Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

Smart Home, Support at Old Age and Support for Persons with Disabilities: Speech Processing for Control of Energy

Abdul Rasak Zubair
Department of Electrical and Electronic Engineering, University of Ibadan, Ibadan, Nigeria
Email: ar.zubair@ui.edu.ng
Emmanuel Sinmiloluwa Olu-Flourish
Department of Electrical and Electronic Engineering, University of Ibadan, Ibadan, Nigeria
Email: emmanuel.oluflourish@gmail.com
Martins Obinna Nnaukwu
Department of Electrical and Electronic Engineering, University of Ibadan, Ibadan, Nigeria
Email: mnnaukwu785@stu.ui.edu.ng

----------**ABSTRACT**----------

Generally, conventional home wiring system use simple latching switch that is being connected to the power supply for controlling electrical appliances such as fan, light, washing machine, air conditioner and television. The switch is usually located at the wall near the electrical appliance. This requires the user to move to the location of the switches to control the appliances. There is rapid increase in the number of people with special needs like the elderly and the disabled. Smart houses are considered a good alternative for the independent life of older persons and persons with disabilities. A smart home is a home that provides its residents the comfort, the convenience and the ease of operation of devices at all times, irrespective of where the resident actually is within the house. Smart Homes include devices that have automatic functions and systems that can be remotely controlled by the user. The primary objective of a smart house is to enhance comfort, energy saving, security for the residents and independent living of people at old age and people with disabilities. A low-cost prototype of a voice controlled smart home system controlling four devices by an Arduino microcontroller via a four-channel relay is presented. Voice control is one of the easiest methods to give input commands and is a more personalized form of control, since it can be adapted and customized to a particular speaker's voice. Voice recognition is a computer software program embedded in a hardware device with the ability to decode the human voice. Most voice recognition systems require "training" (also called "enrolment") where an individual speaker reads text or isolated vocabulary into the system. The system analyses the person's specific voices and uses it to fine-tune the recognition of that person's command. Upon successful recognition of the voice command, the microcontroller drives the corresponding load with the help of the relay circuit. Voice or Speech Processing has been applied successfully for the control of the supply of energy to home appliances.

Keywords - **Smart home, Support at old age, People with disabilities, Speech processing, Voice command, Energy control, Electrical appliances**

Date of Submission: Apr 08, 2022 Date of Acceptance: Apr 21, 2022

1. INTRODUCTION

The development of a smart home is promising in today's age of technology [1,2,3,4,5,6,7]. Smart houses are considered a good alternative for the independent life of older persons and persons with disabilities [8,9]. Numerous intelligent devices, embedded into the home environment, can provide the resident with both movement assistance and 24 hour per day health monitoring [8]. Modern home-installed systems tend to be not only physically versatile in functionality but also emotionally human-friendly. That is, they may be able to perform their functions without disturbing the user and without causing him/her any pain, inconvenience, or movement restriction, instead possibly providing him/her with comfort and pleasure. This field is evolving and is still being defined. The type of user interface for a smart home is of immense importance and should not be complicated to make the living complex.

The notion of a "smart home" was first introduced in the early 1980s when the "intelligent building" concept was also used. In this concept, the intelligent implementation of consumer electronic devices, electrical equipment, and security devices aiming for the automation of domestic tasks, easy communication, and human-friendly control, as well as safety, was proposed. A smart home is a home that provides its residents the comfort, the convenience, and the ease of operation of devices at all times; irrespective of where the resident actually is within the house. A smart home usually consists of electrical appliances such as lighting, fans, air-conditioners, room-heaters, air-coolers, microwave ovens, and electronic gadgets such as television, computers, audio systems, laptops, music-systems, and mobile devices. All these appliances and gadgets can be connected, networked and controlled

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

remotely, over a secure channel using Wi-Fi or the internet or the internet of things (IoT) through software application, from within or outside the house [3,5,6,10,11,12,13].

