This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2018.2849226, IEEE Access

IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Date of publication xxxx 00, 0000, date of current version xxxx 00, 0000.

Digital Object Identifier 10.1109/ACCESS.2017.Doi Number

The experience of developing the UJAmI Smart lab

M. Espinilla[1], L. Martínez[1], J. Medina[1] and C. Nugent[2]
[1]Department of Computer Science, University of Jaén, Jaén, 23071, Spain
[2] School of Computing, Ulster University, Jordanstown, BT37 0QB, UK

Corresponding author: M. Espinilla (e-mail: mestevez@ujaen.es).

Authors acknowledge the partial support from the REMIND Project of the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 734355 and from the Council of Health for the Andalusian Health Service with the project PI-0203- 2016.

ABSTRACT In the context of ambient-assisted living and monitoring activities and behaviours, the concept of smart homes/environments has emerged as a research and development field with many examples appearing in a range of different contexts (universities, research centres, hospitals, residences, etc.). Recently, a Smart Lab called UJAmI based on Ambient Intelligence was created at the University of Jaén in order to provide an environment where solutions in assistive technologies could be developed. This paper presents the experience of developing this smart lab within its first year. The initial space assigned to the smart lab is described through the creation of the smart lab in five perspectives: the layout of the smart lab, the selection of the devices, the deployment of the middleware, the technical infrastructures and the furniture. Finally, following our experience of creating the lab we reflect upon our experience and provide a set of guidelines and recommendations. Ongoing projects within this Smart lab are also introduced.

INDEX TERMS Smart Lab, Smart environments, Smart devices, Middleware, Ambient Intelligence, Ambient Assisted Living, and Assistive Technologies.

I. INTRODUCTION

The University of Jaén[1] (UJA) was ranked amongst the 75 best universities in the world in the field of Computer Science and Engineering, according to the data collected in the prestigious Shanghai ranking (ARWU) 2017[2], published by the Centre for World Class Universities of the Higher School of Education of the Jiao Tong University of China.

The UJA has a teaching and research excellence support strategy in the area of Computer Science and Engineering which has materialized into a non-profit centre referred to as the Advanced Studies Centre in Information and Communication Technologies and Engineering (CEATIC)[3]. CEATIC was organised into six research groups working in multiple fields that cover areas such as wireless sensor networks [1], intelligent systems [2], human language technologies [3], data mining [4], soft computing [5] and fuzzy decision making [6].

Currently, the H2020 research programme[4] is a key tool in the research strategy in CEATIC. The H2020 programme established seven social challenges in order to address major concerns shared by citizens in Europe and elsewhere. Among these challenges is "Health, Demographic Change and Wellbeing" which aims to keep older people active and independent for longer and supports the development of new, safer and more effective interventions. The research and innovation that fall within this challenge include supporting older people to remain active and healthy, in addition to testing and demonstrating new models and tools for health and care delivery.

In this challenge, smart homes/environments are a key tool in supporting research in assistive technologies [15] in areas such as supporting persons with cognitive impairments, providing independence for people suffering from a form of disability, providing support in the management and delivery of health related services and offering support in the monitoring and execution of general daily living activities. As a result, smart

[1] www.ujaen.es

[2] http://www.shanghairanking.com/Shanghairanking-Subject-Rankings/computer-science-engineering.html

[3] CEATIC stands for in Spanish Centro de Estudios Avanzados en Tecnologías de la Información y Comunicación. https://ceatic.ujaen.es/en

[4] The H2020 programme is the financial instrument implementing innovation in the European Union with nearly €80 billion funding available over 7 years (2014 to 2020).

2169-3536 © 2017 IEEE. Translations and content mining are permitted for academic research only.
Personal use is also permitted, but republication/redistribution requires IEEE permission.
See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

homes/environments [7,8,15] are being constantly promoted as a solution to support the effective and efficient provision of healthcare for ageing and disabled individuals living alone.

In order to take advantage of the excellent knowledge within CEATIC and to increase the synergies amongst its research groups, international research groups and other stakeholders, CEATIC decided in August 2014 to develop a smart lab based on Ambient Intelligence (AmI) which would mainly provide solutions based on assistive technologies. The proposal of the smart lab was focused on AmI [9] which is a paradigm in information technology aimed at empowering people's capabilities through the means of digital environments. The aim of the creation of the lab was to produce a real apartment which was sensitive, adaptive, and responsive to human needs, habits, gestures, and emotions which subsequently underpinned assistive technology based solutions in the home.

The development of the UJAmI Smart Lab[5] was a task spanning several months and has produced a number of lessons learnt in both its creation and implementation.

This paper aims to present the experience of developing the UJAmI Smart Lab, considering the initial space assigned in the UJA for the development of the lab and the multiple perspectives that were considered in its development. Based on this experience, a set of guidelines and recommendations have been produced to guide others who may embark on a similar journey to develop a smart lab. Details of the ongoing projects in which the UJAmI Smart Lab is currently involved are also presented.

The remainder of the paper is organised as follows. Section 2 provides a general overview of smart homes/environments with a focus on ambient intelligence. Section 3 describes the space provided by the UJA to develop the smart lab. Section 4 presents the experience of developing the UJAmI Smart Lab in five different perspectives. Section 6 provides guidelines and recommendations to develop a smart lab and Section 7 describes the ongoing projects in which the UJAmI Smart Lab is currently being used. Finally, conclusions are drawn in Section 8.

II. Smart Labs and AmI

Smart Labs have focused on the AmI paradigm, research and technology for developing real life solutions for ambient-assisted living and health monitoring [10][11].

There are multiple developments of smart labs/homes, which follow an AmI paradigm, although on a global scale each one is doing so with a different focus and from a different perspective on the problem at hand. In a common perspective, these environments may take the form of smart labs in an academic setting [14], easy-to-install lightweight hardware in a home or simulation software of smart labs. The most prominent of them are reviewed below.

Ulster University (United Kingdom) developed a smart living environment to support the development of assistive technologies and solutions to support independent living, in addition to a range of techniques for healthcare monitoring and diagnosis [7]. This environment is in the form of a smart apartment containing a living room, dining area, kitchen, small office, bathroom and a bedroom, and is capable of facilitating data collection for individual or multiple inhabitants.

Another recent example is Halmstad Intelligent Home at Halmstad University (Sweden) that is a fully functional 50m^2 one-bedroom apartment built to provide researchers, students and industrial partners with a technology-equipped realistic home environment [8]. The first application of this smart home was an approach for multi-occupancy detection.

The Ubiquitous Home [33] (USA) is a smart home that was developed to study context-aware services. This smart lab has several rooms equipped with multiple sensors: vision sensors, microphones, pressure sensors, accelerometers and other sensor technologies. In order to offer contextual services to each resident, the Ubiquitous Home recognises the resident by providing radio-frequency identification (RFID) tags and by utilising the installed vision sensors.

Another example of smart home is HomeLab [34] (Netherlands). This is a smart home with 34 vision sensors distributed around several rooms with an observation room that allows the researcher to observe and monitor the conducted experiments. The aim of the HomeLab is to provide datasets to study human behaviour in smart environments and investigate technology acceptance and usability.

A programmable and customisable smart home is the Gator Tech Smart House (USA) [35]. The objective of this smart lab is to study the ability of pervasive computing systems to evolve and adapt to future advances in sensor technology.

