Implementation of Smart Spaces: Present and Future

Introduction

Ubiquitous computing transparently assists people in performing daily tasks with the use of computing devices in the physical world. Among ubiquitous computing is an area known as “smart spaces”. A smart space is defined by Ubicomp to be an environment equipped with sensors and devices that can reason based on context to act upon the user’s intent (Lupiana et. al, n.d.). A user’s intent can come from the individual’s profile, location, status and policies. Most of the time, the environment is connected by wireless networks. People in the smart space communicates with the environment and the environment automatically assist the user and try to meet its needs. These technologies can be connected in different ways to assist their users through different forms of smart spaces.

There are two types of spaces proposed in this paper, physical and transient. In a physical smart space, the environment is fixated at a location and only activates when an individual enters the space and interacts with it physically; whereas in a transient space, a temporary space forms with mobility and provides access to the smart technologies based on user’s context. For example, a physical space would have a keyboard for user interaction whereas a transient space would have interaction using a projected keyboard in the space instead (Ebling & Want, 2017). It is important to note that transient space relies more on mobile smart devices such as mobile phones or wearable technologies containing embedded devices that connect to the space as a point of interaction.

Through these definitions, the paper will discuss further about the deployment of smart spaces in society today. In the first section, a literature review of requirements in building a smart space and existing successful implementations of smart spaces will be given. This helps to provide an awareness of existing technologies and enables an insight of a futuristic lifestyle. In the second section, the paper will focus on whether common physical smart spaces should be replaced by evolving technologies of transient smart spaces. As technology advances rapidly, it may be advisable to contemplate on the consequences of using transient smart spaces in terms of existing issues in smart spaces.

1 Implementations of Smart Spaces

1.1 Requirements

To implement a smart space, there are a few requirements that should be met such that the environment possesses autonomy, adaptability and involves human computer interaction in a natural way (Das and Cook, 2005). According to Lukkien (2010), a smart space requires the following criteria:

- Able to be programmable and adaptable
- Shares services with concurrent applications
- Separates application logic and functionality
- Integrates with a network infrastructure

These requirements are met by implementations of an infrastructure with components including (Lupiana et al., n.d.):

- Ubicomp devices
- Wireless networks
- Sensors

- Reasoning mechanism

Ubicomp devices are defined as devices that support user interactions and user mobility. These devices allow the user to interact physically and move freely within the space such as smartphones. Wireless networks are crucial in the interconnectivity of all the components within the space and facilitate context-awareness with situational information about the user. Sensors are devices that collects data from the environment. These sensors are usually connected wirelessly to collaborate and complete a task. Sources of the information from within the environment can be physical properties, motion properties, contact properties, as well as augmented and virtual reality (Cook & Das, 2007). A reasoning mechanism is integrated with computers and processes information (Cook & Das, 2007). This mechanism helps the system to predict a user's desire and the system can make decisions to change its behaviour accordingly. Basically, the software, hardware, and middleware of the system within the space are all connected and enhanced by interaction and mobility within the environment to allow the machine to work based on what the user desires.

1.2 Applications

As there is a rise in technologies, more smart systems are built to enhance live experiences to support the users. Abowd, Atkeson and Essa (1998) had long before predicted the following types of support smart spaces can provide in an environment:

- Monitoring of everyday experiences
  The system uses sensors to detect and recognise what happens in an environment.
- Accessing information
  The system assists the use to collect information from its own data or from external data collected from the internet. The information is then visualized by making use of the displays available in the space.
- Communication and collaboration
  Users can communicate with others virtually and can provide contextual information as well as availability of other users. Cues can be provided to show incoming communications and monitor the urgency of the incoming communications.
- Natural interfaces
  Systems will capture users' input with different types of interfaces such as speech, touch, gesture, and gaze. Other interfaces include brain computer interaction, virtual, mixed, and augmented reality. These interfaces blur the boundaries between physical and virtual worlds.
- Environmental awareness
  The environment provides cues or peripheral awareness that allows activity in another space.
- Guides and tours
  The system identifies visitors in the space and system guides them based on their preferences.
- Training
  System trains users to operate facilities or train procedural actions.

The application of smart spaces falls in different domains, including personal, social, and public. A personal space is a system customized for a user such as smart homes. In social spaces such as workplace and educational institutions, a smart space offers collaboration and sharing of content. A public smart space such as walkways, museums, and galleries, these spaces offer marketing or social benefits for the users (Debella-Teresuk, n.d.).

