

Institution: Middlesex University		
Unit of Assessment: UoA11 – Computer Science and Informatics		
Title of case study: Intelligent Environments – Engineering and Applications		
Period when the underpinning research was undertaken: 2014 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Juan Carlos Augusto	Prof. of Computer Science	2012 onwards
C. James-Reynolds	Associate Prof. in CS	1998 onwards
Ralph Moseley	Senior Lecturer in CS	2003 onwards
Mark Springett	Senior Lecturer in CS	2002 onwards
Jill Stewart	Senior Lecturer in Env. Health	2016 onwards
Period when the claimed impact occurred: 2016-2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words)		
<p>The Research Group on Development of Intelligent Environments creates and improves methods and tools from Software Engineering, Human-computer Interaction and Artificial Intelligence, through direct interaction with societal problems, notably those connected with health conditions. The Middlesex born innovation has advanced Computer Science generating measurable impacts in several directions and citizen groups often neglected by the technology giants. Here we present three of those areas: increasing inclusion for people with Down's syndrome, providing ambient assisted living support for older people in their homes, and encouraging citizens to be more physically active. Our research on context-aware systems guides our development and delivery of systems better tailored to the needs of individuals with specific needs.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>Intelligent Environments are closely related to areas such as Ubiquitous Systems and IoT systems, and refer to systems which exist in a physical environment enriched with sensing technology and Artificial Intelligence algorithms to provide context-sensitive help to humans. Specific challenges in these systems around the core concepts of contexts and context-awareness, which our work focus on. There has been work on contexts from an Artificial Intelligence perspective led by J. McCarthy in the 80's and 90's and then focused on how inferences in different contexts relate to each other in general. However our work is much more guided by the specific needs from practical contexts and what users expect from system services in those contexts.</p> <p>Our research group (http://ie.cs.mdx.ac.uk/) has been working to improve the development of Intelligent Environments (IE) since its creation in 2013. Amongst the challenges we faced there were those on the engineering side with a lack of methods and tools specifically helpful for developing these types of systems. Also, despite the interesting advances in AI, these powerful algorithms did not offer the right balance on expressiveness and efficiency to be run in systems with low resources and with fast reactions expected. Advice on engineering Intelligent Environments (IEs) systems has been patchy or not transferrable. Hence, we created our own refined versions of existing approaches to system development, including the "User-centred Intelligent Environments Development Process" [Augusto et al., 2017], an iterative process centred on stakeholder's engagement. Part of that high level strategy also included our own method to gather "Requirements for Intelligent Environments" and an "Ethical Framework for Intelligent Environment Development" which were used to influence requirements and from there the whole system [Jones et al., 2015]. These were then complemented with specific strategies for "Context-aware Systems Testing and Validation" [Augusto et al., 2020a], [Augusto et al., 2020b].</p>		

In applying AI we have specialized algorithms to make known AI techniques to work in real life IE scenarios. Our algorithms include real-time temporal reasoning to automate sensorized environments [Gimenez-Manuel et al., 2020], machine learning to learn user's habits [Ali et al., 2019], and handling possibly conflicting user preferences [Oguego et al., 2018]. Those automated learning and reasoning algorithms combined with context-awareness resources and specialized interfaces provide a new system architecture [Augusto et al., 2020a] for intelligent environments. This consistent and integrated innovation allowed our team to win the BCS Machine Intelligence Competition RealAI (2019 edition): <http://www.bcs-sgai.org/micomp/intro.php>

These advances on user-centred engineering processes and tools facilitated the identification of relevant contexts and development of context-awareness required for the successful development and deployment of real-life services within various projects including:

- Supporting independence for people with Down's syndrome (Supported during 2013-2016 by the EU through a 4M Euros funded project: "PersOnalized Smart Environments to increase Inclusion of people with DOWn's syndrome (POSEIDON)"): to decide when users require advice or are in an emergency, or determine the system reaction in those detected contexts. Contexts of interest are usually organized at system level (e.g., battery level and connectivity), person level (e.g., physical or mental status), and environment level (e.g., weather or bus service).
- Ambient Assisted Living (Partly supported during 2016-2019 by the EU through a 700K Euros funded project: "SecUre aCCeSSibility for the internet of things (SUCCESS)"): the contexts our Smart Home system detects unhealthy sleeping patterns, unhealthy eating patterns, and 'wandering', all of which are well known to be meaningful to people experiencing dementia-like conditions. These contexts are detected through a specially designed rule-based temporal reasoning system fed by sensor data. House behaviour adapts to user preference through personalization interfaces and unsupervised learning algorithms. The Smart Home system was set up as part of the Smart Spaces lab in our campus: <http://ie.cs.mdx.ac.uk/smart-spaces-lab/>
- Encouraging increase in physical activity within Barnet (a collaboration supported from 2018 onwards with £136,000 by Greenwich Leisure Limited, a charity company based in London working in the sports market with branches all over the UK, and by Barnet Council): this is a Gamification project to encourage citizens to be more physically active. The system achieves that by combining various techniques stemming from psychology (for example, behaviour change techniques or BCTs) which relate individual behavioural contexts to personalized habit formation and lifestyles changes. The stakeholders centred approaches and methods to identify and develop the context-awareness of the system have been used in this project. This project is currently ongoing and use in the community was delayed for a year due to Covid, so it is expected to start trialled in the community after spring 2021.

