From Smart Homes to Smart-ready Homes and Communities

Sumi Helal[1,2]*, Christopher N Bull[1]

[1] School of Computing and Communications, Lancaster University, Lancaster, UK

[2] Faculty of Health and Medicine, Lancaster University, Lancaster, UK

Smart-ready Homes and Communities

*Corresponding Author

Sumi Helal

School of Computing and Communications

Lancaster University

C32 Infolab21

Lancaster, LA1 4WA, UK

Tel: +44 (0)1524 510307

E-mail: s.helal@lancaster.ac.uk

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1. Abstract

Background: People have various and changing needs as they age and the number of people living with some form of dementia is steadily increasing. Smart homes have a unique potential to provide assisted living but are often designed rigidly with a specific and fixed problem in mind.

Objectives: To make smart-ready homes and communities that can be adaptively and easily updated over time to support varying user needs and to deliver the needed assistance, empowerment and living independence.

Method: The design and deployment of programmable assistive environment for older adults.

Results: The use of platform technology (a special form of what is known today as the Internet of Things, or IoT) has enabled the decoupling of goal setting and application development from sensing and assistive technology deployment and insertion in the assistive environment. Personalising a smart home or changing its applications and its interfaces dynamically as the user needs change was possible and has been demonstrated successfully in one house - the Gator Tech Smart House. Scaling up the platform technology approach to a planned living community is underway at one of UK's National Health Services (NHS) Healthy New Town projects.

Conclusions: There is a great need to integrate technology with living spaces to provide assistance and independent living. But to smarten these spaces for lifelong living, the technology and the smart home applications must be flexible, adaptive and changeable over time. However, people do not just live at home, they live in communities. Looking at the big picture (communities), as well as the small (homes), we consider how to progress beyond smart-ready homes towards smart-ready communities.

2. Introduction

Smart homes have long been used as a platform to provide daily living assistance to their occupants through the use of pervasive (sensing) and assistive technologies. People with Dementia (PwD) in particular can benefit from smart homes as the latter not only provide assistance, but can extend PwD's independent living and facilitate their care. In some countries, such as England and Wales, dementia has recently become the leading cause of death [1]; With an ever-increasing ageing population [2], the need for such assistive technologies will only grow - smart environments could alleviate the growing pressure on health and care services.

Smart homes, or "assistive environments", can be designed to provide specific assistance for their occupants. For example, a smart home could provide a dementia-friendly design and include technologies to facilitate extra care with (semi-)automated support [3]. Other assistive environments could focus, for example, on frailty or other physical or sensory disabilities.

As people age, their needs and priorities for assistance change, but these environments are designed to meet specific needs. Changing these environments could incur costs (financial, as well as time) and likely to interfere in space and time with the residents' daily lives. Our aim is for smart homes to grow along with their occupants and adapt to their changing needs. Ultimately, our goal is to "create a 'smart house in a box': off-the-shelf assistive technology for the home that the average user can buy, install, personalise, change, and control without the aid of engineers" [4].

We have explored this through the implementation of the Gator Tech Smart House (GTSH), shown in. 1, in Gainesville, Florida, USA. Our experiences in building "assistive environments" for older adults generated valuable insights and lessons learnt which we are taking forward in an in-progress project to design and build a smart community – the Whyndyke Garden Village (WGV), near Blackpool, UK.

Figure 1 - The Gator Tech Smart House (GTSH).

3. Materials and Methods

GTSH was designed as a programmable pervasive space [5] to overcome the limitation of a manual and ad hoc integration of heterogeneous elements into a smart environment which requires engineers and specialised system integrators. There were several smart house technologies integrated into GTSH [4], including smart objects: smart mailbox, smart front door, smart blinds, smart bed, smart closet, smart laundry, smart bathroom mirror, smart bathroom sink, smart displays, smart microwave (known as SmartWave), smart kitchen (including refrigerator/pantry, stovetop, oven, and dishwasher), smart floor, and smart plugs. Additionally, AI and machine learning techniques for activity, behaviour, situation and phenomena recognition were a major technology utilised in the smart house. Other technologies included home security monitoring, emergency call for help, and a cognitive assistant.

GTSH was designed as an assistive environment for the elderly aging with or into disabilities and hence it included elements in support of mobility (wheelchair-accessible design, zero-threshold, others), and several accessibilities elements addressing cognitive, visual and hearing impairments. Of all the integrated smart home technologies, some are examples of technologies used specifically to assist people with cognitive decline:

- SmartWave [6] – an intelligent meal preparation system to help older people live independently. There are numerous steps involved in preparing a meal which can be impacted by visual, hearing, cognitive or neuro-motor declines. The SmartWave system aims to make it easier for older adults to prepare hot meals (including Gourmet requiring multiple rounds of cooking using different power levels) without having to read cooking instructions or interact with the microwave buttons.
- Mobile Patient Care-Giving Assistant (mPCA) [7] – A mobile cognitive assistant for Alzheimer's patients. This mobile device interacts with a smart space's sensors and provides assistance carrying out daily activities through visual and audio reminders, orientation, and context-sensitive prompting, and monitoring.

