Design and Implementation of a Virtually Interactive Home Automation System Based on an Arduino Single Board Microcontroller

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Abstract-This paper presents concept of setting up a virtual environment between human and its home automation system (H.A.S). A H.A.S is capable of controlling basic home appliances such as: fan, light etc. that is operated at 230V A.C, these appliances can be controlled by giving simple voice command. Beyond controlling these appliances, H.A.S is capable to give a voice automated feedback to the user, hence virtual environment has been setup when human interact with H.A.S. This virtual environment gives a feel to the human, who is interacting with the H.A.S as if talking with another human. Therefore the interaction between human and H.A.S give rise to new concept design that is known as the Virtually Interactive Home Automation System (V.I.H.A.S). The design and its implementation of this concept emphasize using two fundamental points that make V.I.H.A.S unique. First, using open-source electronic platform such as Arduino board, second using modular approach. These two key points are further explained in this paper.

The attempt of controlling home appliances indirectly by the user without any physical intervention, makes this approach more reliable, friendly and interactive thus revolutionizing home automation system into a new dimension of reducing human-machine interaction, thus making it more realistic in nature.

Keywords- Virtual Interaction, Home Automation Systems, Modular Approach, Open source, Mannequins, Wireless Communication, Secured Systems, Emergency Systems.

1. INTRODUCTION

In today's world, technology has become an integral part of the human lifestyle.
Technology focuses on reducing human effort to the maximum and it is incorporated in almost every possible field today. The various technologies such as Home Automation industry is growing rapidly; this is fuelled by the need to provide supporting systems for the elderly and the disabled, especially those who live alone. Home automation systems must comply with the household standards and convenience of usage. This paper details the overall design of a wireless home automation system (WHAS) which has been built and implemented. [1]

In the recent years, the Home Automation systems has seen a rapid changes due to introduction of various wireless technologies The explosion in the wireless technology has seen the emergence of many standards, especially in the industrial, scientific and medical (ISM) radio band. Zigbee is targeted at applications that requires low data rate, long battery life, and secure networking. The wireless home Automation systems is supposed to be implemented in existing home environments, without any changes in the infrastructure. The automation centers on recognition of voice commands and uses low-power ZigBee wireless communication modules along with microcontroller. The home automation system is intended to control all lights and electrical appliances in a home or office using voice commands. The paperwork aim at designing a voice recognition wireless ZigBee based home automation system. [2]

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The development of the new technologies in the field of electronics has brought tremendous changes in the day to day life of every human being. They have entered the fields like industry, medicine, telecommunication and also home automation. This paper introduces the intelligent home automation system (IHAM) which is developed using PIC microcontroller with the ZigBee wireless communication technology, speech recognition technique and GSM network technology that control the home appliance. The proposed system gives the overall framework of hardware and software design, and describes ways to implement the system. The paper also explains the security system for fire hazards that may occur through smoke sensor and GSM Module that is controlled by the same controller that sends the SMS to the user if the smoke is detected. [3]

Intelligent Home Automation Systems are gaining importance in today's technology dependent world. Home Automation Systems provide a sense of security and comfort. Using Wireless technology like ZigBee the cost of wiring of Home Automation System can be reduced as well as a reliable and secure communication can be achieved. ZigBee is a low data rate wireless network standard with added features like low-cost, low power consumption and fast reaction. ZigBee is most suitable for small area networks like homes. This System also allows controlling of devices using Voice commands which reduce user interaction with system directly. This System uses SAPI (Speech Application Programming Interface) a Microsoft Application to enable voice recognition when a user gives voice command to the system. This system contains of three main components:
i) Intelligent Home Server with ZigBee module, ii) Intelligent environment detection sensor modules and iii) Voice command controlling module. The various features

of the system include turning any home appliances or devices, playing media applications, downloading RSS feeds, sending mail, etc. [4]
As we all know interacting with machines always fascinates people, whether it may be a manual interaction i.e. by voice. Based on the preceding materials and keeping the current interest of people and technology in mind, this paper presents an intelligent system which meets user's demand of natural interaction with machines i.e. machine needs to respond back when user gives command.