PlaceLab [36] (USA) is an apartment with several rooms that has many sensors distributed throughout each room, such as electrical current sensors, humidity sensors, light sensors, water flow sensors, etc. The aim of this smart lab is the study of ubiquitous technologies in home settings.

The TigerPlace [37] project (USA) was an effort to tackle the issue of a growing ageing population. It uses passive sensor networks implemented in 17 apartments within an elder-care establishment. The aim of the project was to capture patterns representing physical and cognitive health conditions and then recognize when activity patterns begin to deviate from the norm.

Toyota Dream House Papi[6] (Japan) is another smart house equipped with ubiquitous computing systems and intelligent

[5] http://ceatic.ujaen.es/ujami/en

[6] http://tronweb.super-nova.co.jp/toyotadreamhousepapi.html

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

technologies in order to offer a smart adaptable environment. The goal of this smart house is to provide home assistance services and automation of functionalities as well as energy saving.

Drexel Smart House[7] (USA) was developed through the transformation of an old building into an intelligent living environment, representing the possibility and feasibility of introducing intelligent technological applications into the rehabilitation of present-day houses. It was intended to be used as a ‘living laboratory’ for research and experimentation in the field of intelligent environments.

From the perspective of the smart homes available, the ease of installation of the CASAS architecture is a notable example. This environment facilitates the development and implementation of smart home technologies by offering an easy-to-install lightweight design that provides smart home capabilities out of the box with no customization or training required [12].

This review concludes that smart labs configure the base tool for developing real life solutions for ambient-assisted living and health monitoring. However, the lack of guidelines and the complexity of setting up smart labs limits their creation. For example, there is a significant lack of smart labs in Spain focused on the AmI paradigm for ambient-assisted living in an academic setting. The closest approximation in Spain is CASADOMO[8] of the State Reference Centre for Personal Autonomy and Technical Aid. CASADOMO is a smart home consisting of a living room, kitchen, bathroom and bedroom with accessible technologies for the home that facilitate daily tasks for people who have some type of disability, whether intellectual or physical. However, this smart home is not intended for research, as it is focused on the field of accessibility in order to test certain developments and to be used as a prototype. The UJAmI Smart Lab was developed to take advantage of the excellent research from the UJA on the AmI paradigm to provide tools for ambient-assisted living and health monitoring.

III. Initial space of the UJAmI Smart Lab

The initial space assigned to develop the UJAmI Smart Lab is presented in this Section.

The space provided marked the development of the smart lab and its planning resulted in continuous discussion during the first year of its development.

The dimensions of the room were 5.8 meters long and 4.6 meters wide. The main door to the room is located in a corner. There are two French double windows separated by a half meter on the room’s outer wall. Theses windows occupy approximately the entire length of the wall. From a technical perspective, there were only two network sockets and four power outlets, one of which was an uninterruptible power supply. Figure 1 presents the plan view of the environment.

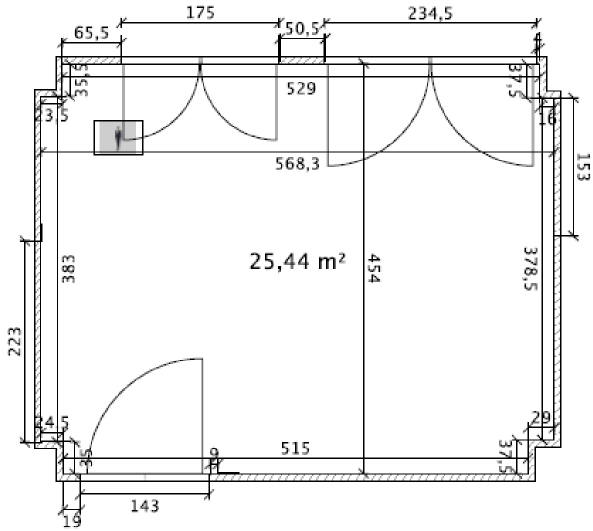

FIGURE 1. 2Dlayout of the room used to develop the UJAmI Smart Lab with all its measurements.

The first task was to remove all furniture, fixtures and fittings in order to have an open and free space in order to design a smart lab with a similar context to CEATIC and with similar objectives.

From the outset, the Smart Environments Research Group (SERG) of the Ulster University provided key support for the development of the UJAmI Smart Lab. The SERG team played a pivotal role and transferred its research and its innovation, as well as sharing its knowledge and its ideas.

IV. The experience of developing the UJAmI Smart Lab

This Section describes the experience of the development of the UJAmI Smart Lab from 5 differing perspectives.

The five perspectives are presented in Figure 2 and include: a) layout of the Smart Lab, b) the selection of smart devices, c) the deployment of middleware, d) technical installations and, finally, e) furniture.

With each perspective, the initial expectations are presented and the positive and negative aspects of the experience are also discussed.

---

[7] http://www.drexelsmarthouse.com/

[8] https://www.youtube.com/watch?v=kG7AohvYfuA&list=PLsqikzfQjXGMx9wJFTB-1PcQx3EnGZFj5&index=2

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2018.2849226, IEEE Access

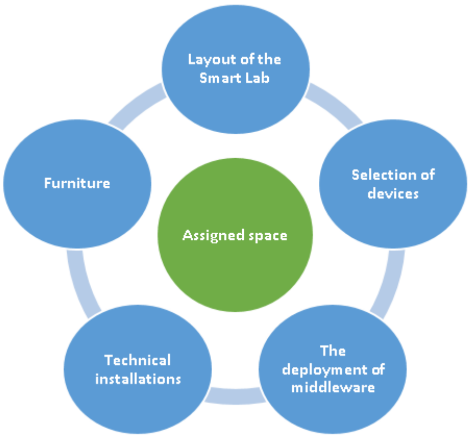

FIGURE 2. Perspectives considered for the development of the UJamI Smart Lab.

A. Layout of the Smart Lab

This subsection presents the analysis carried out to distribute the areas making up the assigned initial space within the UJAmI Smart Lab.

A team of four delegates from CEATIC and SERG of Ulster University was proposed to analyse the layout of the UJAmI Smart Lab. As result of this analysis, two designs were obtained: the initial design and the final design.

Before studying the distribution of areas and their location, CEATIC established as an initial requirement that the space was not to be modified by masonry work. This constraint reduced the flexibility in designing the layout of the space.

According to the review of smart labs in academic settings, the UJAmI Smart Lab would have to include the most common areas in a home to provide solutions in assistive technologies. The areas to consider including in the Smart Lab were: entrance hall, workspace, living room, kitchen, bedroom, and bathroom.

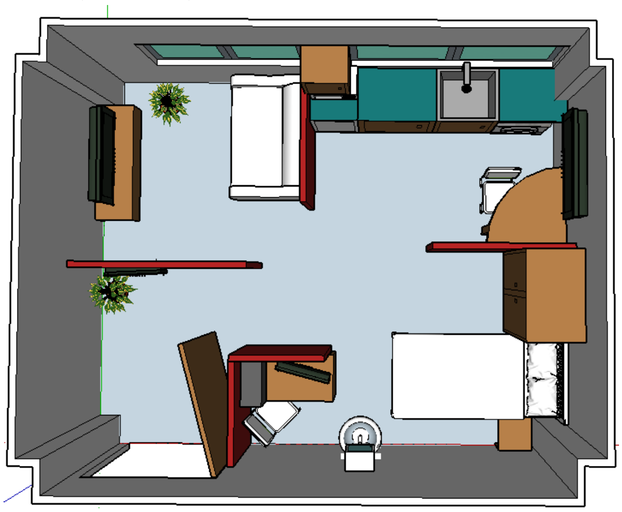

FIGURE 3. First layout of the Smart Lab.