These appliances and gadgets are generally connected to specific sensors, so as to make these automatically adapted to certain situations and in-turn make the occupants feel comfortable. An adaptive smart home would be the one that utilizes machine-learning techniques to discover patterns in the residents' daily activities, and generate automation rules and actions that mimic these actions. Once these systems become aware of the requirements of residents, the residents can then be provided with a better living experience, by predicting their future needs and performing routine tasks. The aim would be to reduce physical movements and labor by the residents, by sensing and proactively responding to their needs. This important application domain is predicted to steadily increase in the future [11].

In recent years, more research on smart homes has been carried out in applying the principles of ubiquitous computing. A smart home adjusts its functions as per the inhabitants' needs, according to the information it collects from the residents, home computers and context. In such an intelligent environment, the steps involving the information processing and network technology are transparent to the user. Interaction between the smart home and its devices usually takes place via advanced 'natural' user interaction techniques involving human-speech. As the choice for natural and expressive means of communication, speech is more desirable for the human-computer interaction.

Elderly or disabled people, who cannot usually help themselves to move around in the house need assistance for remote control of appliances. The growing numbers of elderly population and increasing life expectancy have brought enormous challenges to many aspects of human life, including immobility. According to a study of world aging population by United Nations, 2017, the global population aged 60 years or above numbered 962 million in 2017, more than twice as large as in 1980 when there were 382 million older persons worldwide. The number of older persons is expected to double again by 2050, when it is projected to reach nearly 2.1 billion. Increasing the care for the people at old age is therefore a necessity [14,15,16].

Home automation is the residential extension of building automation concept. It is the automation of a home, some house-work or some house-activity. Home automation need has been increasing significantly in recent years due to higher affordability and simplicity of using smart phones and tablets with seamless connectivity.

A house that is fully automated can be regarded as a Smart Home. Smart Homes include devices that have automatic functions and systems that can be remotely controlled by the user. The primary objective of a smart house is to enhance comfort, energy saving, and security for the residents in the house.

The concept of Internet of Things (IoT) is closely related to home automation concept [13,17]. A Home Automation System inter-connects all the electrical devices, appliances and gadgets in the house through a home network set-up. Access to a home automation system may be allowed using a personal computer, mobile phone or by remote access through Internet, Bluetooth, or Wi-Fi communication [13,17].

In this work, use of voice-recognition to control smart home appliances is proposed. Moving away from the traditional methods such as keyboard or switches to control the devices, voice control is one of the easiest methods to give input commands. Also, voice recognition is a more personalized form of control, since it can be adapted and customized to a particular speaker's voice.

Therefore, a voice-controlled home automation system is designed, so that the users can perform certain tasks by just the use of their voices, moreover, the system is designed to have a hand-held device (remote/phone) so that the user can easily speak their commands closely or remotely.

2. METHODOLOGY

2.1 System Architecture

Fig. 1 shows an overview of the architecture of the proposed Voice Controlled Smart Home System. The electrical devices, appliances and gadgets being controlled are classified into five groups. The system consists of a Microphone which receives voice commands and sends voice commands to the Voice Recognition Module. The Voice Recognition Module has an inbuilt microprocessor through which it is able to process received voice commands. The received voice signals are cross correlated with the already stored voice commands groups such as "Light Group" or "Fan Group" to decode user's instruction. Based on the decoded command, a signal is sent to the Arduino microcontroller. The Arduino microcontroller activates the corresponding outlet such as Light or Fan via one of the channels of the relay module connected to it.

Essential components and sub-systems such as Arduino Uno Microcontroller, Voice Recognition Module, Wi-Fi Module, Liquid Crystal Display, Relay Modules and Power Supply are required for the smart home system.

2.2 Arduino Uno Microcontroller

The Arduino Uno shown in Fig. 2 is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P, it consists of other components such as crystal oscillator, serial communication, voltage and regulator to support the microcontroller. Arduino Uno has 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analog input pins, a USB connection, a Power barrel jack, an ICSP header, and a reset button [18, 19].

2.3 Voice Recognition Module

The Voice Recognition Module V3 of Fig. 3 is a compact easy-control speaking recognition board. It is a speaker-dependent module and supports up to 80 voice commands. Any sound could be trained as command [20,21,22,23,24,25]. Users need to train the module first

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

before recognizing any voice command. Voice commands are stored in one large group like a library. Any 7 voice commands in the library could be imported into recognizer. It means 7 commands are effective at the same time. The voice recognition module could be used in either of two modes: Serial Port (full function) or General Input Pins (partial function).

