Institution: University of Ulster

Unit of Assessment: 11: Computer Science and Informatics

Title of case study: New software products for programming wireless sensor networks

1. Summary of the impact (indicative maximum 100 words)

[text removed for publication], a leading international manufacturer of [text removed for publication], have produced a new software interface ([text removed for publication]) for programming their flagship [text removed for publication] platform ([text removed for publication]) based on research undertaken by Ulster on rapid prototype development of healthcare applications. This new product has led to an increase in turnover for [text removed for publication] in 2012 and is being used in [text removed for publication] countries. [text removed for publication] is also currently marketing (May 2013) a new training product in the form of a [text removed for publication] platform, including [text removed for publication], based on research at CSRI on processing of accelerometry signals.

2. Underpinning research (indicative maximum 500 words)

Estimates from the World Health Organisation suggest that by 2050 the global number of older people will have increased 3-fold from 2000. Coupled with this will be an increase in prevalence of long-term chronic health conditions. Technology-based solutions have been introduced in efforts to address these challenges. One such solution is the "smart environment": a smart environment entails embedding technologies within the environment (e.g. home, workplace, public building) to record users' interactions with objects in the environment, and subsequent processing of the data recorded to infer the activities that are being undertaken by persons in the environment [1]. By understanding a user's behaviour it is then possible to provide support when specific (health-related) conditions that have been monitored over time are detected to be deteriorating, or in cases of an emergency situation.

During 2009 CSRI established a smart environment, funded by the NI Department of Employment and Learning (DEL). This provided an environment of 6,800 square-feet within which sensor technologies were installed, enabling data to be collected for experimental processes. The smart environment has a wireless sensor network: as a user interacts with objects in the environment the sensors continually generate data that are streamed wirelessly. Research has focussed on segmenting the data to identify individual actions (e.g. person entering a room, lifting an object, sitting down) [4]. This work has been extended through research on automated activity recognition algorithms to infer user activities (e.g. making a drink, grooming, watching TV), known as "activities of daily living". The algorithms developed have exploited knowledge-driven approaches underpinned by ontological frameworks, and have been demonstrated to be superior in terms of accuracy of activity recognition in comparison with purely data-driven techniques [2].

Research undertaken within our Centre for Intelligent Point-of-Care Sensors in conjunction with an ESRC-funded PhD studentship (2009-2012) investigated how accelerometry data obtained from wireless sensor networks could be used to better understand the behaviour of persons within smart environments. This work developed innovative approaches to detect daily activities (e.g. walking, lying down, going upstairs), incorporating measures of physical activity (step-counts, distance travelled) [3]. Research on augmenting accelerometry sensor data with physiological information has demonstrated that improved behavioural analysis can be achieved [6].

Research supported through an [text removed for publication] Project (2010-2011) investigated the development of user-friendly interfaces that could be used by non-technical users to programme sensor devices for use in clinical settings. In addition, research supported by a DEL CAST PhD studentship (2010-2013) in conjunction with Intel's Digital Health Labs investigated contactless methods to profile sleeping and approaches for the visualisation of data collected [5]. This work demonstrated the utility of contactless sensing and its cost-effectiveness in comparison with

conventional polysomnography-based approaches.

This work has been conducted by a team of key researchers in CSRI:

Chris Nugent	Professor of Biomedical Engineering (joined as Lecturer, 05/2000)
Sally McClean	Professor of Mathematics (joined as Research Assistant, 1971)
Bryan Scotney	Professor of Informatics (joined as Lecturer, 1984)
Dr Mark Donnelly	PhD student/Research Associate/Lecturer (10/2004-present)
Dr Luke Chen	Lecturer/Senior Lecturer/Reader (09/2005-present)
Mr Richard Davies	Research Associate/Lecturer (07/2001-present)
Dr Ian Cleland	PhD student/Research Associate (10/2009-present)
Mr Liam Burns	Research Associate (08/2007-present)
Andrew McDowell	PhD student (10/2009-present)

3. References to the research (indicative maximum of six references)

* *References that best indicate the quality of the underpinning research*.