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

This research was based on competitively funded projects, with robust peer review systems. The outcomes were published in leading peer review journals and conferences in the field:

S. M. Murad Ali, J. C. Augusto and D. Windridge (2019). Improving the Adaptation Process for a new Smart Home User. *Proceedings of 39th SGAI International Conference on Artificial Intelligence (AI-2019)*. Cambridge, 17-19 December 2019. Available at: <http://eprints.mdx.ac.uk/27908/>

J. Augusto, D. Kramer, U. Alegre, A. Covaci and A. Santokhee (2017). The User-centred Intelligent Environments Development Process as a Guide to Co-create Smart Technology for People with Special Needs. *Universal Access in the Information Society* 17(1):115-130. Springer Verlag. Available at: <http://eprints.mdx.ac.uk/21032/>

J. C. Augusto, J. G. Gimenez-Manuel, M. Quinde, Ch. Oguego, M. Ali, C. James-Reynolds (2020a). A Smart Environments Architecture (SEArch). *Applied Artificial Intelligence*, Taylor and Francis. Available at: <http://eprints.mdx.ac.uk/28682/>

J. C. Augusto, M. J. Quinde, C. L. Oguego, J. G. Gimenez Manuel (2020b). Context-aware Systems Architecture (CaSA). *Cybernetics and Systems*, Taylor and Francis. Available at: <https://eprints.mdx.ac.uk/31198/>

S. Jones, S. Hara, J. C. Augusto (2015). eFRIEND: an ethical framework for intelligent environments development. In: *Ethics and Information Technology*, 17 (1):11-25. Available at: <http://eprints.mdx.ac.uk/15705/>

C. L. Oguego, J. C. Augusto, A. Munoz, M. Springett (2018). Using Argumentation to Manage Users' Preferences. *Future Generation Computer Systems* 81:235-243. Elsevier. Available at: <http://eprints.mdx.ac.uk/22641/>

J. G. Gimenez-Manuel, J. C. Augusto, J. Stewart (2020) Towards empowering people living with dementia in Ambient Assisted Living. *Universal Access in the Information Society*. Springer Verlag. Available at <http://eprints.mdx.ac.uk/30290/>

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

The systems we developed based on our user-centred systems engineering improvements and in our context-awareness reasoning and learning algorithms improvements described in section 2 were used to create systems which had a diversity of positive effects:

Societal Impact: our systems contributed to the quality of life of different sectors of society with special needs. Some of them such as people with Down's Syndrome are usually very much neglected by technology as they are not appealing to the larger dominant innovation companies dominating the digital markets. During the POSEIDON project a total of 200 EU citizens (PwDS, carers and representatives of national organizations supporting PwDS) participated from the workshops and pilots. We gathered evidence people with Down's Syndrome were both keener and more able to use modern digital solutions than previously perceived (see supporting evidence [So1]). Our system to support people with early stages of dementia relate to an increasing section of our ageing population who is willing to stay independent and healthier for longer whilst the human resources required are not sufficient. There is also increasing awareness in society about the negative effects of sedentary life on humans' health. Our system to encourage more active lifestyles is building on that awareness to encourage citizens in Barnet to do more physical activity and benefit from that. Some features of the system aims to increase self-esteem, others to provide reasons for habit building and others to increase social contact within the community (see supporting evidence [So2]).

Capacity-building Impact: as part of various projects we developed and perfected methods and tools. They are available in project repositories (see supporting evidence [Ca1]) which we also disseminated through Tutorials and Keynotes at International Conferences as well as eight research students which are now innovators working in other organizations, half of them in business/industry. Our most recent application of the principles and tools we have designed to assist citizens with context awareness has been used by a company, GLL, to transition from traditional gym based physical activity as their only business model into incorporating app supported individual and team based physical activity. (see supporting evidence [Ca2])

Cultural Impact: we informed relevant decision-makers of the findings of our research which have impact in their specific section of society:

- We helped Down's Syndrome associations to understand how people with Down's Syndrome were able to increase independence and improve lifestyle choices through

digital tools and how that can improve daily life experience for the family as a whole (see supporting evidence [So1]).

