Alternative control method of the smart house: natural gestures

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***Abstract*—Due to the rapid increase of house automation use it is clear that alternative methods of control are needed. This paper presents a control method based on the person's gestures that allows a high degree of control especially on devices that have binary states (on/off). The gesture based interface is suitable for the control of the smart house because it offers a simple yet powerful control mechanism that is appropriate even for children, elderly persons and persons with disabilities due to the intuitive interface. In order to test the functionality of this control method, a smart house control system has been implemented. A bracelet has been implemented using the C language into an Atmega168 microcontroller based board. This bracelet is capable of sensing hand movements, and with the help of a location identification system, even the person's location. The main control system has been implemented using VHDL into a Xilinx Spartan-3E FPGA and it is capable of domestic device control and GUI display.**

I. Introduction

The smart house has been present as a concept for more than a century, just falling short of materialization. There are two turning points for the introduction of domestic technology: the introduction of electricity and the introduction of information technology [1]. The smart house concept arose from the convergence of domestic technologies and dreams of total control, and was sustained by advertising, fairs, exhibitions and magazines. In the 60s, homes started to be "wired", equipped with devices that allow some degree of control over electric appliances. Intelligent behavior was simulated by trying to create a network of devices that communicate with each other. [2] In 1984 a project was initiated by the National Research Center of the National Association of Home Builders that described the heart of a smart house: "In Smart House technology, the dwelling is wired with a single multiconductor cable that includes electric power wires, communications cables for telephone and video, and other conductors that connect appliances and lamps with electronic devices that control the supply and switching of power,"[3] The core of the smart house is trying to make it safer, more convenient and economically friendly. One of the first technologies that made the realization of a smart house possible is the X10 protocol. This is a communication protocol with uses the existing electrical network as a medium of communication, besides their original role as power carrier [4]. This technology offered the freedom to control almost any appliance even from outside the house. As information technology and internet emerged, the smart house concept received a little help in order to expand. There are two particular types of smart houses, the green house that tries to minimize the impact on the environment and the house assisting the elderly. If we try to answer the question "What makes a smart home smart?" we soon realize that there is no definition that is generally accepted for a smart house. The term is closely related to other concepts suck as the digital house, the house of the future and the automated house.

The revival of this concept in the late 1990s has transformed it into reality. The contemporary smart house, according to David Heckman, represents the convergence of three areas: robotics, artificial intelligence and media convergence [5]. At present, the smart house is a common item that is widely available to the general public.

The control methods commonly available in a smart house usually includes the use of touch screens but not always connected to a standard PC, infrared remote control or mobile devices. All these control methods have advantages and drawbacks. The use of touch screens or even standard PC and LCD has the advantage of using standard components for the control system and the common use of the internet but has a major drawback: in order to control the house from any point you need to be near a control box, meaning that the whole house needs to be fitted with control points. The humble and classic infrared remote control is suitable to control a relative small number of devices. Although there are a number of improved remote control devices, they tend to be complicated and are not suitable for elderly people, impaired people or children. The use of mobile devices to control the smart house implies the use of the internet. The main advantage of this method of control is that it uses standard smart phones or even tablet PC that can easily be replaced because the mobile device only displays a simple web page which can be controlled by the user. The main disadvantage is that it tends to be a rather complicated method of control and even expensive.

II. Gesture Based Smart House Control System

A. Gesture recognition

Gesture recognition has the aim of interpreting human gestures using a certain mathematical algorithm [6]. A richer interface between human and machine is therefore created, eliminating the limitation of conventional input devices. Gesture can originate form any body motion and comes from the face and hand. The input devices that can track a person's movements include wired gloves, dept-

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aware camera, stereo cameras, controller-based gestures and single cameras. The wired gloves are the most known of the input devices, being used by some time with great success. The use of fiber optics makes these input devices quite expensive. The depth-aware cameras are special cameras that can generate a three dimensional representation at short range. Stereo cameras can also create 3D representation by using 2 camera arrays. Controller-based gestures are detected using a controller as an extension of the human body, the most common device being the humble gesture mouse. In this category of input devices other 3D sensing input devices are present, for example the wii remote. A single camera is widely used in order to detect gestures, as it is one of the cheapest solutions.