This machine is a small basic home automation system that is designed not only to control the electrical appliances but also to interact with the humans the same as humans interacts with each other. Hence this paper presents the design and implementation of a Virtually Interactive Home Automation System (V.I.H.A.S). Virtually interactive means a process in which human verbally interacts with the machine and there by machine responds by means of a feedback mechanism. This virtual environment is setup in home automation system so that human can have conversation with the system which not only controls all the electrical appliances inside homes but also it gives feeling of a human speaking with user in real time. This is done by playing a virtually automated voice which is nothing but a pre-recorded machine response or query voice that will be played when a human interact with V.I.H.A.S. Those pre-recorded voice are stored in physical storage space that contains thousands of other response or query voices as well. To effectively interact with the user, the microcontroller in V.I.H.A.S processes and understands the user's voice command and there by not only it performs the action but also plays those pre-recorded voice acting as the machine feedback.

V.I.H.A.S is capable of understanding the user's commands by receiving the voice command effectively given by the user. Those commands are sent from a portable device such as phone that can be bridged with V.I.H.A.S's voice recognition unit (V.R.U). Hence when any voice commands are received at the V.R.U, the voice gets converted in serial data strings which are then send to V.I.H.A.S's microcontroller, here those serial data are processed to not only perform desired action but also to give the appropriate voice feedback as well. These processes i.e. from understanding voice command to performing action along with giving voice feedback response to user by mentioning the end of process to waiting for next command, makes the home automation system interactive with the user.

This paper presents design and implementation of such a concept which attempts to not only control home appliance requiring 230V AC supply but also to give more feasibility in controlling appliance by knowing its status of operation and thereby giving feedback to user about it, thus creating an interactive session between user and his/her personal home automation system.

Furthermore introducing a new level of interaction between human and home automation system that creates a possibility in making home automation system more reliable , friendly and more interactive than the manual interaction with the home appliances.

To support above concept, a hardware design for a real time home automation of a 2 floor model has been made and successfully implemented and tested and thus mentioned further here. The model comprises of following segments:
PIR sensor (1st floor)
Bottom light (1st floor)
Top light (can vary intensity level) (2nd floor)
SOS signal (for emergency)

The controlling of above mentioned appliances in real time along with maintaining high levels of natural interaction with human is achieved by using Arduino Mega microcontroller. The microcontroller's job is to process and understand user's commands. After processing and understanding what has to be done, microcontroller sends a signal to the module responsible to perform individual task. These are the list of modules that is proposed in this work and they are:
GSM module
Relay module
Sound processing module
Light dimmer module
Bluetooth module
Speaker

Furthermore, all the above module mentioned are made to work in perfect compliance. To understand the approach of this concept, the paper further discusses the system's design, which not only explain its approach but also the feasibility to work in real time as well. Thereby this is an attempt to design a unique and pragmatic approach of this concept which needs to be executed in real time.

2. SYSTEM DESIGN

It's evident that software which drives the hardware of the system can be updated to a limited number of times, this is because that at some stage hardware tends to be outdated. In several other instance if any part of the hardware get malfunctioned, users have to discard the whole system that may result to loss of money and functionality.
Therefore the system design proposed for this concept not only takes care to deal with above problem but also gives user the rights and also the possibility along with compatibility to make V.I.H.A.S not only to upgrade its software but to upgrade its hardware as well, without any special knowledge to deal with it. Taking above statement under consideration, the system design of V.I.H.A.S is based on two fundamental points.

- Open-source electronic platform
- Modular approach

Open-source electronic platform is flexible and inexpensive also as well it is easy to use, it connects to computer via USB and communicates using standard serial protocol, runs in standalone mode and as interface

connected to PC computers. Also, it comes with free authorizing software. Henceforth adopting open-source electronic platform helps the user to have a good control over the system.

