Institution: Bangor University

Unit of Assessment: Panel B, UoA 11, Computer Science and Informatics

a. Context

At Bangor University we combine knowledge creation of international excellence with innovation and communication to ensure all areas of our research make economic, social and cultural advancements. Our pathway to impact is throughout the life cycle of research – from idea inception through delivery and post award/activity. As such, our processes for embedding impact in research activities and for recording impact reflect this.

Within the School of Computer Science, research expertise in Visualization and Medical Graphics, Knowledge Discovery, and Complex System Modelling has been exploited to support industry, the NHS, and industry-facing government initiatives. Our research is application driven. We produce results that have immediate impact for end users. Industrial organisations from the many Small to Medium-size Enterprises in the region to large multi-national companies actively seek our collaboration and advice. We are also pro-active in outreach activities, and are involved in various standards and policy initiatives.

b. Approach to impact

The nature of relationships with non-academic partners during the REF census period is mutually beneficial and varies greatly. With industry, **Mansoor** is the Bangor University lead for Software Alliance Wales (SAW), with a mission to up-skill businesses by delivering workshops, CPD training, and linking students with local businesses to work on a broad range of projects (including Access to Masters schemes). SAW has aided 196 companies across the region in the last two years including NMi ltd, The Book People, and Semantise Ltd. Consultancy for global industry is evidenced by **Mantiuk's** collaboration with Dolby Laboratories on quantifying image quality in computer graphics; and with Sharp Laboratories Europe on the next generation of stereoscopic high dynamic range displays. **Kuncheva's** monograph *Combining Pattern Classifiers* has sold over 1250 copies and offers a background in pattern classifier ensembles, which is now regarded as one of the most successful pattern recognition technologies with many real-world applications in areas such as image processing, medical diagnosis, and network security.

Consultancy for government and standards organisations includes **Hope's** role as a member of the Science Advisory Council for Wales that reports and provides advice to the Chief Scientific Adviser for Wales on a full range of science, technology, engineering and mathematics issues. **John** is co-chair of the Web3D's consortium's Medical Working Group. The Web3D Consortium develop the ISO ratified X3D open source standard. This working group is extending the standard to add functionality needed for medical applications e.g. volume rendering, and is also actively engaged with the DICOM standards committee. **Mantiuk** is actively involved in the EU COST Action IC1005 "HDRi: The digital capture, storage, transmission and display of real-world lighting", which is producing the HDR JPEG extension standard for high dynamic range video formats, quality metrics, and colour representations.

With funding from the Welsh Government through NISCHR (National Institute for Social Care and Health Research), **John** and **Lim** established an Advanced Medical Imaging and Visualization unit. The unit works directly with the NHS with the purpose to solve practical problems using visual computing technologies. (http://medical-imaging.org.uk/). John also sits on the pan-Wales NISCHR Operational Steering Group, which coordinates all NICSHR funded research activities.

Follow through to identify resulting impacts is evidenced by many successful case studies with our collaborators. One impact from the SAW project resulted from the courses delivered by the Bangor hub on iPhone and Android development. A5 Multimedia Ltd. (Wrexham) was one beneficiary and they were able to release a commercial app that as well as selling in its own right, has become a showcase for the company's development team – an effective way to kick-start a brand new service offering.

John established the Research Institute of Visual Computing (RIVIC) with a £5M grant from the Wales Government in 2009 after Bangor successfully coordinated a funding proposal with Aberystwyth, Cardiff and Swansea. An important element in the proposal was to establish dedicated knowledge exploitation activities to maximise the impact of the research outputs from the institute. To date 171 companies have been contacted and 101 companies assisted in using visual computing technologies in their businesses. Further, an income of £1.2 million of industrial funding has been generated for RIVIC as a result of this follow through from research to industry.

An agile approach to opportunities that achieve impact is fundamental to the success of the school. For example, **Roberts** identified that emerging research results in Visual Analytics could be exploited in the priority area of Data to Knowledge. He was a founding member of the UK Visual Analytics Consortium (UKVAC) that is now working with the support of the US Department of Homeland Security via the US National Visualization and Analytics Center at Pacific Northwest National Laboratory, Washington State, and in close collaboration with the UK Home Office. This has also resulted in other close links with industry: EADS for situation awareness activities and Data Exchange (DX) on global data trading. DX changed their company strategy to data analysis services as a result of this work and it was instrumental in their decision to base the company in North Wales. Graduates from the school have subsequently been recruited by DX.

Funding success from the Welsh Government £70M "Academic Expertise For Business" (A4B) scheme has also demonstrated our ability to quickly respond to opportunities to disseminate research to industry. The VRLink Project (**Roberts**) is developing a special Interest Group for Virtual Environment and Real Environment Knowledge Exchange. The New Computing Technologies Cluster – Wales (**Mansoor**) is bringing together large corporations and key scientists, organisations and companies to collaboratively consider the development of best practice in the sector, nationally and internationally. This will explore and utilise new technologies such as Cloud Computing, Intelligent Sensor Networks and Ubiquitous Computing, Next Generation Networks, Secure Communication and Supercomputing. These activities provide industry with a route to fast adoption of new technologies. The VRLink project also directly resulted in two successful EU Framework 7 proposals: projects IVY and EVIVA have developed and evaluated a virtual collaborative training environment for interpreters.