B. Gesture based control system

A gesture based control system is a classic control system in which the input device has been changed with gesture recognition. The wide range of gesture capable sensing devices makes this control system easy to build. Because the main interface between human and machine is gesture, the communication is carried out easily and in an intuitive manner. Due to the communication method, this control system can be used even by children, elderly people and impaired people. The degree of gesture recognition and gesture types can vary according to the target user.

C. X10 Protocol and the smart house

This protocol is the standard data transition for the Power Line Carrier. It was introduced in the year 1978 and still maintains the original format. The data is transmitted via the power lines with the help of a high frequency 120 KHz signal. This signal is injected into the power lines and it represents ones and zeros. The alternating current is used for synchronizing the timing of signal injection, thus using an existing timing signal that is accessible to both receiver and transmitter. In figure 1 the signal injection method and timing is presented.

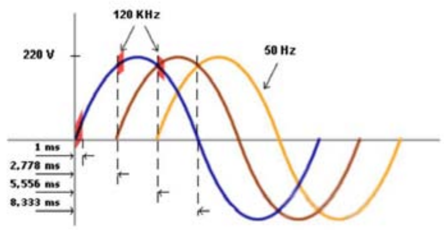

Figure 1. X10 signal injection

Due to the nature of the power network, which is very noisy, the protocol transmits every bit alongside with its complement. In figure 2, the encoding of the protocol is presented. A complete X10 transition involves two data transition. The first data transition is composed of: a start code, house code, device code, end code and it identifies a device within a house. The second data transition is composed of a start code, a house code, a function code and an end code. The second transition identifies a house

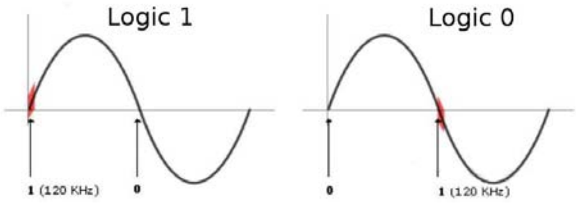

Figure 2. X10 protocol encoding

and the function that the device previously identified is required to undertake. The reason that a full command is split into two is that once a device is activated, it remains activated until another device is activated thus allowing the sending of multiple commands to one device without activating it each time.

Because it uses the existing power lines that are omnipresent these days, the X10 protocol is perfect for controlling devices in a smart house.

III. THE 3D WIRELESS INTERFACE PROJECT

A. Componets

The project is composed by two subsystems that communicate via radio waves and a localization identification system. The user has the possibility of controlling electronic/electric devices only with hand gestures. This implementation supports the recognition of four basic hand movements: up, down, left, right. The main system can be used in two main operation modes: on screen control and direct control. The on screen control operation mode implies the use of a screen on which different action to control objects is displayed. The actions are organized under the form of a menu in which the user can navigate using simple hand movements. The control actions are selected via hand moments only. The second control operation mode allows the user to control different objects without the use of a display system. This method of control uses a localization identification system in order to pinpoint the user location and based on this location different actions are possible. The two subsystems are presented in Figure 3.

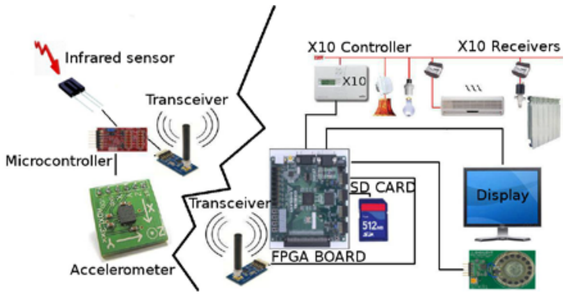

Figure 3. The two subsystems

The first subsystem is a bracelet that acquires dynamics and motion data on the hand. These data is transmitted to the second subsystem. Along side the dynamics data the subsystem send data regarding the user position, data that have been received by infrared from the location identification system. The data are sent in raw form, data processing been done on the second subsystem.

The second subsystem is the control box on which the data processing takes places. The data are received by radio waves from the first subsystem and according to this data the approximate hand movement is determined along side with the user position. These hand movements allow the user to navigate into a menu displayed on a screen. The menu entries are real world actions that the system can undertake. These menu entries are stored on a SD card in order to be easily modified. This subsystem can control objects directly or through an X10 network.