Modular approach is an approach to divide all major component which will be used to perform action as per the command given by microcontroller. This approach has two major benefits, firstly, the device will function independently and with complete isolation, this is done because all home appliance need high power whereas, the system responsible to control those appliance works on low power rating therefore isolation is necessary. Secondly, modules act like a slave which only listen to microcontroller's commands. Hence, if any module malfunction, then it will stop performing that particular action without affecting other devices thereby which the microcontroller will not be interrupted. As it acts like an independent system anyone can easily replace that module quickly rather than replacing the entire system. Therefore modules will act like a plug and play device where in which we just plug the module without worrying about any external factor such as power and electrical specification and after that it is microcontroller's responsibility to communicate with those modules. This way the concept of V.I.H.A.S is highly portable and easy to use as a system as any person can build their own version out of it as well can be employed anywhere easily.

To effectively apply above two fundamental points, V.I.H.A.S, is divided into several independent unit, these units are intended to work in harmony to perform two major task. Below are the list of the units and task which are as follows:

MODULE/UNITS:

1. Command Control Unit (C.C.M) is divided as:
   - Communication Unit (C.U)
   - Voice recognition unit (V.R.U)
2. Master Control Unit (M.C.U)
3. Power Control Unit (P.C.U)
4. Interactive Unit (I.U)
5. Emergency unit (E.U)

TASK:

- Control electrical appliances at 230 V AC
- Maintain interaction with the user.
- Each unit mentioned above acts like a module which plays an important role. Therefore in this design we see that the work load is equally distributed to each unit that is responsible to do certain task. We will now discuss about the units and its intended function.

The C.C.M description is as given below:

Communication Unit (C.U):

About: This paper proposes to use a mobile phone which can run android apps

Function: An application that is running in this phone is responsible to communicate with the V.R.U unit, the prime goal is to listen to User's verbal command and transmit the data to V.R.U wirelessly.

Voice Recognition Unit (V.R.U):

About: Bridging connection between user and the V.I.H.A.S,

Function: Act as a listener, wait for data from the C.U unit to receive and then send the received data in a compatible format to M.C.U.

Master Controller Unit (M.C.U)

About: The heart of the system

Function: Perform action as per user command, responsible to make decision, control P.U, I.U, and E.U.

Power Control Unit (P.C.U)

About: all the home appliances are connected to this unit, and this unit is connect to main 230v A.C

Function: to listen to M.C.U command and switch the appliances ON/OFF

Interactive Unit (I.U)

About: Voice of V.I.H.A.S

Function: intended to communicate with user verbally.

Emergency Unit (E.U)

About: to alert outsider if user need help.

Function: send SOS signal to nearby emergency services.

After mentioning the list of units and there intended function, it's time to interrelate all the above unit with each other. In fig.1 the proposed architectural design is presented and its flow chart demonstrates the way the concept will actually work in real time.

In context with the fig 1.0 and fig 1.1.The first operation is the user opens an application inside the phone that can communicate with the V.RU unit of V.I.H.A.S, then user send some commands and the application transmit it wirelessly to V.R.U unit. The V.R.U accept the command from C.U and sent the data to M.C.U, from fig 1.1 the command 'a' denote to switch ON the appliance connected to P.U port 1 henceforth, based on the data the M.C.U, which is programmed to understand that commands will perform action. Meanwhile the rest of the units acts like a slave and wait for the M.C.U to give the commands. Once the commands are given, the M.C.U waits for the task to be completed. After completing current task, it will talk verbally to the user through I.U, that the task was done. M.P.U is also programmed to do more task apart from controlling home appliance such as, for authentication purpose it ask user to say passcode, to ask user his/her name , also V.I.H.A.S can describe herself and etc. Rest of

the unit follow the command from M.C.U therefore unity of command is maintained in this system.

