

Exploring the Adoption and Integration of Home Autonomous Systems

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By

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On my honor as a university student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Today, we are constantly and consistently surrounded by electronic devices all interconnected by a network. This "Internet of Things (IoT) enables us to collect, store, analyze, and process vast amount of data and provides a way to intervene without human intervention. These devices allow for a new concept that has steadily gained traction in the technological world called a "Smart Home". IoT enabled devices or equipment allow for a home to be more intelligent, interconnected, and remote controllable.

This year, the smart home market is expected to grow to about \$120 billion in value. (MordorIntelligence, n.d.) Companies like Google, Apple, and Amazon are investing heavily into this huge market to provide products and services that take advantage of the market growth. However, even with the huge growing interest, the smart home services have not been widely accepted. Several contributing factors to this include high device prices, limited demand, and long replacement cycles for the devices. (Ricquebourg et al, 2006) The high cost to get started in the smart home technology has been a deterrent and one of the largest barriers to the growth of the system. This combined with the lack of technology and resources to establish a full infrastructure of a smart home have contributed further to the dwindle in interest. Edwards and Grinter further argued another issue is due to the social aspect related to the adoption of smart home services. (Edwards and Grinter, 2001) They argued case studies performed as to the effectiveness of smart home devices focused on the technology failing to acknowledge the users' actual needs from the smart home.

Hence, the focus of my Science, Technology, and Society research paper looks at the adoption, integration, and possible repercussions of home automation. An investigation into which features affects a user, how these smart devices are leveraged for the services they provide. The purpose of this paper is to look at the potential barriers present in the adoption of smart home. By looking into previous literature on the topic, analysis on the acceptance or lack thereof can be seen.

Background

A smart home is defined as a residence which is equipped with a mode of communication usually a network connected to highly technologically advanced household devices, appliances, and sensors that can be remotely accessed, monitored, and controlled. (Balta-Ozkan et al, 2013) These devices provide services to the resident that is needed or wanted throughout its lifetime. The term smart home began to be popularized during the late 1990s, early 2000s when smart phones were popularized. However, by mid 2010 the term had modified towards a home that is aware of what is happening and can react to its environment. (Balta-Ozkan et al, 2013) Smart home devices were used to control environmental system such as lighting, heating, and cooling. This has grown these days to include monitoring users' activities, home environment, and includes fulfilling the demands of a user at a moment's notice.

Recently, with the improvements made in artificial intelligence, there has been a push to implement said AI services to smart homes and their automotive tasks. A prime example of this would be Amazon's Alexa, among others like Apple's Siri, and Google's echo. Most of these devices have been installed in a wide variety of products not always exclusive to the company's specific devices. Items such as

TVs and even refrigerators are now starting to implement features such as searching for news, shopping online, and checking users' schedules. These devices are being developed and pushing for adoption of AI in the IoT space.

Prior studies on smart homes were based on a more technical approach. For instance, there were suggestions for a smart floor technology which knows who, where, and what a user was doing at any given moment. (Kidd et al, 1999) Adami proposed a wrist gadget [like the apple watch] that monitors a users' habits at home. (Adami et al, 2003) Andoh suggested a biometric monitoring system that analyzes the pulse and respiratory rate at home. (Andoh et al, 2004) Many more studies have been conducted to show the improvement and wholeness of a smart home service. These studies have however only focused on the technological aspect relating to how these devices are used and their ease of use significantly lacking analysis on the business or users' perspective for how to keep the devices in consumer's interest.

Discussion

The term "smart" has been used in various other fields most notably in smart phones. The term has been extended into other areas such as smart televisions, smart plugs, smart watches, and now smart homes. In general, the term smart is meant to convey a sense of intelligence like some limited ability to act somewhat autonomously, like an AI system. The conversation as to if the system can perform decisions like a human has been a topic for debate for as long as autonomous systems have been developed, however, it is well known that humans will generally be reluctant to provide all decision-making abilities to what is colloquially called a machine. This is due to the general uncertainty and distrust

that is usually placed on any technology that is autonomous in nature as well as a certain sense of freedom restriction.

