Institution: University of Ulster

Unit of Assessment: 11: Computer Science and Informatics

a. Context

Ulster's Computer Science Research Institute's (CSRI) main user groups and beneficiaries are:

- Patients with cognitive impairments, their carers and associated healthcare professionals requiring assistive technologies; individuals and agencies requiring technologies to support active and healthy aging; companies in the healthcare technologies sector developing new sensor-based products and services; manufacturers of sports and activity-wear with embedded biometric and environmental sensor capabilities.
- Healthcare managers requiring data analytic tools to assess and improve clinical outcomes and patient management; clinicians requiring development and assessment of IT-based therapeutic and rehabilitation programmes, and diagnostic healthcare technologies.
- Companies in the telecommunications sector developing new protocols and services; and rural communities in India requiring low-cost ICT services to support healthcare and agriculture.
- Companies developing products for intelligent document and information management and search, and technical services for image and video-based security applications.

Economic impacts through new or improved products, processes and services for companies in the healthcare technologies and technological garments sectors have been derived from multidisciplinary research within the Smart Environments Research Group (SERG) on sensor-based and assistive technologies. Start-up businesses have been created from research on connected health, intelligent information search tools and steganography in SERG, the Artificial Intelligence & Applications (AIA) group and the Intelligent Systems Research Centre (ISRC), respectively. Health impacts are being derived via a range of research activities: improved patient outcomes from research in SERG on assistive technologies for healthcare and independent living; improved health services from research on modelling of patient management and healthcare technology assessment in both the Information & Communication Engineering (ICE) group and SERG; and impacts on clinical practitioners and services through research in ISRC on neurology of depression and mental illness and on brain-computer interfacing, and through research in SERG on body surface potential mapping and recording protocols for electrocardiology. Impacts on healthcare policy are being derived through research in ICE on cost-effectiveness of interventions; and healthcare delivery applications are being developed within the IU-ATC consortium through research on next generation networks to improve quality of life in developing countries.

b. Approach to impact

The underpinning approach to enabling research impact has been through alignment of research activities with specific aspects of EPSRC and RCUK Cross-council Themes and EU Information Society initiatives for which potential research impact has been clearly identified. Particular alignment is on assistive healthcare technologies, ageing well, independent living, and healthcare management within EPSRC Healthcare Technologies and ESRC New Dynamics of Ageing themes and EU Ambient Assisted Living Joint Programme; telecommunications network management and distributed sensor networks within EPSRC ICT theme; cognitive systems and robotics, neuro-bio-inspired systems, accessible and inclusive ICT, and personal health systems and e-inclusion within the ICT theme of EU FP6 and FP7; and increasing the security of citizens within EU FP7 Security theme. Correspondingly, strategic investment has been made in facilities and infrastructure to support and expand research within these themes: BCI systems and, most recently, a £2.3M MEG imaging system in ISRC; smart labs with simulated living environments, a full body scanner, and community-based healthcare technology test-beds in SERG/AIA; and in ICE, internationally shared test-beds for telecoms network analytics, and access to a high-speed interconnect to N. America.

As a principal approach to enabling research impact, CSRI engages with industrial and healthcare partners in strategic projects that target impact, and develops follow-up for sustained post-project relationships. CSRI has worked directly with healthcare professionals, patients and industrialists in multi-disciplinary partnerships in the EPSRC-funded projects RIGHT, to characterise healthcare problem domains in terms of models and simulation tools, MATCH and MATCH PLUS, to develop decision support tools for patient management and facilitate uptake of assistive technologies for dementia patients and carers, and SMART, enabling self-management for persons with long-term chronic conditions. Similarly, in assistive technologies, healthy ageing and independent living, partnerships with healthcare professionals, user groups and industrialists have been established