The first layout of the UJAmI Smart Lab is illustrated in Figure 3, and comprised the following areas: entrance hall, workspace, bedroom with a wash basin, kitchen and living room. Similar configurations have been proposed in other smart labs [7,8,34,14] as a standard space for carrying out daily human activities.

The first layout presented the following problems: the entrance lacked basic furniture and the work space was not attached to the wall, which meant that the wires could make it difficult for a person to sit at the workspace. Furthermore, the washbasin was integrated into the bedroom, and it was not possible to have a toilet. Regarding the kitchen, it was limited to the installation of only a few appliances given it only occupied one wall. Moreover, the kitchen tap prevented the French double windows from being opened and the kitchen table only had space for one person to sit. Finally, the living room had little space. In addition to the aforementioned problems, there was also a significant disadvantage with the lack of storage spaces. These spaces are necessary to store devices, their accessories, and even their instructions.

After evaluating this first version, a second (and final) layout of the UJAmI Smart Lab was produced as presented in Figure 4. In this second layout, the UJAmI Smart Lab had 4 areas with the most notable change being the bathroom becoming integrated with the bedroom. The problems mentioned in the first version of the layout were addressed as follows: furniture was added to the entrance and the work space was moved up to the wall in order to improve its accessibility. The bedroom was integrated with the bathroom, including the toilet and the washbasin. The kitchen was designed with a larger footprint and had a lot of storage space included within it. In the final design, the kitchen tap did not obstruct the windows being opened. In addition, it could incorporate multiple appliances such as a washing machine, dishwasher, oven and microwave. The kitchen table in this revised distribution could accommodate two people simultaneously. Furthermore, this table could be used as a second workspace. Finally, the size of the living room was increased and furniture for storage was also incorporated into the design.

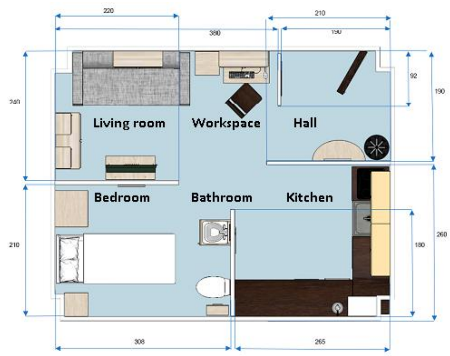

FIGURE 4. Second Layout of the UJAmI Smart Lab.

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Even though the final version was a significant improvement in comparison to the initial proposal, a number of constraints can be identified. There is no adjacent laboratory with windows to monitor the UJAmI Smart Lab to support, for example, Ux assessment. If required, the monitoring could be performed through the use of video cameras. The bathroom would be improved if it were separate from the bedroom and if it included a shower or a bathtub. The workspace and the living room would be improved if they were two independent areas. Finally, panels were used to separate the areas within the smart lab. An improvement would be the use of real walls with doors.

These constraints are largely due to the size of the assigned room and the initial premise that it was not possible to perform masonry work.

B. Selection of devices

This Section describes how the devices were selected to provide solutions in assistive technologies.

On one hand, centres for ageing and disabled individuals were visited to obtain the point of view of entities that deal directly with the end users of future assistive technologies. Among these centres, we can highlight: ageing research foundations, neurology centres, occupational therapy centres and elderly care homes.

Users who could benefit from the proposed solutions in a smart lab are the following [32]:

- People living alone who are unable to seek help in emergencies (unconsciousness, falls, strokes, myocardial infarction, etc.).
- Elderly or disabled people who suffer from cognitive (Alzheimer’s disease, dementia, etc.) or physical (visual, hearing, mobility, speech, etc.) impairment.
- People who need help in daily life to perform personal care activities (eating, toileting, getting dressed, bathing, etc.) and instrumental activities (cooking healthy meals, dealing with medication and doing laundry).
- Informal (relatives, friends, neighbours) or formal (care providers) caregivers for the elderly or the handicapped.
- People living in rural and remote communities or in urban communities with inadequate health service provision.
- People who suffer from chronic disease, and who need continuous monitoring (diabetes, cancer, cardiovascular disease, asthma, COPD, etc.).
- People involved in telehealth care undertaking health care at a distance or telemedicine, with physicians practising ‘virtual visits’.

Needs, requirements and problems were collected in several meetings with these centres in order to consider them in the selection of the devices and technologies to be used in the context of assistive technologies for these users.

On the other hand, the selection of the devices and technologies to be deployed in the UJAmI Smart Lab was a complex task due mainly to the following three factors. The first factor was that there was a huge range of devices and technologies on the market. It is very difficult to analyse all of them comprehensively. The second factor was that devices and technologies proliferate at breakneck speed, implying that the analysis would soon become outdated. Finally, the third factor was the tendency over time to build cheaper, smaller and less energy-consuming smart devices.

In order to undertake the initial selection of devices to be deployed in the UJAmI Smart Lab, the following two premises were established. The first premise was the prioritization of the acquisition of the necessary devices for the identified demos or proposals in assistive technologies according to the visited centres related to ageing and disabled individuals. The second premise was the acquisition of smart devices that were also deployed in similar and close smart labs with a close and strong relationship to UJamI Smart Lab (allied smart labs) with the aim to transfer demos and solutions among smart labs. The initial devices that were acquired and their application in assistive technologies are presented in Table I.

TABLE I
INITIAL DEVICES ACQUIRED FOR UJAMI SMART LAB

Category	Devices	Applications
Environmental sensors	Interruption, movement, pressure, presence, arrival, NFC tags, flood, brightness, temperature and CO2 sensors.	Monitoring human activities, activity recognition, prompting, home automation, detection of unusual conditions and behaviour monitoring
Wearable devices	Smart watches, acceleration sensors and gyroscope sensors.	Fall detection, physiological monitoring and controlling energy expenditure.
Actuators	Light bulbs, led strips, alarm, speakers, Schlage lock.	Reminders, alarms in emergencies, promotion of quality sleeping and wake-up patterns.
Smart Devices	Smart fork and smart cookies	Monitoring human activities
Low cost devices	Raspberry Pi with sensors and actuators. Arduino with sensors and actuators.	Prototypes: control of medication intake, home monitoring and home security.
Indoor location	Beacons, Stickers and Leap Motion.	Indoor location, monitoring human activities and behaviour monitoring
Vision cameras	IP cameras, Web cam, Kinet (XBOX).	Monitoring human activities, behaviour monitoring and rehabilitation

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Screen	Smart TV, electronics tables	Therapy and rehabilitation, improving the communication between health care personnel.
Health devices	Smart Body Analyzer and smart watch	Monitoring human activities
Brain interfaces	BrainLink Macrotellect, Emotiv Insight and Emotiv Epoc+	Remote control, monitor signals, detection of emotions, facial expressions, conscious thought and emotional wellbeing
Human-Computer interfaces	Amazon Echo	Remote control
Robots	Bioloid robotics and Zowi	Therapy and Rehabilitation

These devices could be worn by the user or embedded in the smart lab in order to collect data and obtain a personalized profile of the user's physical and physiological patterns.