Research into the field of smart homes have been performed since the early to mid 2000s, where most studies have focused on groups such as the elderly and disabled. The general idea being thought at the time was that people who need help would be most likely to utilize these smart devices. Vattillo's research into the telecare system adoption, a type of smart home service, found that the most important part of the perceived usefulness of a smart home depended heavily on the intentions that the system is to be used for. However, as smart devices start to grow and the userbase changes, the research on the topic has evolved. Research on the acceptance of users of these devices has increased. Bao looked at the mobile smart home environment finding that compatibility and safety are the most important factor in the mobile smart home acceptance criteria. (Bao, 2014) Some others see that the concept of a smart home with IoT devices will change and expand to include more wireless networks, and even various operating systems. Generally, it is shown that smart services, such as smart homes, need to increase the enjoyment, compatibility, control, and satisfaction of the user for them to be accepted. Typically, controllability would be a significant factor in adopting a smart home. Intelligent control of a system being able to learn a user's behavior and automatically provide smarter control of features contributes heavily as well.

Additional studies have shown the importance of security and privacy in the smart home acceptance. Some identified the level of security in the household as the distinctive decision in acceptance a smart home service. Others argued that clear privacy and data protection is needed to operate at a level that is beneficial

to society even going as far as to say those security and safety levels should be user configurable to mitigate the effects that privacy concerns might have.

However, these conversations and discussions seem to always be one sided. The fundamental understanding needed to configure these systems are always glossed over and the analysis from these studies always seem to focus on a specific group of the population not considering the diverse user classification present in the market.

The initial smart home service was promoted through the automation of the domestic system, aiming for convenience, comfort, stability, amenity, health, reduction of household labor, and energy efficiency. Since then, developments of the wireless Internet and smart phones have extended the concept of a smart home to services that can be remotely controlled anytime and anywhere. In the IoT era, household electrical appliances and information and communication devices are interconnected, and the smart home is developing into a form of an artificial intelligence service that operates by self-understanding the behaviors of the residents. Therefore, the smart home in the IoT era is a concept that adds interconnectedness to the traditional characteristics of automation and remote controllability. Service stability, security, and privacy also have been suggested as important factors that may hinder user acceptance. These factors can be summarized as the reliability of the service. The smart home environment is a factor that must be considered because it is closely related to the user's life and can cause serious damage in the case of a dangerous situation. Thus, automation, remote controllability, interconnectedness, and reliability can be summarized as crucial factors for accepting a smart home service.

Automation is defined as the “execution by a machine agent (usually a computer) of a function that was previously carried out by human”. Home automation was the initial name of the smart home service, and the automation of households and home infrastructure was a key goal of the early smart home. Automation has become prominent in recent years because it has become more affordable and simpler through the development of information technology. In recent years, an interest in AI has enabled higher-level automation. AI technology can advance the function of a smart home by assisting users in an intelligent way. Hence, technology is one of the critical features of a smart home.

The virtue of a smart home is that it can be controlled remotely by mobile devices. This is a core feature of a smart home system since users prefer to instantly control smart home services such as controlling lamps, curtains, and information appliances. However, to design an intelligent and remote-controllable smart home system, a network connection is essential. Many networks exist with a variety of features such as Bluetooth IEEE 802.15.4, Z-Wave, and Wi-Fi. (Koskela, 2004) and To enable remote control, networks should be standardized and interconnected to expand the use of smart home services. Most electronic devices support the Wi-Fi protocol, which allows home devices to be controlled by mobile devices. When remote control is possible, the general concept of smart, anywhere, and anytime, can be implemented.