through extensive project funding (EPSRC; ESRC; MRC; EU FP6, FP7 and InterReg IIIa; HPSSNI; Alzheimer's Association; and the Nestling Technologies Initiative) totalling over £2M, with follow-on activities providing opportunities for both Health and Economic impact. For example, an intelligent medication management system was developed through collaboration with an SME partner in EU FP5, and is now commercially available. Impact from research on intelligent telecommunication network resource and performance management is also enabled through strategic partnerships. CSRI has led UK strategy for impact-focussed research co-operation by establishing the India-UK Advanced Technology Centre (IU-ATC) in next generation networks, systems and services. IU-ATC forms part of a strategic inter-governmental initiative to foster scientific collaboration between UK and Indian scientists and industrial engineers; IU-ATC includes major industrial partners in UK and India (BT, Toshiba, InfoSys, Wipro, Sasken, Tejas) and focuses on developing low-cost energy-efficient technologies for applications to healthcare, agriculture, environmental monitoring, and emergency response. IU-ATC is structured so that industrial and academic partners work together within each research theme to identify and accelerate impact. The 2012 RCUK Impact Review highlights that "The UK is now third on the Indian Government's preferred list of partner research collaborators, from previously not being on the list, due to the IU-ATC". The 2012 RCUK Digital Economy Impact Review Panel report cites IU-ATC as a major example of impact, with significant impacts on Knowledge Economy and Influencing Policy (Economy and Society), and "significant success in gaining further R&D investment, as well as generating international engagement". Partnering sector-leading companies in such large scale projects also enables CSRI to participate in identifying global challenges and focus its research on specific technological solutions to address them. For example, the IU-ATC partnership with BT has shaped our strategies for cloud computing research and development of a Centre for Cloud Computing Technologies.

Again through industrial and healthcare partnerships, CSRI has established and maintains long-standing collaborations with end-users. Funded collaborations with Belfast City Hospital's Memory Clinic and the Northern Health Trust in NI enable user-groups of dementia patients and their carers to inform the development and assessment of cognitive prosthetics. CSRI engages with large-scale user groups to evaluate and characterise the likelihood of uptake and potential benefits and cost savings of assistive technologies, including persons with cognitive impairments in the Cache County (Utah) Study on Memory in Ageing. The multidisciplinary ESRC-funded project Design for Ageing Well enables user groups of active 60-75 year-olds, recruited via walking groups, to inform design and development of technology-enabled garments that encourage and facilitate an active lifestyle for older people. This project has led to commercially available garments that embody technologies for physiological monitoring and has been selected by ESRC as an exemplar Impact Case Study. Since 2008, 8 projects (Autonomous Multiclass BCIs, BRAIN, CogKnow, Design for Ageing Well, MPVS, MyHealth@Age, Nocturnal, SMART) have featured in the Dept. of Health annual Parliamentary Reports on R&D in Assistive Technology. Users with long-term conditions such as stroke, chronic pain and chronic heart failure inform our design of self-management based assistive technologies within the EPSRC SMART project. A major user-group initiative to assess smart home technologies applied to support health and social care has been established through collaboration with the North-East Health Services Executive (Republic of Ireland) and Dundalk Council in the Nestling Technologies Initiative: real living environments have been built, offering 16 intelligent homes that promote and sustain independence and well-being for older people.

Facilitated by InvestNI, direct partnerships with industry are established to focus research onto industrially relevant challenges and enable impact. SAP directly provides funding of £0.5M for 3 projects: PERSERVE, DeepFlow, and STRATOSPHERE. As well as partnership through IU-ATC, BT funds 4 EPSRC CASE studentships in telecommunication network resource and performance management, including industrial internships at BT Research Labs, Martlesham, for researchers to develop joint research programmes with BT team leaders; joint research has led to BT submitting a patent application on management of distributed applications in the cloud (Patent No. 10251589.7-2211, Sept. 2010). Seagate Technologies, Intel, IN2, 360 Production, Bath Institute of Medical Engineering, and Core Systems also fund DEL CAST studentships. Through the University's Office of Innovation (OI), CSRI strongly supports Knowledge Transfer Partnerships (KTPs) with local industries, supervising employees in 9 KTPs (totalling £894K) within the REF period. CSRI also supports knowledge transfer through supervising company employees in 57 new FUSION projects since 2008 (total funding value £2.63M), winning the 2012 "Project of the Year" award for work with

Shimmer Research, Dublin, and leading to new Shimmer products and services. (The FUSION programme is funded by InterTrade Ireland for knowledge/technology transfer to SMEs in RoI). CSRI also sponsors a programme of Visiting Professorships, including appointments that establish and maintain industrial and healthcare sector partnerships. Current such appointees are Nader Azarmi, Director of EBTIC Research & Innovation Centre, UAE; Roy Harper, Consultant Physician, Ulster Hospital, Belfast; and Sean Gaines, Director of International Projects, Vicomtech, Spain.