A pilot live-in trial of the GTSH took place in which a 78-year-old woman with no significant impairments stayed in the house [8]. She was asked to use the house as she would her own, and her reactions and experience were evaluated through questionnaires, in-depth interviews, and tracking of technology use. This purpose of this trial was to explore the initial reactions and the acceptability of the smart house concept.

4. Results

The design and development of the Gator Tech Smart House provided several valuable experiences and important lessons [9]. These insights have been shaping our research agenda for an ecosystem of next generation assistive environments – an ecosystem that can avoid, alleviate or overcome the following four principle limitations which we have endured and learnt of during development of the GTSH project:

Ad Hoc and Non-Scalable Integration – Connecting numerous technologies into a single cohesive space will likely lead to a chaotic integration situation. The experience in GTSH found that integrating devices to work in a collaborative and coherent manner could account for a large portion of the development time and budget. Adding or updating hardware later, at each house, could potentially be an additional drain on resources. A technology that allows for automatic integration and effortless dynamic insertion of new technology elements and devices is needed to enable this sought ecosystem.

Lack of Programmability – As more devices are added, it becomes harder to re-engineer the smart house to realise the possible useful interactions of available services. GTSH found the need for a comprehensive programming model for developing smart home applications through their self-integrated entities.

Difficulty to Evolve, Change, and Manage – Ad hoc integration decisions often lead to increased difficulty when changing or managing installations or challenging when making changes to adapt to specific user's situations. This is particularly relevant at scale. What is required is a capability to evolve a space iteratively throughout its lifecycle. Unlike smartphones – the platforms for apps, once a smart house is built it is expected to be used for decades to come, and hence change management must be an integral part of their design. Programmability hugely supports change management in which a change in the used technology or user needs can be reacted to by reprogramming or sun-setting existing applications or programming new ones.

Ineffective User/Space Interactions – Many smart home projects have attempted user interactions through mobile hand-held devices. This is likely not suitable for older adults, for example, who may have visual or cognitive declines. There is also a need to separate user interface design from application logic, allowing for the interface to evolve or be customised to cater for a given user's needs without affecting the rest of the application.

We analysed the aforementioned four limitations, which have clearly been hindering the emergence of products and services for assistive environments, and adjusted our research agenda to find the blueprints of a workable ecosystem based on requirements drawn from the lessons learned. The lessons learnt led to the development of a technology that ultimately automated integration, enabled programmability, and facilitated change management and the separation of interfaces from the functionality of the smart house logic. The Atlas architecture [9], consisting of the Atlas service-oriented sensor platform (shown in Fig. 2) and the Atlas middleware was a key enabler for the automatic integration of devices and sensors, and the development and programming of smart environments without requiring teams of engineers or system integrators. One of the challenges was to ensure a flexible and open service interface, enabling better automatic integration of devices. This has been addressed by proposing a standard for device description (the Device Description Language (DDL) [10], and a recent extension standard supporting direct device to device interactions (IoT-DDL) [11].

Figure 2 - The atlas platform – a universal adaptor to self-integrate devices into the smart house.

Two primary themes emerged from the pilot live-in trial as lessons learnt from and by the GTSH users [8]: 1) an elevated level of confidence, and 2) the participant's discomfort and frustration with the reliability of the human-space interactions. However, voice recognition technologies have come a long way in recent years thanks to the use of AI, especially with the prevalence of digital voice assistants baked into mobile platforms and home digital assistant devices (for example, offered by Google, Apple, Amazon, and Microsoft). Living in a smart house did not affect her sense of comfort or privacy, or give her a fear of possibly breaking any technology. However, the participant was frustrated that the house did not respond to some of her verbal commands.

5. Discussion/Conclusion

Designing for lifelong healthy living poses some interesting challenges. People's needs change as they age, and their requirements for assistance change too. Smart homes can be built to support a person's needs, but as we found in our studies, smart homes can be expensive and time-consuming to update and change for a person's needs; this is particularly true if done at scale. So instead of thinking about smart homes with fixed goals, functionality, and applications, we need to think about creating smart-ready homes – programmable homes whose IT infrastructure, including devices, sensors, software, and algorithms, can be repurposed to achieve altered goals and support the changing needs of its occupants.