Personal smart spaces

Some of personal smart spaces involves different kinds of interaction for creative works. For example, the SpaceTop and ZeroN involves making use of space itself to interact with virtual reality to display a concept or to illustrate a concept itself (Lee et. al., 2013; Lee, Post, Ishii, 2011). The SpaceTop uses space to provide 3D interaction with a digital interface through sensors embedded on a computer that monitors the user's gestures and transform those gestures into actions within the interface (Lee et al., 2013). For the ZeroN, it uses objects within a space with sensors and remembers the movements made to the objects. The design of the smart space then allows movements to be repeated without physical contact made to the objects (Lee, Post, Ishii, 2011).

Besides that, smart spaces can be found situated within a building or a room itself. Smart homes are first designed for the elderly people who may require special care but values their own private lives. For example, a case study (Chen, 2012) implemented the use of different devices with an integration of a middleware such that the sensors at the physical environment in the home can detect the status of an elderly senior who has declining health. A monitoring services was embedded to his health and activity that is connected to the internet that allows external networks to connect. This external network such as the healthcare service and family so that they can monitor the elderly person and take immediate actions if something goes wrong when the elder person is alone at home. Other implementations such as the Georgia Tech Aware Home, Adaptive House at University of Colorado, Microsoft's Easy Living, and MavHome enables automation of a house based on a learning curve from the activity of its inhabitants (Das & Cook, 2005).

A representative study of Mavhome showed the interaction of sensors with the environment through device controllers (Das & Cook, 2005). Through the sensors, the system was able to monitor the environment like the moisture of the lawn in a house. Then, the system would process data collected from the sensor and decides to carry out an appropriate action such as running the sprinklers on the lawn when it is dry. If the data does not match with previous history, it can prompt an action from the user and learn to make a similar action next time. This kind of interaction assists the user to operate a space even when they are not in the space itself, thus promoting mobility.

Other personal smart spaces can be used to enhance experiences within the environment. Prototypes like IllumiRoom and RoomAlive make use of the environment and project illusions to induce an immersive experience. IllumiRoom uses peripheral projected illusions to give the illusion of virtual reality into the space by extrapolating an entertainment media from the television into real space (Jones, 2015). RoomAlive maps a content onto surfaces in the space and renders virtual objects into the room to create an illusion of a virtual world in real space (Jones et. al., 2014). It reads the movement of the users within the room with Microsoft Kinect and create new content based on these movements.

Social smart spaces

Within workplace and schools, collaboration is required for productivity by sharing content between individuals. Deploying a smart space in these situations enhance communication as well as accessing information, suitable for group work.

In work places, smart spaces are used more commonly for arranging meetings. Many existing technologies already exist such as AIRE project, Roomware, EasyMeeting, NIST smart room, inSpace, SpinSpace, and many others (Cook & Das, 2007; Reilly et. al, 2010a). These smart spaces act as a meeting room, and notifies the availability for communication of workers. They are suggested to be more advantageous than traditional methods such as teleconferencing because it provides equal chance of participation among the group (Reilley et. al, 2010). It also offers a space that can be assessed anywhere at any point in time and provides collaboration using spatial reference points (Reilly et. al, 2010b). Some smart spaces offer collaboration for project management. An example is the dBoard that is designed for remote communication within two teams using videoconferencing and a virtual Scrum board on the 'window' (Esbensen et al., 2005). The researchers found that this type of collaborative spaces was effective especially since the representation of actual Scrum boards were identical with the virtual board. This finding suggested that virtual interfaces may replace physical interface for easy communication between teams of different locations. In that case, it can be more generalized to suggest that a possibility of virtual worlds to replace physical worlds in cases of not having enough physical spaces or as a connection between two far physical spaces.

If not to replace, there are even technologies for cross-reality team spaces highlighted by its flexibility, range, and support for fast prototyping such as the TwinSpace (Reilly et. al, 2010a). TwinSpace merges the virtual world engine of OpenWonderland with the infrastructure of an interactive room built on Event Heap. The virtual element provides a rich customizable control and an ability to utilise desktop applications, notifications, and extension points between the server and client within the space. The physical element is responsible on allowing interactivity and services within the space. These two elements cooperate to generate messages with other embedded sensors in the room and services outside of the room. Thus, a consistency in content and structure can be enforced across the worlds.