B. *The bracelet*

This subsystem detects the hand movements and user location. The hand movements are detected using a three axes accelerometer. The accelerometer chosen for implementation was ADXL345 from Analog Devices due to its 13 bits resolution and the ability to measure acceleration up to 16 g. The user location is determined by receiving information from the location identification system and is also relayed to the control box subsystem. Localization data are received by infrared using an infrared module. The infrared module chosen was TSOP31238 at 38 KHz and has built-in filters and preamps. The microcontroller receives data from the accelerometer and infrared module and relays these data to the control box subsystem to be processed. The microcontroller used is an Atmega168 from Atmel. The two types of data are relayed through radio waves using a radio transceiver. The transceiver used, At86RF212 on a PmodRF1 board, is a low power type that assures that the communication is consistent even in a big house. The bracelet hardware components are presented in figure 4.

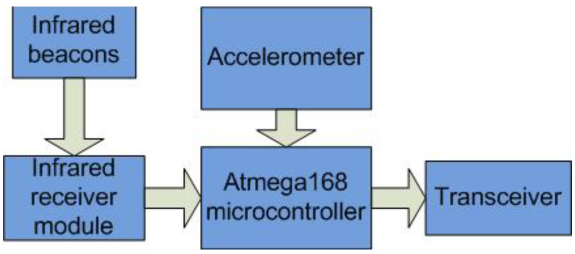

Figure 4. Bracelet components

The bracelet, the microcontroller, is programmed in C language using AVR Studio 4. Because this IDE doesn't have a C compiler, AVR GCC compiler was used from

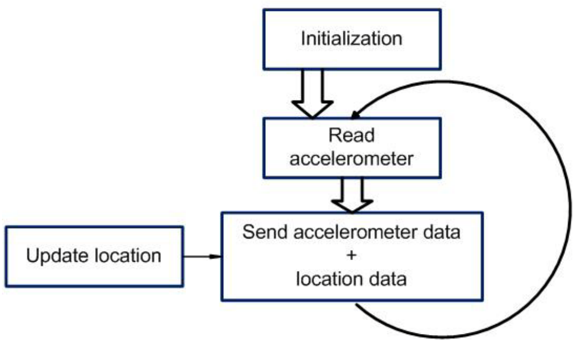

Figure 5. Control box components

the WIN AVR application suite. The main functions that compose the program are presented in figure 5.

C. *The location identification system*

The location identification system consists of infrared beacons that are spread across the area that is to be controlled. In this way, the system can know the persons approximate position and act accordingly. The small beacon uses the RC-5 protocol to emit via infrared a unique code that represents the beacons location. The beacon can be made extra small and a decent battery can sustain an acceptable working interval. The main advantage using this kind of beacons is that the power needed for transition is low, each beacon communicating only with the bracelet and not the main control box. The only component that communicates with the control box is the bracelet which is equipped with a long range transceiver. The beacon is composed of a SAA3010 IC, an infrared LED and a small number of analog components. This way the beacon is cheap and small.

D. *The control box*

The control box is built around a FPGA board. This assures easy upgrade and a cheap yet powerful platform for data processing. The board chosen for implementation was Nexys 2 board mainly due to its low price. The data are received using an identical radio transceiver PmodRF1. The FPGA board has a VGA output that is used for displaying the menu. Any VGA compatible monitor can be used and with an external converter is

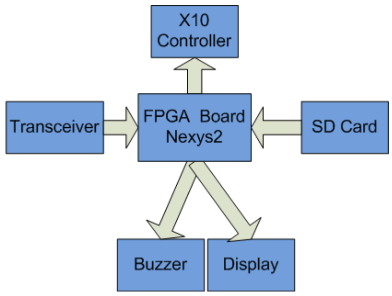

Figure 6. Control box components

possible to display the menu even on a regular TV. The menu entries are stored on a SD card for easy access, the SPI protocol being used for access. The menu entries permit the user to control real objects, each menu entry representing a possible action or a category of actions. The menu entries are stored under a XML similar format. The FPGA board has a build-in serial port that is used for communicating with an X10 controller. The controller used is a CM11 from Marmitek. Via the serial interface the system communicated X10 command that must be retransmitted by the controller via the existing electrical grid. This way any X10 compatible receivers can be used in order to control any household appliance without a direct connection with the control box. There is a possibility to use direct control for the devices that are near the control box. For testing purposes, a personal alarm system was implemented to demonstrate the capability of the system to directly control a device, in this case a speaker. The components from which the control box is constructed are shown in figure 6.