But what is a smart-ready home? It is a space that can easily be changed and updated to accommodate one of many various designs tailored for a person's specific needs. A smart-ready home is one which is designed from the ground up to be: a) accessible to multiple disabilities, b) sentient to detailed activities and numerous vitals and health conditions, c) empowering and assistive to its occupants providing just the right amount (and no more) of assistance and physical/mental/social augmentations, and provide coaching and health guidance, and d) achieving a, b and c “calmly” – a term that refers to the invisibility of the technology and maintaining normality of living spaces (e.g., aesthetics and humanly elements).

Instantiating a smart-ready home into a specific smart home at a given point in time takes on activation of the invisible (cleverly housed) devices and sensors (or addition of new ones under the self-integration principle we have established through the Atlas technology), activation of the needed software components (e.g., specific activity recognition modules for particular activities), deployment of artificial intelligence (by collecting data and performing analytics), and finally, linking all technology elements together through a program that consists of several inter-related or independent applications.

Imagine a young healthy family unit; they will not need a dementia-friendly home. However, as they age, and given forthcoming advances in early diagnosis of likely “future” dementia, there may be a need to prepare to live in a dementia-friendly space. Rather than moving, or going through a massive home modification project, it would be convenient and efficient if this family’s home was designed to easily change and be reprogrammed to provide dementia-friendly capabilities. Some design decisions may transcend healthy life-long living, but others, for example applications that provide cognitive assistance, are only required by specific people.

Some architectural design enablers supportive of the “smart-ready” principle is just as important as the technologies to be used. Space to house sensors and devices and their wiring, invisibly, is very important. Availability of power, and absence of barriers to Radio Frequency (RF) signals, is also crucial. Easy access to technology housing space becomes also equally important. Two architectural design elements were experimented with in the GTSH: the dropped ceiling crown-moulding with conduit for DC/AC power outlets, and residential-grade raised floor with tile blocks. Both were successful in hiding the technology and proven to be easy to access and utilise. There is more that is currently being researched and that should be done to support life-long living and smart-ready home principals.

Finally, as we agree on the importance of high-tech in smart-ready homes, let us not overlook the high value of low-tech. For instance, a fast cooling stove surface is a dementia-friendly feature; a smart microwave similar to the one referenced in this article is also a dementia-friendly feature; a split dish-washer unit (see [2]) and an oven with a sideway door support frailty avoiding pending over for the oven or reaching up to kitchen cabinets.

A gallery showing some of the architectural, high-tech, and low-tech elements in the GTSH is assembled and placed online at [12] as supplemental information.

Whyndyke Garden Village

While the GTSH focused on the individual living space, people’s lives extend beyond the boundaries of their homes – they do not live in a bubble; people go out, visit coffee shops, socialise, and integrate with their communities. People live at home, but they also live in their community. Any movement towards smart and assistive environments should consider how they smarten or integrate the community. That said, however, home still needs to be perfected as it is where personal comfort is; if there is something that is not right about the home, it doesn't matter what we do in the community.

The Whyndyke Garden Village (WGV) is a 91-hectare housing development planned for the Fylde coast (UK), with planning and bootstrapping funds provided by NHS England[1], with 1,400 planned homes. The objective of this development is to design a town of the future, building a healthy community with education, health, work, and neighbourliness at its core. One of the priorities of the village is to establish a digital infrastructure that promotes active and healthy living and supports residents' engagement in their own health care (health self-care). The planned infrastructure includes technology for affordable smart-ready homes and a digital community infrastructure. We will be taking all our lessons learnt from the GTSH and the Atlas technology and exploring how to make a smart-ready village.

The digital infrastructure will consist of smart-ready homes each equipped with a home edge computer connected to the WGV secure and scalable cloud tenancy. It will include a variety of health kiosks starting with Alexa-style conversational kiosks at home, to self-operated kiosks around the town centre, to pharmacy operated large kiosks linking to near-by surgeries (clinics). A key outcome for WGV is evidence that it reduces the GP/patient ratio, and hence the kiosks infrastructure is geared to facilitate the new patient-engaged delivery model of care. Other technologies in WGV include environmental sensors, town-wide activity tracking, the WGV mobile app with physical web interactions, a community hub with a massive engagement (multi-touch, multi-user giant displays), among other elements.

[1] https://www.england.nhs.uk/ourwork/innovation/healthy-new-towns/whyndyke/

6. Statements

6.1. Acknowledgement

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6.2. Statement of Ethics

The study's protocol has been approved by the University of Florida's Institutional Review Board. Participants in these studies have given their written informed consent.

6.3. Disclosure Statement

Nothing pertinent to disclose

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6.5. Author Contributions

Sumi Helal: Directed and contributed to the conception and design of the work both in the GTSH and the digital health infrastructure of the WGV. Revised this article and gave final approval.

Christopher Bull: Draft and revised this article.

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