[1] L Chen, J Hoey, CD Nugent, D Cook, Z Yu (2012). Sensor-based Activity Recognition, *IEEE Transactions on Systems, Man and Cybernetics - Part C*, vol. 42, no. 6, pp.790-808. DOI: 10.1109/TSMCC.2012.2198883

[2] * L Chen, CD Nugent, H Wang (2012). A Knowledge-driven Approach to Activity Recognition in Smart Homes, *IEEE Transactions on Knowledge and Data Engineering*, vol. 24, no. 6, pp. 961-974. DOI: ieeecomputersociety.org/10.1109/TKDE.2011.51 [***This paper is included as an output in the current REF submission.***]

[3] * I Cleland, B Kikhia, C Nugent, A Boytsov, J Hallberg, K Synnes, S McClean, D Finlay (2013). Optimal Placement of Accelerometers for the Detection of Everyday Activities, *Sensors*, vol. 13, pp. 9183-9200. DOI:10.3390/s130709183

[4] * X Hong, CD Nugent (2013). Segmenting Sensor Data for Activity Monitoring in Smart Environments, *Pervasive and Ubiquitous Computing*, vol. 17, no. 3, pp. 545-559. DOI: 10.1007/s00779-012-0507-4 [***This paper is included as an output in the current REF submission.***]

[5] A McDowell, MP Donnelly, CD Nugent, M McGrath (2012). Utilising Wireless Sensor Networks towards Establishing a Network of Sleep Profiling, *International Journal of Computers in Healthcare*, vol. 1, no. 4, pp. 346-363. DOI: 10.1504/IJCIH.2012.051809

[6] CD Nugent, L Galway, L Chen, MP Donnelly, SI McClean, S Zhang, BW Scotney, G Parr (2011). Managing Sensor Data in Ambient Assisted Living, *Journal of Computer Science and Engineering*, vol. 5, no. 3, pp. 237-245. DOI: 10.5626/JCSE.2011.5.3.237

Key Grants

Project: Cross Border Centre for Intelligent Point-of-Care Sensors
Funder: NI Department of Employment and Learning £1,991,283 (to Ulster)
Dates: 11/2008-03/2011
Ulster grant-holders: CD Nugent, D Finlay, P McCullagh, SI McClean, BW Scotney

Project: Deployment of Sensing Technology in Connected Health Care
Funder: NI Department of Employment and Learning £623,900 (to Ulster)
Dates: 02/2009-03/2011
Ulster grant-holders: CD Nugent, D Finlay, P McCullagh, L Chen, SI McClean, BW Scotney

Project: [text removed for publication]
Funder: [text removed for publication] (to Ulster)
Dates: 09/2010-12/2011
Ulster grant-holders: MP Donnelly, CD Nugent

Project: Design for Ageing Well: PhD Studentship
Funder: ESRC New Dynamics of Ageing (RES-353-25-004) £51,301 (to Ulster)
Dates: 10/2009-10/2012
Ulster grant-holders: CD Nugent, D Finlay, P McCullagh, SI McClean, BW Scotney

4. Details of the impact (indicative maximum 750 words)

[text removed for publication], a leading international manufacturer of [text removed for publication], have produced a new range of support tools and resources for assisting end users in the design and development of applications of their [text removed for publication] platform ([text removed for publication]), based on research undertaken by CSRI. This enables simple and effective biophysical and kinematic data capture. [text removed for publication] have also produced a new training product in the form of a [text removed for publication], based on research in CSRI on processing of accelerometry signals.

During 2007 CSRI was invited to join the launch of a new [text removed for publication] [E1] that supported the acquisition of biophysical and kinematic data in an easily configurable manner. Following this event, collaboration with [text removed for publication] has been intrinsic to CSRI's research programme in assistive technologies [1, 3, 5, 6] [E2]. At an event sponsored by [text removed for publication] (2010), research activities within the domain of Connected Health were presented by [text removed for publication] and CSRI [E3]. This raised awareness of research within the area of wireless sensing in Connected Health to industrial representatives on an all-Ireland basis.

