Control, Intervention, or Autonomy? Understanding the Future of Smart Home Interaction

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Abstract

More and more smart home devices are hitting the market. While current applications on mobile devices and classical interface elements (e.g., wall mounted switches) are used to interact with these devices, we investigate in this position paper what interaction paradigm might be used in the future. We discuss different smart home devices and argue what interaction paradigm might be most useful. As an increasing number of smart home devices can act as autonomous agents interface paradigms like intervention interfaces or autonomous interfaces might become the main communication channel between the smart home user and the smart home system of the future.

Author Keywords

Smart Home; Augmented Reality; Intervention User Interface.

ACM Classification Keywords

H.5.2 [User Interfaces]: Information and presentation

Introduction

Smart home devices penetrate more and more our daily lives. Systems such as smart heating or smart room lighting received considerable attention lately. Due to a high level of connectivity, they can be controlled via various types of user interfaces. These include smartphone applications, voice

control (e.g., Amazon Alexa or Google Home), or classical wall switches. Research also showed that AR applications can support users during the interaction with a smart home system [7].

Various smart home devices can be controlled. The room temperature can be set to a certain degree and the brightness and color of each light can individually be changed to the user's preferences. While this seems to be the ultimate goal of home automation, the question arises if the user still needs to be in the loop. With current ubiquitous sensing technologies, body temperatures of the humans in the room can be measured and room heating adapted to a level that moves their body temperature to a decent level. Thus, the system can fully act autonomously. On the other hand, however, classical user interfaces should be designed in a way that the user stays in control, following Shneiderman's golden rules (e.g., support internal locus of control) [6]. This, in contrast, would indicate that the user always should be in direct control of the smart home objects so that he or she has the feeling of being in the center of the action. In addition to these two ways of interaction, a new interface paradigm, namely intervention user interfaces, might be a solution to get the advantages of both worlds.

In this paper, we discuss different approaches to control smart home devices. We provide examples in which the different interface paradigms clash in the smart home domain. We discuss potential solutions that tackle these issues and ways that have to be explored to design smart home systems in an optimal way.

Interface Paradigms
Throughout the years, several interface paradigms have been used or envisioned to interact with smart home devices. In the following, we introduce four different types of

interfaces and briefly discuss their characteristics regarding smart home.

Direct Manipulation Interfaces
Most devices in a common home environment offer interfaces such as switches which can be used to manipulate their behavior (e.g., a light switch that changes the state of a light bulb). As the complexity of these devices increases, these interfaces may become unsuitable for proper interaction and the control of the various features. Nevertheless, they offer an easy mapping and are currently the default way of controlling non-smart home devices.

Remote Interfaces
With the advent of smart home devices, remote interfaces gain more and more importance. Mainly these interfaces are provided by an application running on a mobile device like a smartphone or tablet. These applications allow various types of control. They can be used to adjust the temperature, the brightness, or the color of a light bulb to the desire of the user. The user is in direct control on how the smart home device behaves. The user also directly understands what he or she is doing. In addition to mobile applications, research introduced further means of interacting such as gesture or posture detection [5].

Intervention Interfaces
The more a system is configured to work autonomously the less input by the user is required. Particularly continuous interaction is often superfluous. However, the user desires an applicable level of control of the system. At this point, the term *intervention* was implemented as an interaction metaphor. Schmidt and Herrmann defined *intervention* in the field of human-computer interaction as an action of the user that influences the behavior of an automated system [4]. Thus, *intervention user interfaces* support the user's awareness of automated processes. Further, it lets

the user change the behavior of the running processes. Particularly in cases in which autonomy might not fully be able to fulfill the user's desires, an intervention interface can be useful.

Autonomous Interfaces
With an increasing number of sensors deployed in homes as well as an increasing power of artificial intelligence and machine learning systems, a system fully autonomously controlling a smart home might be the reality soon. This, on the flip side, would result in the user abandons all control to the system. The question arising here is if the user needs to be in control of all smart home devices. The heating, for example, is mainly controlled by the user in cases in which he or she feels too cold or too warm. Given a thermal camera, for example, measuring the body temperature of the user as input, a fully autonomous system might easily be capable of adjusting the room temperature in a way that the user neither need control nor intervene.