In the Serial Port (full function) mode, the V3 board has the capacity to store up to 80 voice commands each with a duration of 1500 milliseconds. This mode will not convert commands to text but will compare them with an already recorded set of voices. So technically there are no language barrier. Commands can be recorded in any language.

In the General Input Pins (partial function) mode, the module will deliver outputs for only 7 commands out of the 80. For this method, it is required for one to select and load 7 commands in to the recognizer and the recognizer will send outputs to the respective GPIO pins if any of these voice commands gets recognized.

The voice recognition module works at an input voltage range of 4.5 - 5 volts and will draw a current less than 40 mA. This module can work with 99% recognition accuracy if it is used under ideal conditions. The choice of microphone and the noise in the environment plays a vital role in affecting the performance of the module. It's better to choose a microphone with good sensitivity and try to reduce the noise in the background while giving commands to get the maximum performance out of the module.

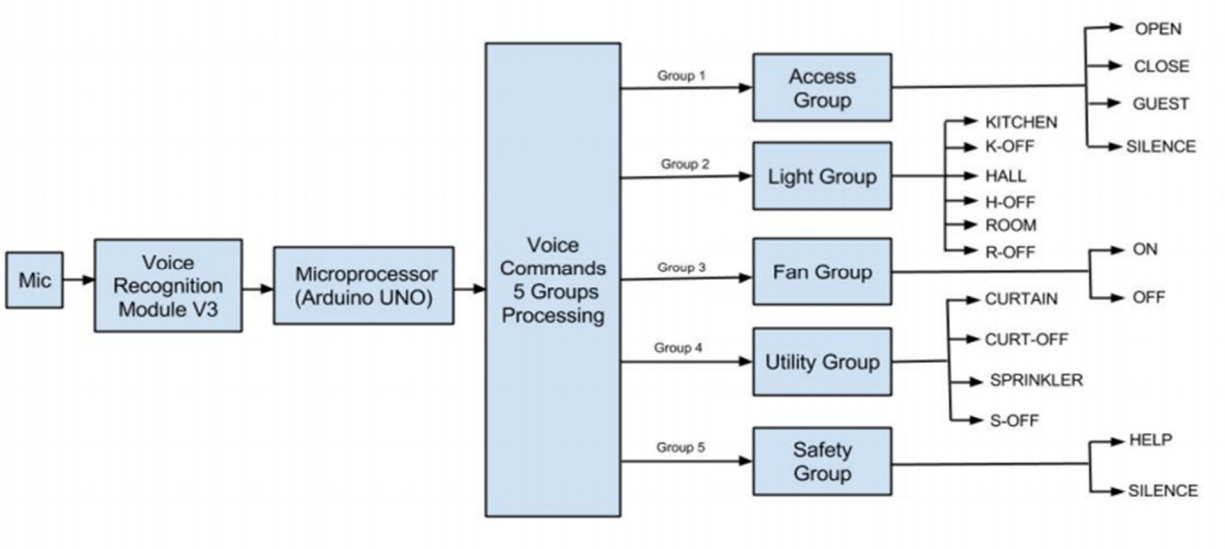

Fig. 1 System Architecture

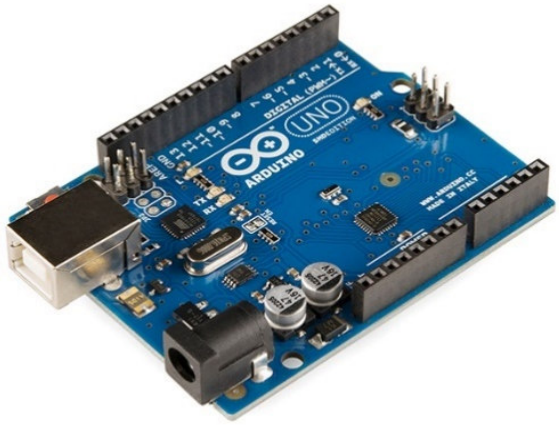

Fig. 2 Arduino Uno

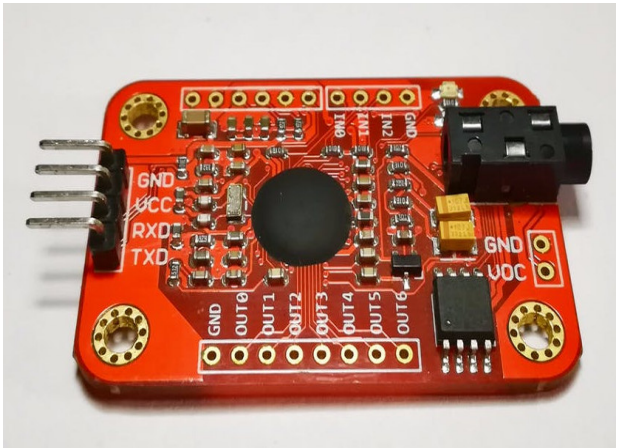

Fig. 3 Voice Recognition Module

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

Speech is the most prominent means of communication amongst humans. Human-to-human interaction is based on speech, emotion and gestures, thereby making it a lot easier to understand one another. On the other hand, the communication between humans and computers is based on either Text User Interface (TUI) or Graphic User Interface (GUI). It is a lot easier for humans to recognize a person's voice than computers. Hence, speech recognition in machine learning is a game changer as developing machines that can understand and uniquely identify a person's voice would make Human-Computer interaction more intriguing.

It is important to note that voice recognition differs distinctly from speech recognition. In speech recognition the subject of analysis is the spoken text, while in voice recognition the subject of analysis is the voice of speaker and the spoken text remains secondary here, though both are taken into account. Thus, voice recognition is better for controlling and accessing the appliances with optimum security. Fig. 4 shows the block diagram of the voice recognition sub-system.