The OI facilitates staff to explore and develop commercial potential of their research, undertaking IP and market assessment. Since 2008, CSRI has 54 Technology Disclosures (involving 19 staff), and 20 GB/EU/US/International patents (9 granted; 11 pending). OI offers competitive "Proof-of-Principle" (PoP) awards to help staff demonstrate an invention's commercial potential and identify additional development support required to take it closer to market: since 2008 CSRI has 11 PoP awards, totalling £88K. Through OI, InvestNI offers competitive "Proof-of-Concept" (PoC) awards of up to £100K to support pre-commercialisation: CSRI has 6 PoC awards since 2008 (total £599K: drug dosage monitoring devices, secure digital watermarking, surveillance via gait identification, brainwave-controlled devices, delivery of streaming music, autonomic computing environments). For commercialisation, the University directs investment and incubates its spin-out companies through its knowledge and technology venturing company, Innovation Ulster Ltd., securing and/or contributing to early stage investment. *SophiaSearch*, *HidInImage* and *CENT Healthcare* have been spun-out in this way from research in CSRI on intelligent searching of large scale document repositories, embedded encryption technologies, and connected health technologies, respectively.

CSRI supports industrial visits/exchanges, both inward and outward. For example, Nugent held an Industrial Fellowship in 2012 with I+, an Italian SME in e-health. CSRI also takes advantage of schemes designed to encourage entrepreneurship and enable impact. The annual NI Science Park's £25K Entrepreneurship Award competition identifies IP from publicly funded research; 10 proposals from CSRI have reached the final stage of the competition since 2008, winning Hi-tech, Digital Media, and Bio-tech categories 3 times. OI offers competitive "Impact Awards" that have been obtained by CSRI to explore opportunities for impact (4 awards since 2010: low-cost assistive technologies for rural communities; public engagement in understanding of research in intelligent systems; hosting the 2010 Computers in Cardiology international conference; and modelling phases of care for stroke patients). The University formally recognises staff achievement in relation to research impact, with Academic Enterprise one of three tracks for personal promotion, and an annual Distinguished Academic Enterprise Fellowship award (2 in Computer Science since 2008).

c. Strategy and plans

A major vehicle for enabling impact has been the establishment of research centres that embody impact within their objectives and infrastructure. The NI Knowledge Engineering Lab (NIKEL) was established in 1992 with funding from International Computers Ltd. Projects within NIKEL spurred the establishment of research facilities for healthcare informatics and technologies to support independent living. The Centre for Software Process Technologies (CSPT) was established in 2002, with EU and government agency Centre of Excellence funding, to influence improvements in industry process standards. CSPT continues to lead industry best practice and, by working with NI software companies, develop a high quality ICT industry. ISRC, established in 2007 with funding of £14.5M, has a full-time business manager and integrated business realisation unit and incubator facilities, with a focus on technology transfer and new industrial and community partnerships to inspire and support regional economic development. ISRC embraces the previously established Electronics Production and Innovation Centre, which provides a managed workspace giving both established and incubation companies access to specialised equipment, facilities and expertise.

Plans for structured and sustainable embedding of impact into the CSRI research and innovation strategy focus on establishing Competence Centres, initially funded through InvestNI's strategic programme. Within InvestNI's Corporate Plan, Competence Centres are collaborative entities established and led by industrial partners to undertake a commercially focused research programme designed to increase company competitiveness and stimulate SME engagement in research-led product development. CSRI is currently partnering industry in establishing 3 InvestNI-funded Competence Centres. One is already approved in 2013 with initial 5-year funding of £5.0M:

- ***Connected Health Innovation Centre (CHIC)***

  CHIC will lead transformational research in e-health, tele-monitoring, and home-based care that aligns care needs with technology providers, researchers and clinical experience, building on

partnerships with Health and Social Care Trusts, universities, investment organisations and Government. The research programme is directed at commercial opportunities in global health-care transformation by a collaboration of organisations, including providers of healthcare and healthcare devices (Heartsine, Mindray Medical Int'l, Randox, CIGA Healthcare), and software, analytics, and digital media services (Accenture, Aridhia Informatics, Kainos Sw, EMC(UK)).