Smart Home Devices
Today, more and more home items are extended with the possibility to be remotely controlled. In the future, almost all traditional systems will receive these capabilities. We discuss some of the current smart home devices with respect to the interface that might be most appropriate. Thereby, we do not consider malfunctioning of sensors nor the setup procedure that both would require additional user input.

Lighting System
Considering a lighting system, a normal basic interaction in any house is the direct manipulation interface (e.g., on/off light switch). In smart houses, light could be handled automatically based on the user location and activity detected by sensors either embedded in the environment or on the user. This, however, requires the user intervention in case

of exceptional activity (i.e. turning manually a reading lamp on). Mobile interfaces might be of good use if the user wants to control sophisticated features of the lighting system (e.g., changing color or light temperature). For the default operations (e.g., switching on and off), the mobile interface poses a lot of overloads (i.e., getting mobile, unlocking a phone, selecting an application, etc.) making it less useful.

Heating System and Ventilation
Nowadays, most of the smart heating systems depend totally on the smart thermostat for detecting the in-room temperature and adjusting it to the user preference. While this satisfies the user expectation, it is not adaptable to the user needs. One good solution is to have the room temperature adjusted to the user's body (i.e. human is cold ergo more heating). To be able to apply such approach is to provide intervention interface with options, especially if the adjustment of the heating system would clash with the appliance of the ventilation one. Taking the scenario of scheduled window openings, which is required by the user for ventilation purposes, the system would have a conflict of goals requiring the user to intervene.

Kitchen Appliances
While activating the heat and light systems might depend on the user's presence and activity, other devices such as smart kitchen appliances might also be influences on the user's spontaneous likes or emotions (e.g., baking chocolate cake when being sad). A smart coffee machine could brew the coffee based on the current sleeping behavior so that the coffee is ready once the user awakes. While this certainly requires intervention from time to time, remote control might rather be exceptional. Direct control also might still be useful, particularly for devices that might pose potential threats when used wrong (e.g., a stove that en-

ables itself). Further, more sophisticated kitchen system would also involve direct input [3].

Cleaning Devices
Cleaning robots already work mainly autonomously to-day [2]. If the user is not at home, they do not interfere with his or her activities and start cleaning the floor. Cleaning can be done without direct or remote interaction with the human if no exceptions occur.

Door Lock
Smart door locks allow the user to provide access to their house remotely to friends waiting in front of the house when the host is late or to package delivery when nobody is at home. Since this is a crucial aspect and providing access to one's house has huge privacy implications, we believe that this type of smart home device might rather be controlled directly or remotely. The user might prefer staying in control rather than being comforted by autonomous controls.

Windows
In the future, smart homes will also contain window ele-ments that are smart [1]. Windows will be built out of sev-eral elements that can be individually darkened by users similar to pixels on nowadays screens. These windows can provide several applications such as preventing users from being dazzled by the light or preventing people from the outside looking into the house. These applications might work – once they are set up – without any direct control or intervention of the user. Thus, they can be autonomously controlled.

Conclusion
The examples presented in this work show that for most smart home devices the classical interfaces are not the most promising ones. We believe that intervention user in-terfaces, as well as autonomous interfaces, might be the

interfaces that will shape the interaction with smart home devices. As soon as users trust the system enough to allow moving their control to the computer, classical interfaces will become an exception and mainly used for intervention only. However, there might always be devices for which the user wants to stay in control. One example for which the user might not easily pass the control to an artificial intelligence is the smart door lock since the potential privacy threat can be severe.

In the future, we plan to conduct large-scale assessments of how users currently use smart home devices and what interfaces they prefer. We believe that within the next years, user's preferences will dramatically change as soon as they understand the benefit and gain more and more trust in smart home systems.

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