The initial set of devices can analyse sounds, images, body motion, ambient parameters (light, temperature, humidity, etc.), vital signs (blood pressure, body temperature, heart/pulse rate, body/weight/fat, blood oxygenation, ECG, etc.), sleep patterns and other health parameters, daily activities, and social interactions.

Usually, these devices connect through wired or wireless networks to service systems to support the effective and efficient provision of healthcare for ageing and disabled individuals living alone.

It is noteworthy that the set of devices in the smart lab should always be kept current and updated over time. Thus, the new devices to be incorporated should cover the new needs that arise associated with new demos, proposals or solutions, when current devices become outdated or the improvements of the new versions are substantial. Finally, demos from another allied Smart Labs that have relevant devices should be obtained to share experience and knowledge.

C. The deployment of middleware

This Section presents the deployment of middleware in the UJAmI Smart Lab that integrate the heterogeneous devices.

Middleware is a key tool in smart labs in order to manage the data generated by the devices, its storage and its retrieval.

In this context, there are a huge number of current platforms. Firstly, a web-based system for managing and monitoring smart environments was proposed in [19], which integrated environmental sensors and actuators. This system was based on MySQL and allowed integration with Open Hub[9], offering advantages as regards processing the information, accessible services and analytic capabilities. The main strength is its ease of use and its interface, which is illustrated in the Figure 5. The main weakness of this middleware is its limitations as regards the type of devices that can be integrated.

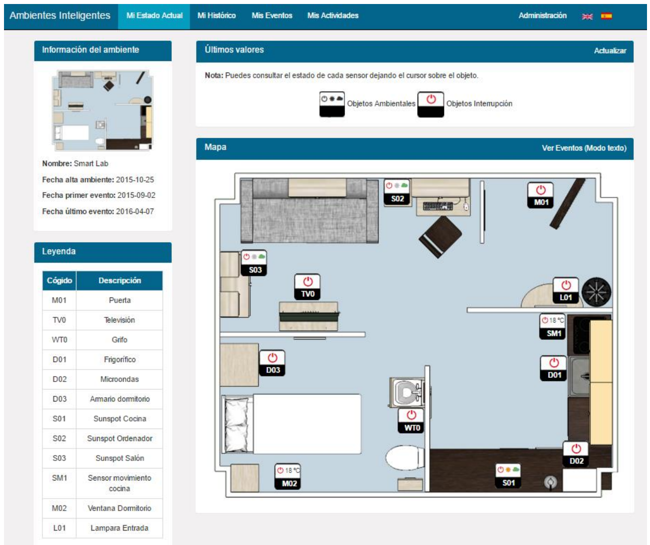

FIGURE 5. **Web-based system for managing and monitoring smart environments.**

Secondly, middleware based on ZeroC Ice[10] was proposed in [20], which implements an approach for distributing and processing heterogeneous data based on a representation with fuzzy linguistic terms. This middleware presented a lightweight distributed architecture to integrate relevant objects in real-time environments. Among the included devices were environmental sensors and vision sensors.

Although this middleware manages the data generated by the devices, its storage and its retrieval, it lacks research-oriented features.

The benefits of using a framework that includes a common protocol for data collection, a common format for data exchange, a data repository and related tools to underpin research are noteworthy.

For these reasons, the UJAmI Smart Lab is moving towards the deployment of a common middleware referred to as SensorCentral [27]. This platform incorporates several research-oriented features such as offering annotation interfaces, metric generation, exporting experimental datasets, machine learning services, rule based classification, forwarding live sensor records to other systems and quick sensor configuration. Furthermore, the main feature of SensorCentral is that it is compatible with an open data format referred to as the Open Data Initiative (ODI) [28].

[9] https://www.openhub.net/
[10] https://zeroc.com/

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2018.2849226, IEEE Access

The Open Data Initiative (ODI) proposed a framework that is illustrated in Figure 6 for the collection, annotation, management and sharing of data gathered through research in pervasive health and smart environment systems. It includes the provision of open access protocols to conduct experiments and a standard format for the exchange of datasets in order to be evaluated (see Figure 7). The structure of the ODI repository [13] was formalized through development of an ontology to unify the representation of ODI objects, experimental protocols, and event logs. Furthermore, a XML-based standards approach was proposed for storing event logs, using eXtensible Event Stream (XES) which enables data sharing, manipulation and ontology integration.

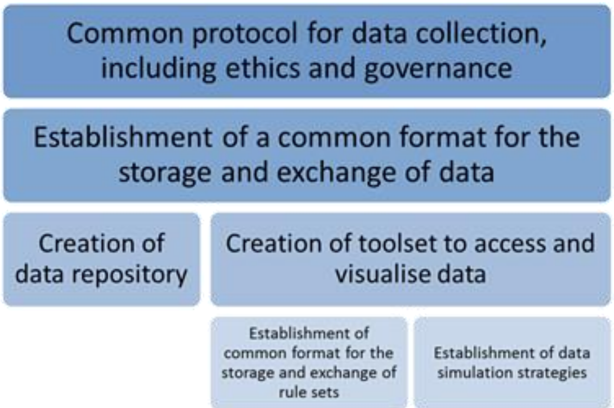

FIGURE 6. Framework proposed by the Open Data Initiative

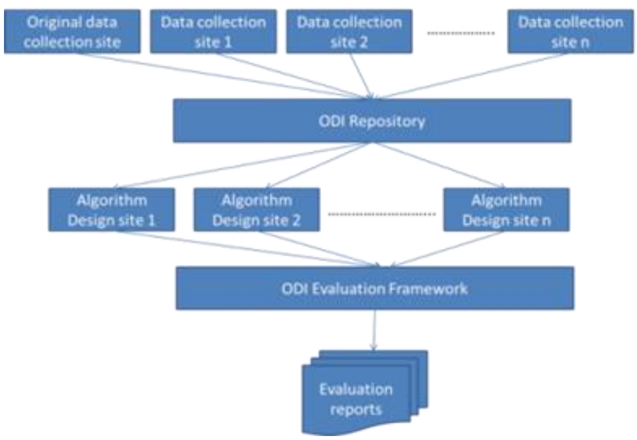

FIGURE 7. Scheme of the evaluation framework proposed by the Open Data Initiative

D. Technical installations

The experience of configuring the technical installations for UJAmI Smart Lab is presented in this Section.

Four installations were considered in the UJAmI Smart Lab: energy/electrical, lights, network and, finally, water.

Due to the budget limitation, water was not included in the environment and the original lighting was not modified. There were two other factors to consider for configuring the electrical and network installation. The installation would have to be flexible in order to easily deploy new devices in the future and have isolated electrical areas for safety.

As regards the water installation, the cost of introducing water into the room from other rooms of the building was excessively high. As an alternative, it was proposed to include two closed water circuits with an engine in the bathroom sink and the kitchen sink.

The lighting installation was not considered a priority. It was therefore decided that the roof lights remain and several lamps with smart bulbs and brightness sensors were acquired.

The devices to be connected to electrical and network installations were analysed. From the perspective of the electrical installation, the main devices that would be connected were: household appliances (television, washing machine, dishwasher, ceramic hob, etc.), workspace devices (routers, personal computer, laptop, etc.) and, finally, devices that required direct energy to work, such as IP cameras, or energy to charge smart watch or other device batteries. From the perspective of the network installation, most of the devices would be connected to Wi-Fi. The main devices that would be connected by Ethernet were: workspace devices (routers, personal computers, laptops, etc.), IP cameras and a smart TV.