Signals need to be processed by Digital Signal Processors (DSP) so that the information that they contain can be displayed, analyzed, or converted to another type of signal that may be of use. To illustrate this concept, Fig. 5 shows how a DSP is used in an MP3 audio player. During the recording phase, analog audio is input through a receiver or other source. This analog signal is then converted to a digital signal by an analog-to-digital converter and passed to the DSP.

The DSP performs the MP3 encoding and saves the file to memory. During the playback phase, the file is taken from memory, decoded by the DSP and then converted back to an analog signal through the digital-to-analog converter so it can be output through the speaker system. In a more complex example, the DSP would perform other functions such as volume control, equalization and user interface.

The major components of a DSP include the Program Memory which stores the programs the DSP will use to process data and the Data Memory which stores the information to be processed. Another component of the DSP is the Compute Engine which performs the math processing, accesses the program from the Program Memory and the data from the Data Memory. The DSP has the Input/Output interface which serves a range of functions to connect to the outside world.

Cross correlation is a standard method of measuring the similarities/relationships between two signals. It is a measure of similarity of two series as a function of the displacement of one relative to the other. There are some cases where it is necessary to compare one reference signal with one or more signals to determine the similarities between signals and to determine additional information based on their relationships. Voice Recognition involves cross correlation of command with stored commands to decode the user's instruction.

2.4 WI-FI Module

The ESP8266 Wi-Fi Module in Fig. 6 is a self-contained (SOC) with integrated TCP/IP protocol stack that can give any microcontroller access to a Wi-Fi network. The ESP8266 is capable of either hosting an application or off-loading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware.

