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ConductHome: Gesture Interface Control of Home Automation Boxes

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***Abstract*—**This paper presents the interface ConductHome which controls home automation systems with a Leap Motion using "invariant gesture protocols". This interface is meant to simplify the interaction of the user with its environment. A hardware part allows the Leap Motion to be carried around the house. A software part interacts with the home automation box and displays the useful information for the user. An objective of this work is the development of a natural/invariant/simple gesture control interface to help elder people/people with disabilities.

***Keywords*—**Automation, ergonomics, gesture recognition, interoperability, leap motion, invariant.

I. Introduction

HOME automation is a fast growing domain which aims at centralizing the control of systems and subsystems at home. It offers solutions regarding convenience, energy efficiency, security and communication [1]. The rapid advance of new technologies and connected devices is bringing constant changes in Society. The dream of the "house of the future", which answers user needs and anticipates them to make lives easier, is becoming a reality.

Because of the broad range of existing products with their own protocols, it creates a complex environment to be dealt with [2], [3]. The speed of development and obsolescence of these technologies forces permanently the user to keep up-to-date his knowledge about these devices and their uses [2]. This trend is a source of issues about access to these technologies and their ergonomics. Moreover, the use of multiple interfaces increases user confusion when he has to choose the adequate solution considering his needs [4], [5].

Home automation field included technical skills/ abilities/ field/ services/ expertise from electronics, building physics, automation, computing and telecommunications used in buildings, and allowing control centralization of the different systems and subsystems in a house or a company. It proposes solutions answering convenience, security and communication issues/needs which can be found in houses, hotels, public places etc. Examples of home automation uses are, as shown in Fig. 1:

- Steering of home appliances by scheduling/time programming or action sequences. The launching can be associated with an event (motion sensors, remote, etc.) [6]-[9].
- Energy, heating, air conditioning, ventilation, lighting, opening and closing of the flaps and water consumption management
- The recharge of electric appliances can also be controlled [6], [7], [10], [11].
- Security of goods and persons (alarms, motion sensors, security phone etc.) [1], [6], [7], [10].
- Home adjustments for people with disabilities and dependencies [4], [10], [12].

This paper proposes the development of the interface ConductHome meant to simplify the interaction with a home automation environment.

Fig. 1 Display of Typical Home Systems

II. Overview

A. Communication and Compatibility

The principle of home automation is based on building networks between the different electrical house appliances controlled by a centralized "intelligence". The intelligence managing the ++++ of devices is a programmable central, embedded module or a micro-computer interface (tactile screen, server, etc.).

Interoperability is one of the main criteria for efficiency of a home automation system. It is the ability to communicate easily, fluently and comprehensively to all the elements within the automation system [2], [9], [13]. This capacity is put under pressure because of the increasing variety/development of

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devices for home automation [5]. Indeed, an increasing number of users want to integrate new automation devices into their own home automation system. But due to the large supplier number and the different uses or application fields of these devices, the consumer can easily end up buying a non-compliant appliance. The same problem is encountered when the consumer wants to update/change one of its subsystems (heating system for example). The use of different protocols creates difficulties for communication in the whole system. As a result, such situation will lower the global efficiency of house home automation system.

B. User Interfaces

The user interface is the space where interactions between humans and machines take place. It is meant to give the user the possibility to give orders and to interact with the machine or software. The management tools provided by the user interface allow him to control the home automation system through a monitoring screen or a centralized remote desk. Some home automation solutions can be connected to web networks/internet, so the system can be controlled from outside the house [3], [5], [7], [8]. Thus a notebook, a mobile phone/smartphone, a tablet, a remote, a TV interface or even a screen and a mouse can be a possible interface to control such a system. The main problem the user faces is the lack of interoperability between home automation equipment and boxes [9]. Indeed, some devices can only be connected to one kind of automation box. To avoid adding any layer that could end up being incompatible with some already existing systems, the system proposed here has been designed as a link between the user and his home automation box. Moreover, for some people, it is not really easy to handle and master this kind of equipment because some menus are not user-friendly and the device holding the software is sometimes not fitting. It makes the use of such equipment non-intuitive and ergonomically not attractive [7], [10], [11].