Considering that the potential devices to be connected to the electrical and networking installations as well as the UJAmI Smart Lab had two working spaces (the official work space and a table in the kitchen that could be also used to work), the following configuration was chosen.

A double channel for data and electricity around the entire perimeter of the room was installed. The conduit allows the installation of any power plug or network plug along it, which is a flexible solution.

A small channel for electricity and data is installed in each corner leading from the main conduit to the roof. The aim of these four small channels is to have a connection to the roof, initially to connect four IP cameras. The conduit and a small channel to one corner of the room to connect the IP Camera is illustrated in Figure 8.

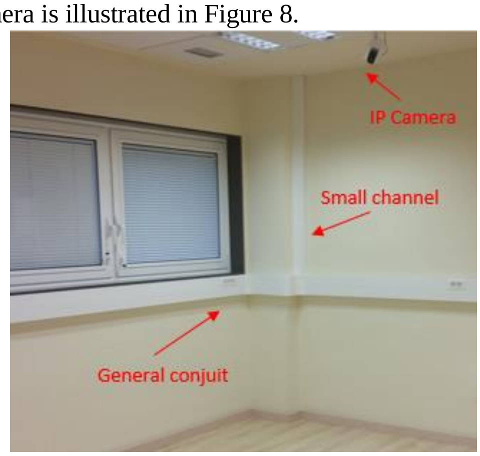

FIGURE 8. A corner of the Smart Lab with the central conduit and the small channel to the roof

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

A number of power sockets were installed along the conduit close to the anticipated position of devices that would be connected (television, lamps, microwave, etc.). Two boxes with multiple sockets were installed on the workspace and on the kitchen table. Furthermore, special power sockets required for the use of some appliances (microwave and fridge) were installed. Finally, three pre-installations were carried out, considering the following potential areas: CCTV, presence and floor sensors.

A number of special single and multiple sockets were considered for the kitchen. The workspace is also grouped into two areas (workspace and kitchen). Furthermore, the connections of the roof are groupedFinally, there are several spaces to include new pre-installations (floor, CCTV, presence).

E. Furniture

The experience of choosing the furniture for the UJamI Smart Lab is presented in this Section.

When choosing the furniture the costs were minimised whilst at the same time trying to provide as effective a design as possible. Figure 9 presents the initial layout of the kitchen prior to its installation. Figure 10 depicts the kitchen after its installation.

The first design of the kitchen roughly reflects the final state. In the final stage, the space to incorporate the washing machine was increased and the fridge and the dishwasher were moved to free up more kitchen space.

FIGURE 9. **Layout of the kitchen in the UJAmI Smart Lab before its installation**

The initial list of all the furniture of the UJAmI Smart Lab is presented in Table II, indicating the figures of the paper where the areas are shown with some of the deployed smart devices.

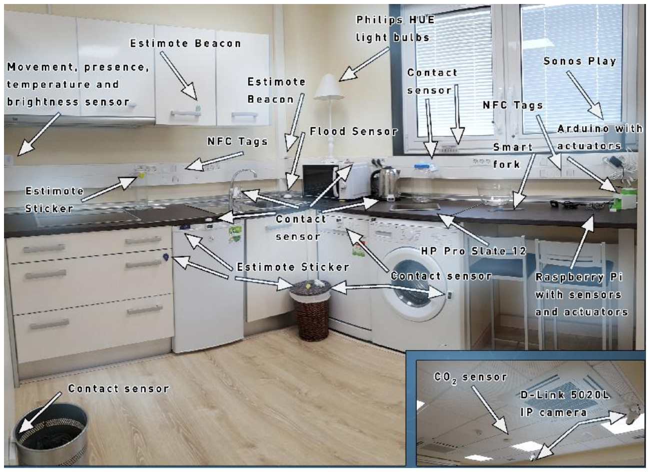

FIGURE 10. **Picture of the kitchen of the UJAmI Smart Lab with the kitchen appliances after its installation and the deployed smart devices.**

TABLE II
FURNITURE OF THE UJAMI SMART LAB

Areas	Furniture
Kitchen (Refer to Figure 10)	Kitchen furniture, sink. Dishwasher, extractor hood, ceramic hob, microwave, two high chairs, lamp, kettle and bin
Bed room with integrated bathroom (Refer to Figure 11 and Figure 12)	Headboard, storage bed, bedside table with three drawers, wardrobe with one door and two drawers, mattress and lamp Toilet, washbasin cabinet and towel rail
Work space (Refer to Figure 13)	Work desk, work chair, side table with three drawers and lamp
Living room (Refer to Figure 14)	Console table for TV with two drawers, console table with two doors, two sets of shelves with two holes, shelving with one door, three-seater sofa, table lamp and wastepaper basket
Hall (refer to Figure 15)	Console table with one drawer, umbrella stand, coat stand and table lamp

The separation of the areas in the Smart Lab was created by means of four panels in order to take advantage of the light provided by the two French double windows. The selected panels have an approximate height of 2 meters (the height of the room is approximately 2.5 meters) to allow the light to pass over the panels. In addition, one end of each panel has a column with rectangle glass windows that allows further light to pass through. Each panel is fixed to the floor and to some furniture.