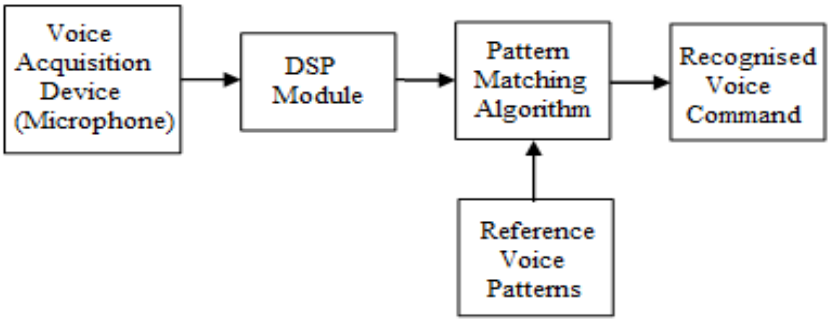

Fig. 4 Voice Command Recognition Process

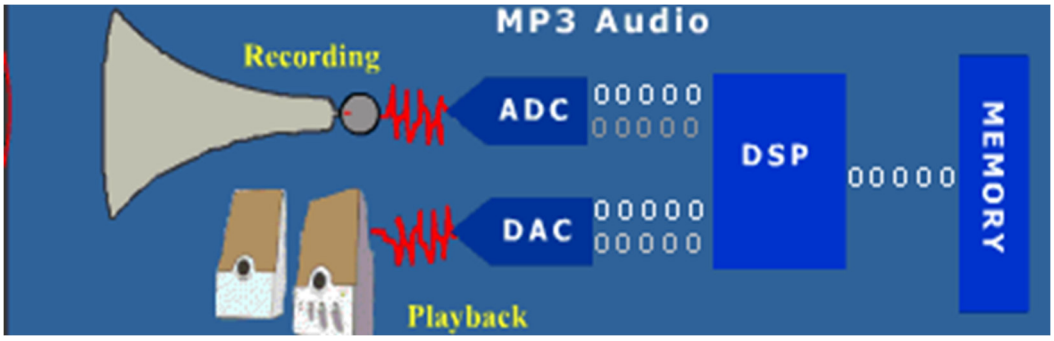

Fig. 5 Digital Signal Processing of audio signal

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area.

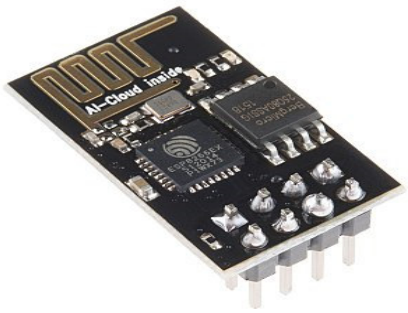

Fig. 6 Wi-Fi Module ESP8266

2.5 Liquid Crystal Display (LCD)

Liquid Crystal Display (LCD) of Fig. 7 is the output subsystem. Its inexpensive, simply programmable and has no limitation for displaying custom characters, special characters and animations. The LCD is optimized by using an I2C adapter, the I2C which uses only two bidirectional open-drain lines, Serial Data Line (SDA) and Serial Clock Line (SCL), pulled up with resistors. Typical voltages used are +5 V or +3.3 V although systems with other voltages are permitted. The I2C adapter helps to optimize the number of pin used to control the liquid crystal display. Instead of using about 8 to 16 pins to control the LCD, four pins are being used; two of which are for power and the other two are for data communication (SCL and SDA).

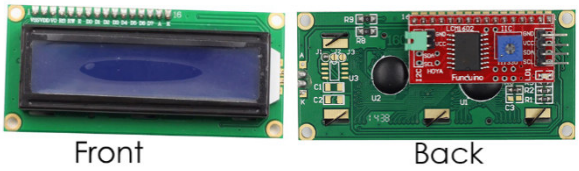

Fig. 7 Liquid Crystal Display

2.6 Relay Module

A relay is usually an electromechanical device that is actuated by an electrical current. The current flowing in one circuit causes the opening or closing of another circuit. Relays are like remote control switches and are used in many applications because of their relative simplicity, long life, and proven high reliability. Four of such relays are shown in Fig. 8.

The relay's contacts consist of a Normally Closed (NC) Terminal, a Normally Open (NO) Terminal and a Common (COM) Terminal at the center. When the relay is un-powered, the NC terminal is connected to the COM terminal and the NO terminal is open. When the relay is operated, the COM terminal switches over and is now connected to the NO terminal and NC terminal is open.