Staff are enabled to achieve impact by the provision of specialist equipment, central support for patenting of technology, and encouragement to establish spin-out companies. For example, **Mansoor** is a director of spin out company CAST Ltd. One particularly successful project was VSAR - Viewers' Situational and Spatial Awareness for Applied Risk and Reasoning. This £3.1M collaborative project, co-funded by a grant from the Technology Strategy Board involved provided the BBC, IBM, NPL and Serco with novel software for emergency planning exercises.

The specialist equipment that underpins much of the research impact includes a rear projected stereoscopic powerwall (2.8m by 1.8m screen), a wide range of haptics devices, various desktop stereo and head mounted displays, high resolution and high speed cameras, a 3D printer, magnetic and optical trackers, and an eye tracker. In addition, the Visual Perception laboratory is set up for conducting subjective experiments measuring performance of the visual system as well as quality evaluation of visual content. The laboratory provides high quality, colorimetrically calibrated displays and well controlled viewing conditions. A unique piece of equipment is a custom-built high dynamic range display, which produces images of extremely large contrast (up to 240,000:1) and brightness (up to 2,500 cd/m^2).

Institutional facilities and expertise are utilised to share best practice and maximise resources and potential for cross-disciplinary synergy. Responsibility for fostering and assessing research with impact lies with the University Research Strategy Task Group (which includes **John** as a member). The University has introduced annual Impact Awards to provide an opportunity for staff to showcase examples of excellence in Public Policy and/or Public Services, Culture and Society, and, Business Performance and/or Outstanding Innovation.

c. Strategy and plans

The core of our strategy is to fully utilise the expertise and infrastructure available within the school and university to both advance research and maximise non-academic impact. One of the EPSRC priority areas is "Data to Knowledge" and we are well placed to assist industry in this fast growing area as a result of our research specialisms, e.g. through the A4B scheme. The initiatives described above deliver valuable technical support and work-force up-skilling, and will be continued and built upon to ensure that we are successful in being a catalyst for industry, the NHS and other non-academic users to benefit from new technologies. The work of our early career academics will be fundamental to our future success and they will be supported and mentored to achieve impact: **Vidal** with his optimisation of PET reconstruction for radiotherapy treatment planning; **ap Cenydd** on novel technologies for medical procedures training; and **Weng** on her work in multimedia security and forensics.

Impact will be further enabled through significant infrastructure investments in Bangor and Wales:

- High Performance Computing (HPC) Wales is a partnership between the Welsh universities, Government and Fujitsu. The supercomputing infrastructure and service provided is unique in the UK and gives businesses and researchers access to world-class, secure and easy to use high performance computing technology.
- The university's major strategic development of a £46M Arts and Innovation Centre 'PONTIO'; promoting cross disciplinary research and providing a public platform for knowledge exchange in the strategic areas of Environment, Health and Culture. The school is particularly active in the latter two domains.
- The Bangor University Science Park, a £10M investment from the Welsh Government, planned for completion in autumn 2014, will provide facilities for business incubation and university spin-outs.

Outreach activities are also an important element of our strategy to encourage and develop the next generation of computer scientists. **Teahan's** new e-book series on Artificial Intelligence (Bookboon) has been downloaded over 300,000 times in 2012 and is introducing international students to this topic. Technocamps (**Mansoor**) is a successful project run from within the school that is targeted at inspiring young people to take an interest in Computer Science. Its primary outputs are to engage with 11-19 year olds to inspire the participants in furthering their studies in STEM subjects. Within the last year Technocamps has engaged with over 400 participants of which over 100 have returned for further sessions. We are actively encouraging schools to adopt the new curriculum as this will drive the future intake of undergraduates. We also host and organise the annual Royal Institution Mathematics Masterclasses for Young People in North West Wales (**John**). Between 50 and 60 school children are selected by their schools to attend this popular event each year.

d. Relationship to case studies

Our strategy to collaborate with the NHS is demonstrated by the impact described in the case study: "Minimally Invasive Procedural Training for Clinicians Using Virtual Patients". The Advanced Medical Imaging and Visualization Unit provides an immediate conduit for fast deployment of the results from research in this area into hospitals. We have invested in both people and infrastructure to build an international reputation in this area, and this is paying dividends.

Collaboration with industry through joint supervision of research projects is a successful part of our on-going impact strategy. The relationship with First Hydro Company has been an exemplar of this approach. This work initially took the form of student projects, which then resulted in the contracted research that is described in the case study: 'Improving the Performance of Dinorwig Hydro Power Station'. The real-time simulations delivered to the company yielded tangible economic benefits. Student involvement in these research projects has led to a number of graduates being recruited by the company.