The control box in programmed mainly in VHDL language. The Picoblaze microcontrollers were programmed using assembly language. The development environment used was XILINX ISE WEBPACK 11. The software modules in the control box are presented in figure 7.

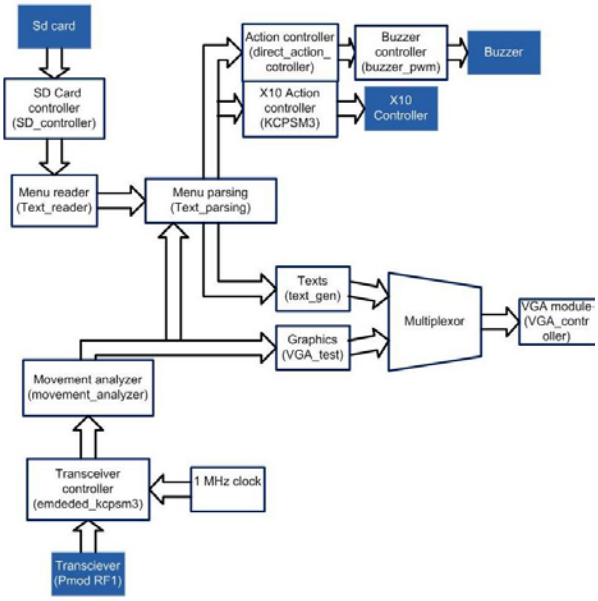

Figure 7. Control box components

E. The menu

The menu is composed of the entries stored on the SD card. These entries represent the different actions that the system can undertake along side the different organizing entries. The organizing entries are used to create a treelike structure of actions that group similar entries offering a more intuitive interface. The entries are stored on a SD card for easy access and are stored in a XML like raw format. This format is presented in figure 8.

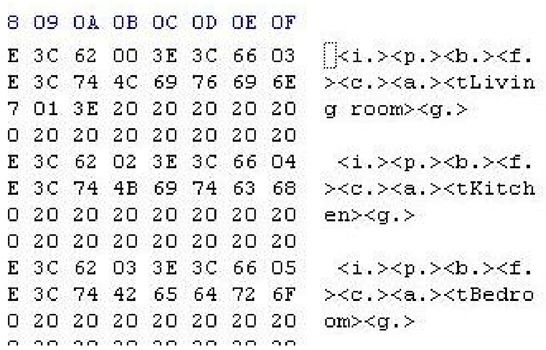

Figure 8. Menu entries store format

F. Gestures recognizing algorithm

In order to determine the movement identification method, a series of data from the accelerometer have been captured and plotted into graphs. For example in Figure 9 a right movement graph is presented. Based on this graphs, the method of movement identification was chosen. In this case, due to the necessity of recognizing only four basic gestures, a compare based algorithm is used. This algorithm works well if the number of gestures that has to be identified is small, but if the number of gesture increases, a more powerful algorithm needs to be used in order to ensure a precise identification.

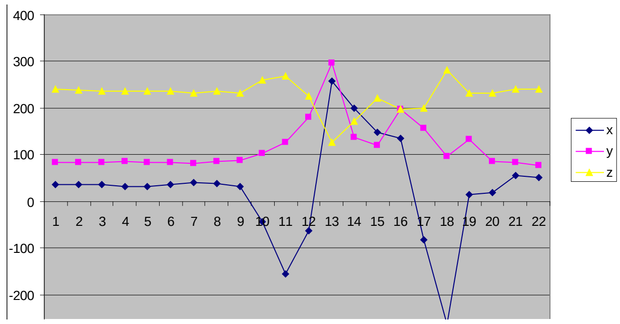

Figure 9. Right movement captured data

IV. PERFORMANCE IMPROVEMENTS

In order for that the system to allow a more complex method of control, more gestures must be recognized by it. In order to demonstrate the functionality of the system, only four basic gestures are identified: left movement, right movement, up movement and down movement. By recognizing more gestures, the system will be able to allow a greater degree of control and even a more intuitive control system for the end user. The system can also be controlled by hand tilting only, giving persons with a low degree of mobility a possibility to use the system. A gyroscope could also increase the data amount that reaches the data processor core allowing it to detect more precisely the hand movement. The location identification system could be replaced with a more precise method of identification, thus allowing a greater number of actions associated with the same location.

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