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2018.2849226, IEEE Access

FIGURE 11. **Bedroom in the UJAmI Smart Lab**

FIGURE 12. **Bathroom in the UJAmI Smart Lab**

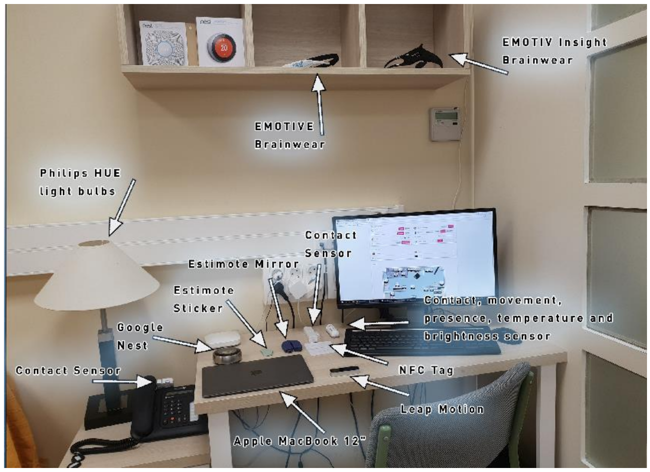

FIGURE 13. **Workspace in the UJAmI Smart Lab**

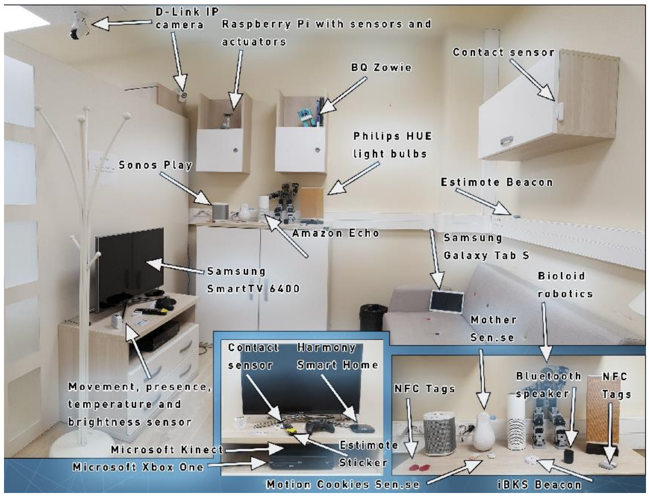

FIGURE 14. **Living room in the UJAmI Smart Lab.**

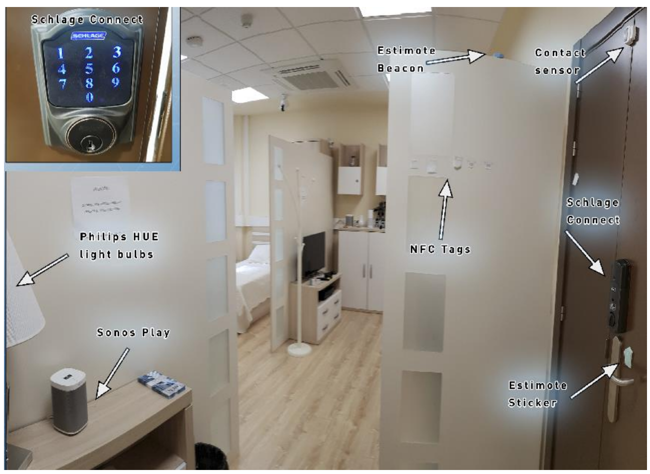

FIGURE 15. **Hall area in the UJAmI Smart Lab**

An important point is the separation of the areas by wooden panels in the UJAmI Smart Lab. The manner in which the wooden panels were fixed can be viewed as a disadvantage as if there is any change in the UJAmI Smart

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

Lab in the future, the panels must be detached and later re-attached.

V. Guidelines and recommendations

This Section describes guidelines and recommendations to develop a smart lab.

Table III presents the guidelines and recommendations and other relevant aspects.

TABLE III
GUIDES AND RECOMMENDATIONS

Category	Guides and recommendations
Distribution	- Have storage space to store devices, their accessories, instructions, etc. - Have a flexible and adaptable distribution of the areas.
Middleware	- Establish a shared model to collect data with other smart lab allies. - Choose middleware that can be shared with other smart lab allies.
Smart devices	- Increase the number of devices over time. - Consider new functionalities of the new devices to cover the new needs that arise in relation to proposals of assistive technologies. - Consider devices that can transfer solutions to smart lab allies.
Technical installations	- Prioritize flexible electrical and network installations. - Design the water, light and floor installations according to the solutions to be developed.
Other aspects	- Create a website with information about the smart lab, including a corporate image. - Establish a multidisciplinary networking effort to involve centres with end users. - Establish and consolidate smart lab allies to share knowledge. - Devote staff to the laboratory in order to maintain the functionality of the basic demos as well as keep the smart lab ready.

During the first year, developing the UJAmI Smart Lab was a difficult task. The official presentation of the laboratory was in September 2015; however, the development of the laboratory has been a living process from its origin. New devices, new demos, modifications of facilities are always required and they always have to be analysed and evaluated.

The decisions and assumptions made in the first year have conditioned the ease or difficulty of implementing new developments in the project. For example, three months after the official presentation (December 2015), a smart floor was installed thanks to extra financing. The entire space had to be cleared and the panels had to be unhooked from the floor and furniture. All the furniture had to be removed from the laboratory. Figure 16 presents the UJAmI Smart Lab while the smart floor was being installed.

FIGURE 16. **Installation of the Sensor Floor in the UJAmI Smart Lab**

The installation of the smart floor in a later phase was complex. It is therefore recommended to configure spaces in smart labs in the early stages as far as possible, or to provide additional spaces to enable the reconfiguration of the smart lab.

VI. Ongoing projects

Currently, the UJAmI Smart Lab is a key element in research and innovation projects at different levels in the UJA with multiple stakeholders: within the UJA, increasing the synergy of the research groups (not only of research groups in the ICT area, however, also in other areas such as health, medicine, psychology, etc.), industry, health centres, etc. In the next sections, the most relevant ongoing projects in which the UJAmI Smart Lab has been involved are described.

A. REMIND project

The UJA is currently involved, from 2017 to 2020, in the European project of the H2020 programme entitled "The use of computational techniques to improve compliance to reminders within smart environments"[11] with the acronym of REMIND that is led by Ulster University with a consortium of 16 partners from 10 different countries.

The aim of this project is to create an international and intersectoral network to facilitate the exchange of staff to advance developments in reminding technologies which can be deployed in smart environments for persons with dementia. The focus is on developing staff and partner skills in the areas of user-centred design and behavioural science coupled with improved computational techniques which in turn will offer more appropriate and effective reminding solutions. This is further supported through research involving user-centric studies into the use of reminding technologies and the theory of behaviour change to improve compliance of usage.

[11] https://cordis.europa.eu/project/rcn/207045_en.html

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

B. Activity Recognition

The goal of activity recognition is to identify activities as they occur based on data collected from sensorised objects in the smart lab. This is a challenging problem and has received significant attention in the relevant literature [30].

In this regard, firstly, a data-driven approach was developed entitled "Dynamic Instance Activation" (DIA) in the context of human activity recognition for smart environments [21], using datasets consisting of dense-sensor data and their associated class labels (activities). It was designed to minimise the negative impact in situations of data incompleteness and inconsistency. The developed algorithm attempted to maximise the accuracy of the classification process in a way that did not compromise the overall computational effort by means of the use of similarity and aggregation functions. DIA has great potential to be further improved if other more advanced similarity and aggregation functions were utilized.

Secondly, a knowledge-driven approach was proposed for activity recognition by means of a rule-based inference engine based on a fuzzy linguistic approach. The proposed approach is semantically clear, logically elegant, and easy to initialize, using fuzzy logic to model the uncertainty related to the expert knowledge as well as the temporality of the sensor data [22].

Machine learning techniques were proposed in the context of activity recognition in order to reduce the computational burden. A methodology based on feature selection was proposed to reduce the number of sensors required whilst still maintaining acceptable levels of activity recognition performance [16][23] and an approach based on prototype generation algorithms was proposed to reduce the vast amounts of data produced within smart environments for sensor-based activity recognition [24].

Finally, the UJA and Ulster University have launched an annual event referred to as the "UCAmI Cup" within the context of the International Conference on Ubiquitous Computing and Ambient Intelligence (UCAmI). The aim of this competition is to provide participants with the opportunity to use their tools and techniques to analyse an openly available human activity recognition dataset and to compare their results with others working in the same domain, with the same dataset.

In the first year of the UCAmI Cup, the competition was focused on the recognition of a range of human activities, performed by a single participant, in a single manner. The dataset was collected in the UJAmI SmartLab over a period of 10 days in 2017. The dataset contains the following four data sources:

- Event streams from binary sensors.
- Spatial data from the smart floor.
- Proximity data between a smart watch worn by the inhabitant and Bluetooth beacons.
- Acceleration data from the same smart watch worn by the inhabitant.

Researchers from nine countries (China, Spain, Sweden, Mexico, Argentina, UK, Ireland, Colombia and South Korea) have shown their interest in participating in this 1st UCAmI Cup.