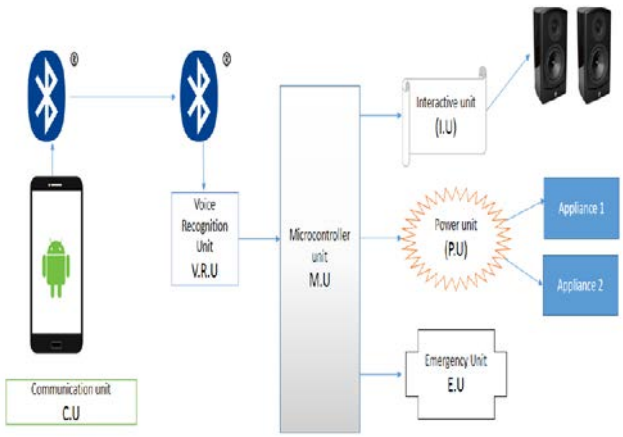

Figure 1 - Architectural Design.

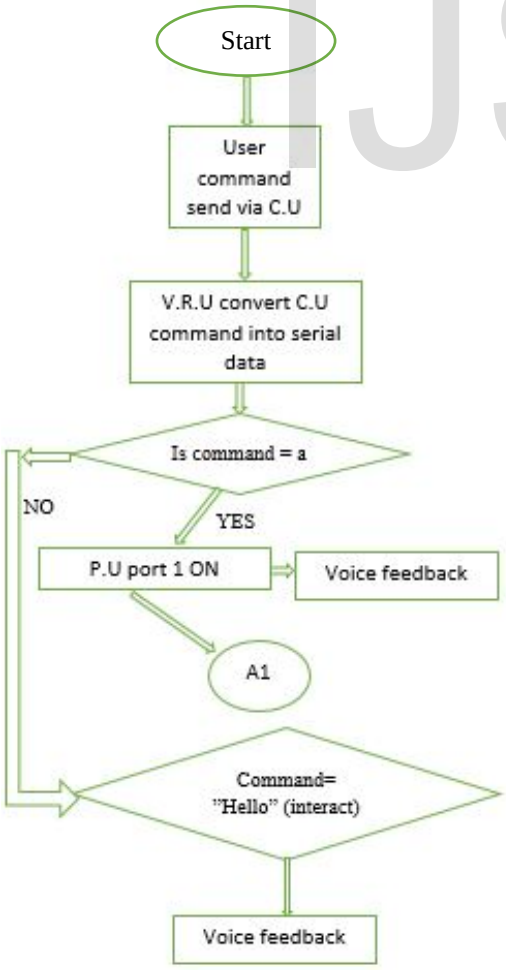

Figure 2 - Flow chart

To make all unit work in perfect harmony, it is essential that the M.C.U should communicate with all the units. Therefore the need of common communication protocol is needed.

In this system design, all the unit communicates with the M.C.U through serial communication, this is because, it is the most easiest and common protocol that every device has inbuilt. Therefore every unit having TX/RX port can communicate with the M.C.U. This fulfils our purpose of replacing the units needed for upgradation or replace defective modules, hence modular approach is achieved.

It is also necessary that M.C.U should be compatible with most of the systems along with update process which included user's modified instructions that can control the voice tone of the system and many more. To avail such facility it is important to use open source electronic platform so that user can have full rights to modify their system. Therefore the M.C.U should be flexible and easy to use. Overall the system design should not only support software updating process but also hardware as well.

This system is designed with an excellent feature for keeping the system protected from external access as well provide user security and accessibility. The key feature of our project is mentioned below:

Key Features:

1. **Secured Systems:** This System proposes security by passcode authentication which is required for the complete access of it. The user of this system would be given a unique passcode which provides security and isolates unwanted access, when the system asks for it. An algorithm has been created in order to use this feature in the system so that the user has control over it with total security.
2. **Power Saving:** This System is designed in such a way that it serves the purpose of Power Management i.e. the system has a control over high rated appliances to switch it OFF/ON by sensing human presence or any movement or else temporarily switch to sleep mode. The System resumes to its original state when put into sleep mode, provided if the correct passcode is provided.