The first stages of a second Competence Centre, that will enable translation of intelligent systems research to market analytics, have been established via £537K funding from InvestNI and industry:

- ***Capital Markets Engineering Centre***
  The Capital Markets sector is strategically important to NI to deliver a strong knowledge-based economy, high-value employment, and FDI. The local sector has world-leading technology providers and end customers, comprising both local indigenous businesses and multi-nationals. This Centre comprises 5 major financial sector organisations (NYSE, Fidessa, First Derivatives, Citi, Singularity) committed to pursue R&D to create IP and differentiate the region from other geographical locations. The companies have already established a Capital Markets Programme, funding 10 PhD studentships (£300K): 5 students based in ISRC at Ulster and 5 in ECIT at QUB.

A third Competence Centre proposal is well developed, and will be submitted to InvestNI in 2014:

- ***Cloud Computing Technologies Centre***
  Led by sector-leading industrial partners: BT, Intel, Microsoft, and IBM, and involving SMEs in the *Whisple* network of NI ICT companies (Equiniti ICS, SQS, Anaeko, Replify, Goldblatt McGuigan), this Centre will focus on the development of cloud computing technologies to address issues of network virtualisation, security, "big data", mobility, performance management (QoS), open stack, and migration of legacy systems and applications.

Expanding engagement with industrial and healthcare partners in strategic projects that target impact continues to be part of CSRI strategy. With overall Phase 2 funding of £10.2M from EPSRC and the Indian DST (2012-2014), industrial collaborations established within IU-ATC will continue to enable impact for CSRI research in telecommunication network performance management, converged networks, and context-aware energy protocols. Most recently, CSRI is also leading UK research collaboration in food safety technologies through a theme within EPSRC's IT as a Utility Network+ to enhance access to, and trust in, IT facilities. The consortia established through the MATCH, MATCH PLUS, and Design for Aging Well projects, and the healthcare and social partnerships developed through the Nestling initiative are the basis of future collaborative proposals to deliver impact through the uptake of technologies for healthcare management, assistive healthcare delivery, independent living and healthy ageing. Plans for impact in connected health will leverage capital investment of £482K obtained from InvestNI (Apr 2013-Sep 2016) for a suite of both University-based and community-based test-bed and demonstrator facilities to provide proof-of-concept and evaluation services for new commercial devices, and progression of pre-market devices into commercially viable Connected Health systems and Assisted Living products. New InvestNI R&D funding of £457K (Aug 2013-Aug 2016) will connect NETCOM to the Hibernia Network landing station adjacent to Coleraine campus, giving access to the Project Kelvin high-speed interconnect to N. America: NETCOM will be the "Research Lab with fastest connections (to USA) in Western Europe", in a unique position to leverage UK-USA and NI-RoI-USA joint research programmes that involve industrial collaborations. CSRI is a founding member of the IEEE Inter-Cloud Test-bed Project (Oct 2013), which includes 21 cloud and network service providers, cloud-enabling companies, and academic and industry research institutions from US, the Asia-Pacific region, and Europe, and will contribute to developing standards for cloud-to-cloud interworking.

d. Relationship to case studies

The Modelling Phases of Care case study exemplifies the unit's focus on influencing cost-effective and patient-centred healthcare management and delivery, based on engagement with healthcare partners in strategic projects, end-user collaboration, and facilitation by OI. The unit's focus on economic and health impacts through improved assistive technology products is exemplified by the "DGHome" case study, based on funded partnerships with healthcare providers and industry, user group evaluation, an industrial fellowship, and investment for spin-out; the "wearable technologies" case study, based on partnership with industry via a funded multidisciplinary strategic project, user group participation, and direct industry partnership; and the "Shimmer Research" case study, based on direct industry partnership supported by a FUSION award. The "DANTE" case study is also based on developments from funded project collaboration and direct industry partnership.