C. Decision support systems in healthcare

Decision support systems are widely used in the field of healthcare to assist physicians and other healthcare professionals with decision-making tasks, for example, for analysing patient data.

The regional government (Andalusia - Spain) is funding a project between the UJA and the Hospital Complex of Jaen (Spain) in the field of cardiac rehabilitation, which is key to reduce mortality in at-risk patients with ischemic heart disease. The aim of the project is to develop a decision support system for the monitoring of patients with ischemic heart disease participating in a secondary prevention and cardiac rehabilitation programme in order to improve the accessibility of the cardiac rehabilitation programme in Health Centres. As a first result, a cardiac rehabilitation programme is embedded in a wrist-worn device with a heart rate sensor, which provides real-time monitoring of physical activity during sessions in a safe and effective way. For this, a linguistic approach based on fuzzy logic has been proposed in order to model the cardiac rehabilitation protocol and the expert knowledge from the cardiac rehabilitation team [31].

Furthermore, a decision support system with an intelligent medication controller [25] was developed based on fuzzy logic, which analyses the data streams on body temperature provided by a wearable device. Its main innovation was a pharmacokinetic and pharmacodynamic analysis. A low-cost prototype of a dispenser was developed that integrated the proposed controller to dispense adequate doses and waiting time based on previous intakes.

A decision support system based on fuzzy rules in a wearable device was proposed for the early detection of preeclampsia in women at risk in [26]. A dataset containing data on pregnant women with high risk of preeclampsia from a health centre in Colombia was analysed in order to validate the proposal. The proposed methodology and the developed wearable application can be easily adapted to other contexts such as diabetes or hypertension.

D. Indoor location

Indoor locations provide multiples benefits in the development of home-based care systems. Such solutions are able to locate the location of people indoors and, for example, to identify a medical emergency in order to request immediate help [29]. Furthermore, indoor locations can also be considered as a complement to activity recognition [9].

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

In the context of indoor locations, a comparison between algorithms was developed for the detection of fiducial markers [17] placed in the UJAmI Smart Lab while an inhabitant wearing a Google Glass conducted a set of daily living activities. Lighting conditions were modified to assess fiducial marker detection rates on a frame- by- frame basis.

In Ref. [18], an indoor localization process was presented by means of the use of a single 'always on' wearable camera, which was implemented using the Google Glass platform. Occupant location was determined using machine vision techniques that identified reference objects located within the environment which were then cross-referenced against a knowledge base that contained the known location of the objects.

VIII. Conclusions

UJAmI Smart Lab is the name of the Smart Lab developed by the UJA focused on AmI. This paper has presented the experience undergone in the first year of the development of the UJAmI Smart Lab. The initial space assigned to develop the UJAmI Smart Lab has been described and the experience of developing the UJAmI Smart Lab has also been presented from the following five perspectives: the layout of the smart lab, the selection of devices, the deployment of middleware, the technical installations and, finally, the furniture of the smart lab.

Guidelines and recommendations to develop a smart lab, considering the experience of developing the UJAmI Smart Lab, have been presented. Finally, the ongoing projects in which the UJAmI Smart Lab is involved have been presented.

REFERENCES

[1] Yick, J., Mukherjee, B., Ghosal, D. Wireless sensor network survey (2008) Computer Networks, 52 (12), pp. 2292-2330.

[2] Hayes-Roth, B. An architecture for adaptive intelligent systems (1995) Artificial Intelligence, 72 (1-2), pp. 329-365.

[3] Human Language Technologies for Knowledge Management (2001) IEEE Intelligent Systems, 16 (6), pp. 84-94.

[4] Han, J., Kamber, M., Pei, J. Data Mining: Concepts and Techniques (2012) Data Mining: Concepts and Techniques, 703 p.

[5] Rodriguez, R.M., Martinez, L., Herrera, F. Hesitant fuzzy linguistic term sets for decision making (2012) IEEE Transactions on Fuzzy Systems, 20 (1), art. no. 6030926, pp. 109-119.

[6] Estrella, F.J., Espinilla, M., Herrera, F., Martínez, L. FLINTSTONES: A fuzzy linguistic decision tools enhancement suite based on the 2-tuple linguistic model and extensions (2014) Information Sciences, 280, pp. 152-170.

[7] Nugent, CD, Mulvenna, Maurice, Hong, Xin and Devlin, S. "Experiences in the development of a Smart Lab". International Journal of Biomedical Engineering and Technology, 2 (4). pp. 319-331. 2009.

[8] Lundström J. et al. (2016) Halmstad Intelligent Home - Capabilities and Opportunities. In: Ahmed M., Begum S., Raad W. (eds) Internet of Things Technologies for HealthCare. HealthyIoT 2016. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 187. Springer, Cham

[9] G. Acampora, D. J. Cook, P. Rashidi and A. V. Vasilakos, "A Survey on Ambient Intelligence in Healthcare," in Proceedings of the IEEE, vol. 101, no. 12, pp. 2470-2494, Dec. 2013. doi: 10.1109/JPROC.2013.2262913.

[10] Rashidi, P., Mihailidis, A. A survey on ambient-assisted living tools for older adults (2013) IEEE Journal of Biomedical and Health Informatics, 17 (3), pp. 579-590.

[11] Chen, L., Nugent, C.D., Wang, H. A knowledge-driven approach to activity recognition in smart homes (2012) IEEE Transactions on Knowledge and Data Engineering, 24 (6), art. no. 5710936, pp. 961-974.

[12] Cook, D.J., Crandall, A.S., Thomas, B.L., Krishnan, N.C.: CASAS: a smart home in a box. Computer 46(7), 62–69 (2013).

[13] McChesney, I., Nugent, C., Rafferty, J., Synnott, J. Exploring an open data initiative ontology for shareable smart environment experimental datasets (2017) Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 10586 LNCS, pp. 400-412.

[14] Poland, M.P., Nugent, C.D., Wang, H., Chen, L. Smart home research: Projects and issues (2009) International Journal of Ambient Computing and Intelligence, 1 (4), pp. 32-45.

[15] Nugent, C.D., Finlay, D.D., Fiorini, P., Tsumaki, Y., Prassler, E. Home automation as a means of independent living (2008) IEEE Transactions on Automation Science and Engineering, 5 (1), pp. 1-8.

[16] M. Espinilla, J. Medina, A. Calzada, J. Liu, L. Martínez and C. Nugent, "Optimizing the configuration of an heterogeneous architecture of sensors for activity recognition, using the extended belief rule-based inference methodology", Microprocessors and Microsystems, vol. 52, AMSTERDAM, NETHERLANDS, ELSEVIER SCIENCE BV, pp. 381-390, 07/2017.

[17] C. Shewell, J. Medina, M. Espinilla, C. Nugent, M. Donnelly and H. Wang, "Comparison of Fiducial Marker Detection and Object Interaction in Activities of Daily Living Utilising a Wearable Vision Sensor.", International Journal of Communication Systems, vol. 30, New Jersey, John Wiley & Sons, Ltd, 2017

[18] C. Shewell, C. Nugent, M. Donnelly, H. Wang and M. Espinilla, "Indoor localisation through object detection within multiple environments utilising a single wearable camera", Health and Technology: Springer Berlin Heidelberg, pp. 1–10, 2016.