Henceforth to claim such system design, this paper proposes a hardware implementation which is discussed in the next topic. In that section a detail discussion of the hardware of each unit is explained.

3. HARDWARE IMPLEMENTATION

To implement above system design which is proposed to run V.I.H.A.S, it is essential to apply it in real time. This section of the paper deals with assembling the hardware as per modules mentioned in previous section.

Modules which contain respective hardware are as follows:

- **Communication unit (C.U):** A phone capable to run android application. User is expected to send voice command from the phone which is having an app responsible to connect with the V.R.U.
- **Voice Recognition Unit (V.R.U):** Consists of HC-05 chip in general, which waits for the user's phone to connect with HC-05 module via Bluetooth, and listen to user command.
- **Master control unit (M.C.U):** Arduino Mega, an open source electronic platform which give several benefits that was explained in system design section.
- **Power unit (P.U):** It consists of relays whose input is 5v and output is 230v AC, in this way Arduino Mega can switch the relay ON and OFF to have a control over the 230v devices. This unit is called power unit because this relay is directly connected to mains and all appliance are connected to the relay. Controlling relay will henceforth gives microcontroller to control the power distribution to the home appliances.
- **Interactive unit (I.U):** This is the most important part of this concept design. This hardware design talks with the user verbally. In order to make it more interactive almost 250 sound response were recorded and stored in a pendrive first, which include the way V.I.H.A.S will respond when user will interact with it. To play those sound files, VS1053 DSP processor is used along with a PIC microcontroller. The design approached is shown in Fig 2.

  The PIC microcontroller interacts with the Arduino Mega's command which gets directed to information to play as sound files from pen drive. PIC then decodes the command and processes the selected sound file, whereas after giving command to PIC, Arduino Mega goes back to its loop. PIC is programmed to control VS1053 chip to decode digital recorded MP3 sound file at 320Kbps. PIC sets the path of the selected sound file that is stored in a pen drive and then command DSP processor to process that particular file only. Hence sound file is played via speaker which user can hear it.
- **Emergency Unit (E.U):** Uses a SIM300, it contains all necessary hardware to send SMS using a service provider SIM card. It waits for Arduino Mega to give command to send message to local emergency services. In emergency mode, when user wants to send SOS, Arduino Mega first shuts down all the appliance and then communicates with the SIM300 system by sending initialization command, and then the user message is recorder or a standard SOS message such as "need help" is send to the SIM300. In our case SIM300 is internally programmed by the manufacture which sends the message data to the emergency service that is received serially form microcontroller.

After discussing the hardware, it can be understood that the modules mentioned above help to reduce load of the microcontroller and therefore an effective system is formed which not only satisfy the concept of V.I.H.A.S but also make it easier to design and implement as well.