III. System Design

From previous discussion, a good interface should be intuitive, easy to use, with natural and intuitive interactions, and mobile. The large panel of connected and smart devices allows answer last mobility issue. As these technologies are new, most of them should be used with most natural interactions for humans: oral/verbal and non-oral/gestural/non-verbal/behavioral [8], [11]. Gesture is a non-verbal interaction Humans use in everyday life and even allows people speaking different languages to communicate. It seemed to be the most relevant interface for the communication with devices. Gesture recognition sensors are the solution to combine a natural gesture interface and ergonomics. But, as for home automation, there is a very wide range of sensors that can fill this function and we are also facing a problem with interoperability [9]-[11]. The other issue to face is ergonomics. The use of home automation systems implies the knowledge of such technology. As this field grows very quickly, one can easily get lost within all the new interactions and protocols that are needed to handle those devices [5]. It is even harder for the elderly/people with disabilities to stay up-to-date as they already have issues with the use of usual/common equipment/systems. It also became quite obvious that people get confused, lost or bored easily if the panel of gesture interactions is too important.

A. System Requirements

The software is meant to facilitate the navigation in home automation box menus and give easy access to all house appliances. The hardware includes a gesture recognition device and a way to display information and to communicate with the software. The whole system is designed to be simple and intuitive. Devices can be selected and controlled easily and one does not need to learn any complicated instructions to do so. The system should provide only a few numbers of gestures to control appliances not to confuse the user with a too large panel of interactions.

B. Interoperability

With the home automation box protocols, it was easy to manage the interoperability. Indeed, we only needed to collect the APIs identifiers of the box and appliances to connect them all together. As it is not an important issue, research has been focused on ergonomics in the use of home automation systems.

C. Ergonomics

Ergonomics can be defined as the practice of designing products, systems or processes to take proper account of the interaction between them and people who use them (comfort design, functional design, user friendly design, etc.)

It is today becoming a problem in the use of all the devices from new technologies created every day. It generates issues for access, people with disabilities, technological environments, elderly people etc.

Getting an efficient ergonomic device appears as the most important part in the system. It should necessarily include an electronic part such as a microcontroller or an embedded computer, and of course use gestures as the way of communicating with the system. To control house applications, one usually needs to navigate through menus to select parameters or appliances and also give orders to one of them via the application. This implies different interactions (gestures, use of a mouse or even oral commands) to navigate, select, give orders, etc. Instead of simplifying the control of environment, such approach makes in reality the process more complex to user because of usual tree like combinatorial explosion.

In present case Leap Motion software has been selected to catch user instructions as this is a recent and accurate gesture recognition device. However, Leap Motion is not as reliable as expected as it has difficulties to recognize complex gesture and even worse for combination of gestures. To eliminate the difficulty, the basic principle of proposed solution is to get out of the general model of Tree View and propose a straightforward interface with normalized commands and orders. Instead of selecting devices with different commands, through successive panels there will be conversely only one

action to select any kind of device and one set of gestures to control them all. To implement this solution one needs to split the appliance process control into two communication channels: one to choose the device(s), another one to control it/them.

The Leap Motion will be used to control the appliances. Another component will have to ensure the selecting part. It is also necessary to display some information to the user, such as selected device(s) state including energy consumption, and conversely, let the user enter his identifier or other information. For the two-way communication with the user, a tactile screen is better solution. Indeed, the tactile part makes the user able to enter data to the software.

For the selecting part, the appliances of home automation system will be associated to buttons. This association can be customized by the user through the touch screen.

IV. Final System and Results

A. System Structure

The final system is composed of two parts: the hardware and the software.

The hardware is composed of a Raspberry-Pi 2, a touch screen, the Leap Motion, a LED keypad and batteries. It is all integrated in a box to piece everything together. The prototype has been virtually design and simulated in operation.