[19] D. Zafra, J. Medina, L. Martínez, C. Nugent and M. Espinilla, "A Web System for Managing and Monitoring Smart Environments", Bioinformatics and Biomedical Engineering - 4th International Conference, IWBBIO, Granada, Spain, April 20-22, 2016, Proceedings, Francisco Ortuño, Ignacio Rojas , vol. 9656 : Springer International Publishing, pp. 677-688, 05/2016.

[20] J. Medina, L. Martínez and M. Espinilla, "Subscribing to fuzzy temporal aggregation of heterogeneous sensor streams in real-time distributed environments", International Journal of Communication Systems, vol. 30, issue 5, no. 3238, New Jersey, John Wiley & Sons, Ltd, 2017.

[21] A. Calzada, C. Nugent, M. Espinilla, J. Synnott and L. Martínez, "Activity Recognition Using Dynamic Instance Activation", 10th International Conference, UCAmI 2016, San Bartolomé de Tirajana, Gran Canaria, Spain, November 29 – December 2, 2016, Part II, vol. LNCS 10070: Springer International Publishing, pp. 75–83, 2016.

[22] J. Medina, M. Espinilla, F. Moya and C. Nugent, "Activity recognition by means of rule-based inference engine based on fuzzy linguistic approach", 13th Scandinavian Conference on Artificial Intelligence Halmstad, Noviembre 2015.

[23] F. J. Quesada, F. Moya, M. Espinilla, L. Martínez and C. Nugent, "Feature Sub-set Selection for Activity Recognition", Inclusive Smart Cities and e-Health, vol. 9102: Springer International Publishing, pp. 307-312, 2015.

[24] M. Espinilla, A. Rivera, M. Dolores Pérez-Godoy, J. Medina, L. Martínez and C. Nugent, "Recognition of Activities in Resource Constrained Environments; Reducing the Computational Complexity", 10th International Conference, UCAmI 2016, San Bartolomé de Tirajana, Gran Canaria, Spain, November 29 – December 2, 2016, Part II, vol. LNCS 10070: Springer International Publishing, pp. 64-74, 2016.

2169-3536 (c) 2018 IEEE. Translations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.

[25] J. Medina, M. Espinilla, L. Martínez and A. L. García, "Intelligent multi-dose medication controller for fever: from wearable devices to remote dispensers", Computers and Electrical Engineering, vol. 65, England, Pergamon - Elsevier Science LTD, pp. 400-412, 01/2018.

[26] M. Espinilla, J. Medina, A. L. García, S. Campana and J. Mario Londonez, "Fuzzy Intelligent System for Patients with Preeclampsia in Wearable Devices", Mobile Information Systems, vol. 2017, issue 7838464, England, London, HINDAWI LTD, pp. 1-10, 2017.

[27] Rafferty, J., Synnott, J., Ennis, A., Nugent, C., McChesney, I., Cleland, I. SensorCentral: A research oriented, device agnostic, sensor data platform (2017) Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 10586 LNCS, pp. 97-108.

[28] Nugent, C., Synnott, J., Santanna, A., Espinilla, M., Cleland, I., Banos, O., Lundström, J., Hallberg, J., Calzada, A. An initiative for the creation of open datasets within the pervasive healthcare (2016) An Initiative for the Creation of Open Datasets within the Pervasive Healthcare, pp. 180-183.

[29] Santoso F and Redmond S. J, Indoor location-aware medical systems for smart homecare and telehealth monitoring: state-of-the-art. Physiological Measurement, 36 (10). 2015.

[30] Chen, L., Hoey, J., Nugent, C.D., Cook, D.J., Yu, Z. Sensor-based activity recognition (2012) IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews, 42 (6), art. no. 6208895, pp. 790-808.

[31] J. Medina, M. Rosa Fernandez-Olmo, M.D. Peláez and M. Espinilla, "Real-Time Monitoring in Home-Based Cardiac Rehabilitation Using Wrist-Worn Heart Rate Devices", Sensors, vol. 17, no. 2892, SWITZERLAND, MDPI AG, 12/2017.

[32] Chan, M., Campo, E., Estève, D., Fourniols, J.-Y. Smart homes - Current features and future perspectives (2009) Maturitas, 64 (2), pp. 90-97.

[33] Yamazaki, T. The ubiquitous home. Int. J. Smart Home 2007, 1, 17–22.

[34] De Ruyter, B.; Aarts, E.; Markopoulos, P.; Ijsselsteijn, W. Ambient intelligence research in homelab: Engineering the user experience. In Ambient Intelligence; Springer: Berlin/Heidelberg, Germany, 2005; pp. 49–61.

[35] Helal, S.; Mann, W.; El-Zabadani, H.; King, J.; Kaddoura, Y.; Jansen, E. The gator tech smart house: A programmable pervasive space. Computer 2005, 38, 50–60.

[36] Intille, S.S.; Larson, K.; Tapia, E.M.; Beaudin, J.S.; Kaushik, P.; Nawyn, J.; Rockinson, R. Using a live-in laboratory for ubiquitous computing research. In Proceedings of the International Conference on Pervasive Computing, Innsbruck, Austria, 29 November–1 December 2006; pp. 349–365.

[37] Skubic, M.; Alexander, G.; Popescu, M.; Rantz, M.; Keller, J. A smart home application to elder-care: Current status and lessons learned. Technol. Health Care 2009, 17, 183–201.

M. Espinilla was born in Jáen, Spain, in 1983. She received the M.Sc. and Ph.D. degrees in Computer Sciences from the University of Jaen, Jaen, Spain, in 2006 and 2009, respectively. She is currently an Associate Professor with the Department of Computer Science, University of Jaén. She led the development of the UJAmI Smart Lab of the CEATIC in the University of Jaén from its conception. Currently, she is a member of the centre's steering committee. Her research interests include ambient-assisted living, activity recognition, mobile and ubiquitous health, ambient intelligence, group decision making, decision support systems, intelligence systems, fuzzy logic and linguistic modelling.

J. Medina. He received the M.Sc. and Ph.D. degrees in Computer Science in the University of Granada, Spain, in 2007 and 2010, respectively. He developed the initial demos in the UJAmI Smart Lab. Currently, he is working as researcher in the University of Jaen in the research group Intelligent Systems Based on Fuzzy Decision Analysis (Sinbad2). His research interests encompass fuzzy logic, e-health, intelligent systems, ubiquitous computing and ambient intelligence.

L. Martínez was born in 1970. He received the M.Sc. and Ph.D. degrees in Computer Sciences, both from the University of Granada, Spain, in 1993 and 1999, respectively. He was the head of CEATIC and promoted the development of UJAmI Smart Lab during the period of his administration (2011-2015). Currently, he is Full Professor of the Computer Science Department at the University of Jaén. His current research interests are fuzzy decision making, linguistic preference modelling, fuzzy systems, decision support systems, personalized marketing, computing with words and recommender systems.

Chris D. Nugent received the B.Eng. degree in electronic systems and the D.Phil. degree in biomedical engineering from Ulster University, U.K., in 1995 and 1998, respectively. He provided key support in the development of the UJAmI Smart Lab with his previous experience in the development of a smart lab. He is currently a Professor of biomedical engineering in the School of Computing, Ulster University. His research interests include intelligent data analysis for smart environments and the design and evaluation of pervasive and mobile solutions within the context of ambient-assisted living.

21 … slations and content mining are permitted for academic research only. Personal use is also permitted, but republication/redistribution requires IEEE permission. See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.