4. IMPLEMENTATION AND TESTING

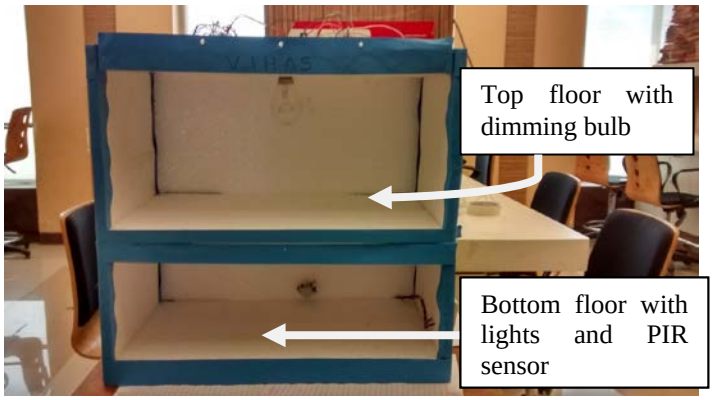

Figure 3 - Front view of our project model

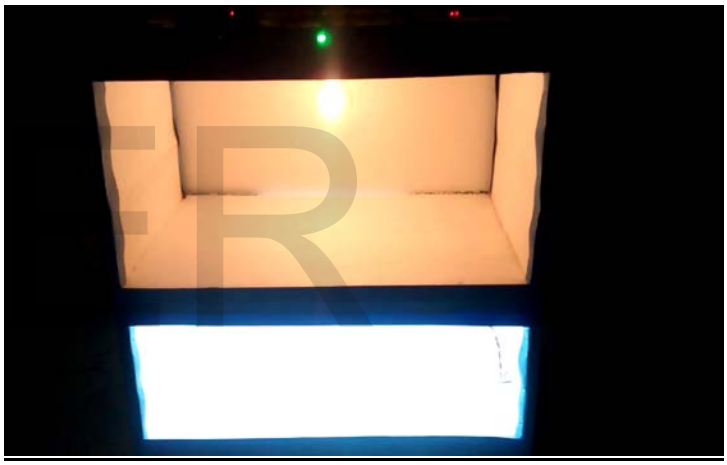

Figure 4 – System in active mode

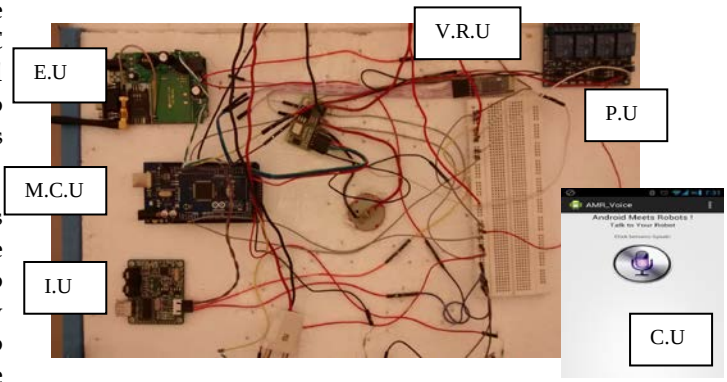

Figure 5 - Complete top level circuitry

5. FUTURE SCOPE

This concept purely supports open source platform that has capability to be adjusted accordingly to suit the user's

choice of operation. By simply connecting certain modules that will suit the requirements, the Arduino board can be modified for a wide range of applications. Though this concept currently propose to, use in the home automation and for verbal interaction. By adding other and more advanced modules, one can use this concept for a wider range of home automation applications. By using advanced programming, more tasks can be performed like dimming of lights, fan speed control, etc. It can also be used for actions like temperature detection and control, footstep sensing for system activation, and other related actions for a wider range of automation solutions -

- This technique can not only be used in home automation system but also for automated control of automobiles, industrial systems and other control related application systems.
- Voice controlled systems also can be used for automatic speed control, variation of intensity of lightings for the above applications.
- In future this technology will also be used to command robots and intelligent systems in homes and industries for simplification and reducing human physical effort.
- As the systems implementing this technique can be made quite secure by using predefined voice codes and password mechanisms, they can be kept safe by unnecessary use. That is the system will respond only for certain keywords or perfectly matched passcode.
- There is a research being carried out in various universities and research centers to design a revolutionary way of presenting "**Mannequins**" to the customers visiting malls and accessory outlets.

- These mannequins will be totally equipped and as in will virtually interact with the customers same as another human being expresses his own emotions and wants to another human. This will totally revolutionize the way shopping is done by customers which will help them gaining information about which fabric to buy and why, through these almost a human-mannequin interaction can be improvised in the near future.

6. CONCLUSION

Using the open source hardware and the required modules for programming and connectivity with the controller, I have successfully gathered the parts and information for designing our Virtually Interactive Home Automation System. I not only hope to achieve the purpose of controlling appliances using our machine, but also help to enable a better relationship between humans and technology. By using a modular approach, we have made our project simple, accurate and easy to construct and modify whenever needed. I hope that further advancements will be made to our project in the future and make lives better for the users.

7. ACKNOWLEDGEMENTS

This concept could only be successfully implemented and completed with the constant support of my university faculties and lab assistants of the same. I owe my thanks for their well extended help and support.

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