1. Raspberry-Pi 2

Raspberry-Pi 2 is a Nano-computer allowing the execution of various versions of GNU/Linux exploitation system and other compatible software. This component carries the software computing the information sent by Leap Motion about user's gestures and orders, analyzing them and sending requests to the home automation box for execution of selected actions on equipment.

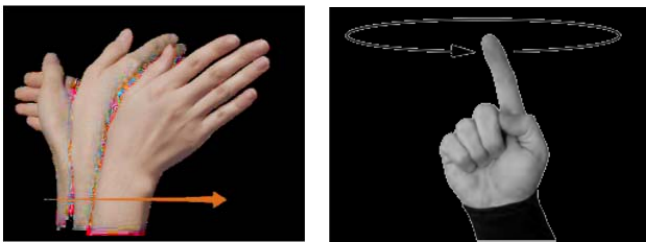
2. Leap Motion

Leap-Motion is a motion device developed by Leap Motion, Inc. It can detect hand gestures and movement through a little camera. Open sources development kits are provided to allow the community develop applications using this technology. In proposed system, ConductHome will receive information sent by Leap Motion to translate them into understandable request for home automation boxes.

The choice of Leap Motion answers the interface issue. But one needs to add a screen to "see" the equipment and the menu. The hand movement set has been reduced to basic movements: hand swipes and finger circles, shown in Fig. 2.

3. Trellis

Adafruit's Trellis is a LED keypad and a necessary interface because if everything is controlled by hand gesture, it becomes very complex to navigate through all the menus and choose a device. By addition of Trellis to Leap Motion as an input device, the user will be able to communicate with the software, for example to refresh the list of connected equipment to the box, or to select a particular device for command. The Trellis simplifies the whole protocol because it allows selecting one or many devices so the gestures made will have effect on all the requested devices at the same time without navigating through many menus to do so.



(a) Hand swipe (b) Finger circle

Fig. 2 Basic Gestures of Vocabulary Communication with Home Systems

4. Software

The software has two main functions:

- Provide the information from selected device(s) and display ConductHome current configuration through graphical interface from screen capture.
- Handle the signals received from Leap Motion, treat them and send the corresponding requests to home automation boxes, and more generally get information on system and its environment.

B. Analysis

As previously stated, many solutions have been proposed to control what could be called "Tomorrow houses" or simply automation systems. The uniqueness of present solution stays in the fact that it is not just another way to communicate with automation systems which is proposed. Gesture recognition has already various applications (video games, surveillance systems mainly and soon medical applications) and has been studied to ease elderly people life, especially by pairing it with home automation systems [10], [12]. Contrary to other classical approaches (such as computers, phones or tablets) there is here no interface filled with menus and submenus to be browsed and understood to be used correctly. Everything is accessible on one unique panel/facial/physical interface.

Each appliance connected to the home automation box can be selected and controlled through the main interface represented by the combination of LED keypad and Leap Motion. Information on selected device and global house configuration are displayed on the screen. Other advantages of proposed solutions are the very limited number of instructions which has to be stored and treated by the computing unit, and the consecutive robustness that stems from it. Indeed the system has only a few possible inputs and this fixes the main imprecision issue of gesture recognition. Here as the different utilized gestures are easy to distinguish from each other it is not an issue for the user to "get the trick" and to make his orders clear to the device. ConductHome device limits the number of movements and offers an invariant solution to control home automation devices: one gesture will have the same effect no matter what devices are selected. This simple and robust process is barely sensitive to interpretation errors and is easy to handle.

V. Conclusion

The development of a gesture controlled interface for home automation systems, using Leap Motion software, has been presented. A simplified interface has been proposed by splitting the selection process thanks to a LED keypad. Selected gestures invariants allow then the user to control all appliances with very limited number of gestures whatever the type of device is. The result is an intuitive and user-friendly interface that can help elderly or disabled people.

For now, ConductHome system is implemented for existing home automation boxes and devices such as sensors and dimmers. This system can be adapted to market evolution in order to make it more efficient and intuitive to users.

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