Through the creation of the smart environment within CSRI, funded through the DEL-funded Deployment of Sensing Technology for Connected Health project (2009-2011), the [text removed for publication] became one of the core sensing technologies used. The [text removed for publication] was used to measure activities such as walking, lying down and lifting objects, in addition to measuring activity levels through step-counts and distance travelled. Analysis of the data gathered from such sensors was used as the basis for the development of automatic activity recognition-based systems [1, 2]. In addition, the experience gained by CSRI in working with wireless sensors [3, 4, 5, 6], processing of the recorded data and its visualisation for healthcare professionals [1, 2, 6], and reducing the complexity of sensor programming, formed the basis of a funded collaboration with [text removed for publication] through the [text removed for publication] (2010-2011). The collaboration involved the development of an interface to configure and visualise the data generated from the [text removed for publication] to streamline the production of host-side [text removed for publication] applications in a manner that would be accessible to non-technical users. Results from research on user interface design for healthcare professionals undertaken by CSRI were used to inform the development of this new software interface ([text removed for publication]). Specifically, these results address the appropriate methods to design an interface to enable non-technical users to configure rules, and how complex information is to be visualised. The resources in the [text removed for publication] provide a flexible architecture that supports the configuration, visualisaton and analysis of the data collected by the [text removed for publication]. Configuration and programming of the [text removed for publication] usually requires the use of an integrated development environment geared towards electronic and software engineers. The [text removed for publication] provides an intermediate layer between the user and the integrated development environment. This intermediate layer enables healthcare professionals to configure [text removed for publication] devices easily, monitor functions such as vital signs, movement and orientation, and dictate how the information is visualised, all from a non-technical perspective.

The successful completion of the [text removed for publication] Project and development of the [text removed for publication] were independently assessed by consultants from the [text removed

for publication]. The outcome of the assessment was that, from a selection of 50 projects, the collaboration won the 2012 [text removed for publication] Project of the Year Award [E4].

The development of the [text removed for publication] has provided an economic benefit for [text removed for publication]. The company have stated that through collaboration with CSRI and the development of the [text removed for publication] product their company witnessed a [text removed for publication] increase in turnover during 2012 [E5, E6]. The product is being used in [text removed for publication] countries.

In addition, [text removed for publication] has stated that the number of staff within their Research and Development department has increased as a direct result of this collaboration with CSRI. This collaboration has supported the employment of [text removed for publication] new members of staff at [text removed for publication], one of whom has taken the role of Research and Development Director within the company, and the others as research and development engineers [E5].

In addition to the production of the [text removed for publication] product, a further collaboration between [text removed for publication] and CSRI led to the joint development of a new product launched by [text removed for publication] in May 2013 [E5, E7]. This new product is targeted at the Educational market, and provides a starter-pack for the [text removed for publication]. This is a new product range for [text removed for publication] and has been guided and supported by CSRI based on our research on processing of accelerometry signals [3, 5, 6].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[E1] Workshop details for the [text removed for publication], 2007.
This item demonstrates the long-standing collaboration that CSRI has with [text removed for publication] and [text removed for publication].

[E2] Corroborating contact: Senior Technologist at [text removed for publication].
[text removed for publication]

[E3] Workshop details for the event sponsored by [text removed for publication] and held at the premises of [text removed for publication], 2010.
This item demonstrates the long-standing collaboration that CSRI has with [text removed for publication] and [text removed for publication].

[E4] Factual Statement from [text removed for publication].
This item provides corroborating evidence for the [text removed for publication] 2012 prize awarded for the collaboration between CSRI and [text removed for publication].

[E5] Factual Statement from [text removed for publication] in the form of a letter.
This item provides corroborating evidence detailing the value to [text removed for publication] of working with CSRI, the translation of the collaboration into a product, the resulting increased revenue for [text removed for publication], and the resulting increase in the number of technical staff employed by [text removed for publication].

[E6] [text removed for publication] news item detailing successful collaboration between CSRI and [text removed for publication].
This item provides corroborating evidence of the [text removed for publication] increase in [text removed for publication] turnover during 2012 based on collaboration with CSRI and the corresponding new product definition.
[text removed for publication]

[E7] [text removed for publication] website details of product launch.
This item provides corroborating evidence of the new product launch by [text removed for publication].