Interconnectedness is defined as the ability of devices, applications, and services to relate to each other to work together. To proliferate a smart home, devices should be able to adapt to changes in the preferences, requirements, and

needs of a user. The system should easily connect to new devices in a smart home. It is critical to correspond through the network for a smart home to function properly. However, many types of network and communication protocols are a barrier. Networks can be wired, or wireless, and other types of communications exist. At present, the technical standard is inadequate due to the high cost of satellite links and the limited transmission between electronic devices.

The goal of this paper was to understand and explain customers' behavioral intentions to adopt smart home services, unlike the previous research that examined the user behavior associated with smart home service adoption based on acceptance theories. Three factors, controllability, interconnectedness, and reliability had a significant impact on the acceptance behavior of a smart home service. It is very interesting that automation itself does not have a significant effect. This can be interpreted as people generally seek relatively safer and more effective remote management features rather than highly advanced automated services. People may want the devices of a smart home to be under their control rather than being fully automated because a home is safe and represents their personal space where they can rest. Considering that controllability is the most important antecedent for adoption, it becomes apparent that the automation that people want is eventually intelligent and represents an optimal controllability that is close to a limited form of automation.

Other major influencing factors are user characteristics such as age, gender, residential types, and experience. The expectations and demands for smart homes have been found to vary depending on the user characteristics. First, it is known that there are differences in the perception and needs of smart homes depending

on the age of the users. For example, although a smart home can provide a convenient and easy automation system, most people generally tend to want the system to be under their control rather than be fully automated or show a concern about the cost of automation. On the other hand, some studies have shown that the elderly population generally tends to respond positively to most smart devices and sensors associated with health problems. Especially in the perception of automation, the elderly generally shows a positive attitude. Gender differences have also been addressed in many studies. A study by Yang showed that females had greater intention to use the smart home services than males. (Yang, 2015)

Other research revealed that the effect of factors affecting smart home adoption (e.g., perceived usefulness and compatibility) vary by gender, finding that females are more affected by perceived costs in the smart home adoption process compared to males. Differences in the level of education have been validated in some studies. It is generally known that users with higher education tend to pay more attention to the usefulness and benefits of innovative technologies. Others further found differences between groups with high education levels and those with low education levels in their expectations and adoption of smart home devices. However, the impact of income level presents a point of contention in this field of study. The cost burden of the initial purchase, installation, and maintenance of smart home services is a major barrier to the adoption of the services. In particular, the cost burden caused by the structural changes in the space required for using new services has been reported to be one of the factors hindering smart home adoption.

For instance, research into smart homes revealed that the users' perception that structural and technical infrastructure must be prepared before using smart home services has a significant impact on the adoption of the services. (Koskela, 2004) Overall, the cost burden is a key factor in adoption. Interestingly, on the other hand, the impact of income levels on the adoption of smart homes has been supported in very few studies. For example, in the Yang's study income levels did not directly affect the adoption of smart homes. He found an indirect effect of income levels, but it did not reach statistical significance for it to be a factor in consideration.

In addition, smart home adoption is also affected by the type of housing, such as apartments, condos, mansions, that users currently reside in. Some studies noted that the needs and intention to use smart home services vary depending on the type of housing the users live in. The researchers speculated that the difference may be due to different levels of infrastructure in place depending on the type of housing. Finally, the adoption of technology can be influenced by users' related experiences. Koskela emphasized the effects of experience as one of the factors that accelerated the diffusion of innovations. In the context of a smart home, some studies have confirmed that the user's relevant experiences affect the expectations and adoption of smart home services.

Conclusion

Overall, studies on smart home adoption suggested that there are several cognitive factors that influence users' decisions to adopt smart homes and that the process of the decision may vary depending on the user's characteristics and background conditions. Research results show that interconnectivity and reliability

are required along with the right level of automation. Furthermore, because there are differences in preference factors according to the characteristics of users, it has been confirmed that the service design that considers these characteristics is necessary. If these factors are taken into consideration, smart home services that have not been activated in the past should spread and the market for smart homes should grow.

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