best Public Promotion of Engineering in 2010. An EPSRC Senior Media Fellowship "Intelligent Robots in Science & Society" (EP/G063052/1) continued the impact of WWR; notably including co-organisation of a joint AHRC/EPSRC initiative on robot ethics resulting in publication of EPSRC's 'principles of robotics'. Such work continues to be supported via UWE's partnership with the University of Bristol in the National Coordinating Centre for Public Engagement. This was established in 2008 as part of the £9.2m Beacons for Public Engagement funded by HEFCE, RCUK and the Wellcome Trust.

An example of the Unit's flexible and imaginative approach to impact building from such work is the use of European Regional Development Funds in a "knowledge escalator" project (**Smith**, 2010-11), identified through UWE's RBI. The AIG's involvement in the EU FP7 DynaVis project (**Smith**, 2005-09) created innovative dynamically reconfigurable machine vision systems and the outcomes were exploited by partners ranging from end-users (e.g., Sony DADC), commercial machine vision system providers (e.g., Asentics GMBH), other universities, as well as Eurexcel (the European Association of Innovating SMEs) to maximise the impact of this research in other applications. Thereafter, knowledge escalator funds were used by the AIG to re-purpose the primary research outcomes from DynaVis in collaboration with local web design (e.g., CX Partners Ltd) and usability (e.g., Pure Usability) companies, creating intelligent interactive tools for web site design ("IPAT"). Appropriate licensing for wider release is currently under development through RBI.

As highlighted above, the Unit's approach to impact is underpinned by UWE's Research, Business & Innovation unit, tasked with facilitating partnership and impact through a wide range of activities, including collaborative and contract research, knowledge and technology transfer, commercialisation, consultancy, enterprise, professional development, and a range of different

types of business and community engagement including innovation networks. For example, RBI was heavily involved in both Impact Case Studies submitted by the Unit, providing support for intellectual property protection and licensing, spin-out advice and support, etc. Other recent activity for the Unit includes supporting five Knowledge Transfer Partnerships and obtaining a patent (WO 2012/120314 A2) relating to work emerging from an EPSRC Career Acceleration Fellowship in BRL (EP/1004653/1, **Ieropoulos**) on microbial fuel cells, in collaboration with Wessex Water.

c. Strategy and plans

One of UWE's four key priorities in its recent 2020 strategy is "Research with Impact**:** world-class performance in selected areas of research that meets the needs of a sustainable economy and society, and feeds the scholarship and enquiry that underpins our learning and teaching." The Unit will address this strategy in terms of impact beyond academia by:

1. continuing the current approach of establishing and evolving long-term research and development partnerships with national and international industries, organisations and academic leaders through which impact is forged (with increased strategic planning of partner secondments, co-supervision and co-bidding);
2. engaging Unit members in reflective exchange of impact pathway development experiences (thereby expanding a culture of critical and proactive thinking around impact alongside mentoring support, in turn influencing forward planning of related activities);
3. putting in place further entrepreneurship training in association with RBI that helps staff expand their understanding and confidence surrounding how to promote, protect and exploit their intellectual property; and
4. embedding (in partnership with the SCU) science communication into major projects at their outset in order to foster stronger and wider interest from and dialogue with users (leading to greater engagement of staff in communication of their research to non-academic audiences).

d. Relationship to case studies

Each of the submitted Impact Case Studies reflects the Unit's collaborative and evolutionary approach to impact - underlining how impact arises from working *with* users.

The CRISTAL study (Impact Case Study 1) demonstrates the value of developing and exploiting long-term partnerships both with large European organisations (such as CERN, where CRISTAL has been used to support the construction and running of the Electromagnetic Calorimeter of the CMS experiment at the Large Hadron Collider) and commercial companies (e.g. M1i, which has exploited CRISTAL as the Agilium product since 2004). The recent award of €1.5M to UWE, M1i and Alpha3i in the CRISTAL-ISE EC Industry-Academic Partnership Pathway is a clear exemplar of this strategy. This work was initiated by C3S in 1996 through CERN's Doctoral Scheme (4 PhD positions, **McClatchey**), grew with a Royal Academy of Engineering International Fellowship (**McClatchey**, 1997-99), and then developed into a number of EU projects (Health-e-Child, neuGRID, N4U, CRISTAL-ISE, **McClatchey, Liaquat**). This research has led to C3S's establishment of start-up Technoledge to further improve the impact deriving from CRISTAL.

The OntoREM study (Impact Case Study 2) also demonstrates the Unit's approach to impact through a growing relationship with a commercial partner but over a shorter timescale. In 2006 C3S (**Odeh**) was approached by Airbus (Filton, Bristol) regarding application of UWE work on requirements specification to aircraft programmes which resulted in an initial co-supervised MSc Dissertation project. A PhD studentship was subsequently funded by Airbus, which was followed by contract research funding, all of which has led to the development of a novel requirements engineering methodology that is knowledge-centric in relation to the associated requirements engineering process. It has demonstrated that such new approaches can be co-developed with industry and can be used in practice for next generation product development and exploitation, yielding appreciable cost and time savings. Moreover this work has also led to a patent being filed in the US and OntoREM has been taken up by Airbus for application in its Photonics projects as part of efforts being exerted to generalise the application of OntoREM in Airbus and other industries.