For learning, smart spaces are built to support development in people. The main users not only comprise of students, but as well as educators and trainees. For social activity to happen, technologies like inSpace Table, inSpace Wall, SpinSpace and Podium makes use of sensors within a room to control the flow of information and social interaction on a specific workspace itself (Reilly et. al, 2010b). With Podium, it facilitates as a mobile presentation kiosk that is represented by a virtual avatar mapped by a real presenter, allowing communication with participants not within the environment (Reilly et. al, 2010b). In a classroom, the space can be transformed by deploying electronic devices and tools to assist teaching. Wang (2008) has stressed the importance of flexibility in such spaces. While interactive whiteboards have been used to offer engagement in learning, it was suggested that the objects within the physical space such as furniture can be moved to accommodate different arrangements. The idea of interactive classrooms has shown to be effective in terms of showing positive engagement and fascination to the technologies (Wang, 2008). Therefore, smart environments provide a sense of teamwork and collaboration remotely beyond the physical limitations of a space.

Public smart spaces

Implementations of smart spaces in the public domain can be found at trade shows, conferences, festivals, events, museums, and many others where human traffic is frequent. The idea is that these spaces may be used to provide information or to enhance an experience for the inhabitants of the space. It can also be used for a retail experience such as the Gatorade Mobile Roadshow held in various locations in USA in the year 2016 (Debella-Teresuk, n.d.).

A detailed example is the virtual store developed by Tesco deployed in South Korea (de Maeurbille, Oham, & Trine, 2015). As the average workers in the country has long working hours and having a high penetration rate of internet, the concept attempted to invoke consumption within a short time. Using a smartphone, customers scan the QR codes on posters of the products. The purchase is then paid online while home delivery can be arranged such that customers can get their products to home without the physical load of groceries. The concept has proven success with increased sales online.

2 Replacement of physical smart spaces with transient smart spaces

Considering that smart spaces are still facing challenges and issues with the current state of technology, it would be better not to replace physical spaces entirely. As Satya (Ebling & Want, 2017) have mentioned, there are security issues such that physical spaces would be better as it confines the content within the boundaries of a space.

2.1 Challenges of smart spaces

As smart spaces require interoperability between hardware and software, some smart spaces use a middleware to integrate this interaction (Chen et. al, 2012). This connection is then brought together with wireless networks. With technologies embedded in the system, huge amount of information about the users such as location and preference are collected and stored. As they are connected over the internet, there are heavy issues especially relating to privacy and security. Users may not want to be monitored all the time although business models take advantage of it to provide services (Ebling & Want, 2017). Even with ways to control the information flow, there could be sensitive information leaks and threaten privacy of users.

As a system gets more complexed with more devices, the network configuration itself poses as problem to enable flexibility, automation of internet addresses, as well as protocols for devices to work interchangeably (Heidemann, Govindan, & Estrin, 1998). And since there is an increase number of sensors, resulting in an increase in energy demand (Ebling & Want, 2017), there may be financial costs and health risks (from radiation emitted from these devices) involved.

Incorporating a wide use of natural user interaction, it may lead to user distraction and user intent interference. The wide range of interaction can interrupt a user's desire and it could take time for the users to practice using these technologies. Furthermore, it is a challenge to set up the system to improve the mappings of virtual content onto real physical objects (Reilly et al., 2010).

Generally, smart spaces have an open architecture compared to traditional physical spaces such as an aircraft cockpit having a closed system. The safety precautions must be changed rapidly parallel with technological advances for security purpose. Furthermore, while physical spaces have well established models, a transient smart space are still in development. The internodes within the space are often loosely interrelated resulting in variable reliability as the systems are not standardized. The frequent development is often required for customization and may continue to evolve after deployment (Chen, 2012). As a result, it may be advisable to not replace transient spaces entirely.

Conclusion

Smart spaces implemented in society today covers many different domains and industries allowing for interaction and mobility. Considering the wide applications of smart spaces in different domains, the requirements of deploying them is like a double-edged sword that has benefits in opening a system architecture but the structure itself poses as a challenge for smart spaces for being too accessible. Issues such as the deployment of the environment itself provoking privacy, and interaction within the system as a distraction have been discussed. Until a middle point is found in these issues, it is advisable not to replace physical smart spaces with transient smart spaces entirely. Future work can be placed on securing the system while keeping it accessible.

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