- We also informed three teams of senior managers from different boroughs in London about the potential of Ambient Assisted Technologies to provide a digital safety net and point of advice to citizens experiencing early symptoms of dementia-like conditions (see [So2]).

Economic Impact: given our products were not marketed by ourselves and consisted of prototypes, methods and tools which help then design other marketable products, we rely on third parties reporting of economic impact. From our products the one which had best traceable benefits so far is our contribution to POSEIDON which has been used since by one of the Scandinavian companies involved in the project. The company used the concepts developed with our help during POSEIDON to improve their offer resulting in a number of different variants of specific products which have been delivered to the European market, especially in the North of Europe. These reportedly produced financial gains to the company which are described to the extent they are traceable by the company Karde (see supporting evidence [Eco1]).

International Reach: some of our activities involved partners from outside the UK and we are aware that at least at European level our work on supporting the developments of contexts and their linking with specific situations of interest for citizens with specific needs has been exploited by a Scandinavian company. Also as part of the legacy of the POSEIDON project we have raised awareness of the digital possibilities for this section of society and we are aware EDSA (the European Down's Syndrome Association) still considers the project an important landmark (see supporting evidence [Int1]). An independent U.S.A. based science journalist who has written for several of the most important USA newspapers have made several interviews on our work within the Ambient Assisted Living area to include our views and work in an upcoming book addressing the impact of technology in modern indoor living [Int2]. POSEIDON is one of the 90 global projects pre-selected for the World Summit on the information Society Prizes 2020 edition [Int3].

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

[So1] POSEIDON participant's questionnaires, interviews, workshops and pilots attracted participation of hundreds of families across Europe. Their feedback and statements from the various non-academic stakeholders were positive on usefulness and usability and can be consulted in the deliverables available in the project webpage: <http://www.poseidon-project.org/research-scientists/deliverables/> See also testimony of this in letter issued by DSA-UK and signed by the organization representative. The POSEIDON project then led to a smaller and more focused project with one of their branches: DSActive. They commissioned from us an exploratory research project funding a Master by Research student who produced a prototype of an app to educate children with DS on the concept of healthy food. See letter signed by DSActive.

[So2] See letter from London Housing Association where they acknowledge their visit to our Hendon Campus Smart Home helped them to understand the benefits of work in this area and also the impact that caused on the visitors and the actions they will take in their respective boroughs: "*...the visit to the lab changed for better their perception of what is feasible with Smart Homes technological augmentation Participants agreed on the importance of taking the knowledge gained from the workshop to their local authorities and other organisations.*".

[Ca1] A number of guides, methods and tools for user-centred design and development of context-awareness features are offered for free through places such as:

- the Developers section in the webpage of the POSEIDON project: <http://www.poseidon-project.org/developers/>
- the Research Group Github: <https://github.com/GOODIES-RG>

These have been used to create the innovation in the three application clusters we have described, and externally at least by Karde (one of the Scandinavian partners of POSEIDON).

[Ca2] letter from GLL explaining the benefits of engagement with our Research Group on exploring Personalized Behaviour Change Techniques as an alternative to their business options.

[Eco1] See letter signed by the C.E.O. of Karde company, a previous partner of our POSEIDON project, where they acknowledge:

- the positive influence of our participation in the group: *“The collaboration with Middlesex University in the POSEIDON project had an impact on society through better understanding of the skills of people with learning disabilities and their abilities to become independent members of the society and actively take part in the working life. Also, our activities had a positive influence on public policy and services towards the target group because of increased attention from politicians and public sector. Finally, our collaboration increased the quality of life for the target group through more independence and better integration in the society.”*
- and the financial benefits that taking part of POSEIDON brought to their organization *“Since POSEIDON Karde has won several national and international contracts for projects which aims to help people with learning disabilities. You may say following the spirit of POSEIDON. The projects have lasted one-two years and have had budgets on around 50.000 - 200.000 euros. Karde has had about 20 projects at an average of 100.000 euros which adds up to 2.000.000 euros in the period 2015 – 2020. It will be wrong to say that all of them are results of POSEIDON, but it can be fair to say that 50% is in the POSEIDON spirit, making e-learning and support systems for people with learning disabilities.”*.

[Int1] See reference to the POSEIDON project in www.edsa.eu/poseidon-app/

[Int2] The Great Indoors, by Emily Anthes. Scientific American. 2020. Available from: <https://us.macmillan.com/books/9780374716684>

[Int3] www.itu.int/net4/wsis/stocktaking/Prizes/2020/DetailsPopup/15428178241886969