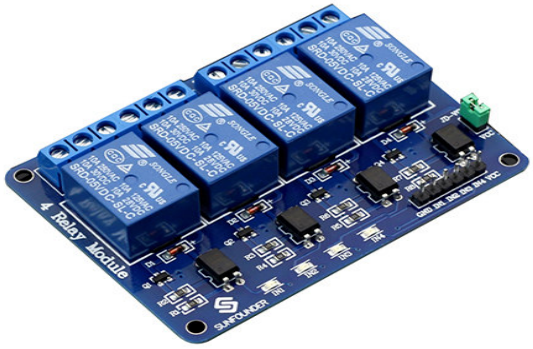

Fig. 8 A 4-channel relay module

Connecting these relay modules to the Arduino's 5V pin means both the trigger current (IN) and the current to drive the relay coil are being supplied by the Arduino board as shown in Fig. 9. The datasheet for the SRD-05VDC-SL-C shows that the relay coil takes ~72mA to operate.

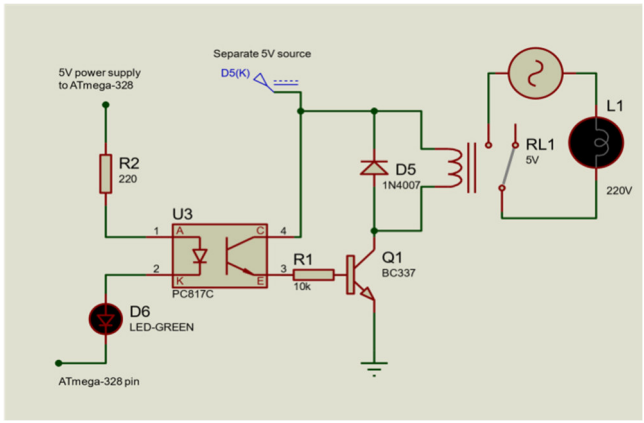

Fig. 9 Relay with PC817C Optocoupler

2.7 The Power Supply

The hardware needs two separate power supplies, a 240V ac power supply to the devices under control and a regulated 5V dc power supply to the Arduino microcontroller. The Arduino also supply required power to other components such as the liquid crystal display, control subsystems of relays and the voice recognition module. This is done to make sure that each component has sufficient power supply to perform their respective functions, the Arduino has enough voltage to supply the components and that the Arduino microcontroller is isolated from other components to protect it against power surge.

2.8 Display and Speaker

A hand-held device (phone) was incorporated into the system so that the user can easily speak their commands, otherwise they would have to walk over to the microphone to speak which may be inconvenient for some users. A speaker was incorporated into the system so that the user can be notified of the current state of the device after an issued command is implemented in addition to the LCD.

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

2.9 System Software Components

2.9.1 Arduino IDE

The Arduino integrated development environment (IDE) is a cross-platform application written in Java. It includes a code editor with features such as syntax highlighting, brace matching and automatic indentation. It is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a sketch.

Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original Wiring project which makes many common input/output operations much easier. Users only need to define two functions to make a runnable cyclic executive program:

Setup (): a function run once at the start of a program that can initialize the settings.

Loop (): a function called repeatedly until the board powers off.

The Arduino IDE uses the GNU tool chain and AVR Libc to compile programs, and uses avrdude to upload programs to the board.

2.9.2 Fritzing

Fritzing is an open-source Electronic Design (EDA) solution. The motivation to create the software comes from both the processing programming language and the Arduino microcontroller. Fritzing allows a designer to document an Arduino based prototype and create a PCB layout for manufacturing. The input metaphor is inspired by the environment of designers (the breadboard-based prototype), the output is offering nearly no options and is focused on accessible means of production. It is intended to reduce cost of manufacturing projects.

2.10 System Implementation

The hardware implementation includes the physical connection of all devices and peripherals as shown in Fig. 10. The number of relay modules can be increased to accommodate more devices under control; one additional relay module for four additional devices under control. Only three relays are shown in Fig. 10. Other relays are connected in the same way. Complete hardware package for control of four devices is shown in Fig.11.

3. RESULT AND DISCUSSION

3.1 Training of the System with Voice Commands

The training stage of the voice recognition module was achieved using its instruction manual. It requires uploading VR_sample_train sketch to the Arduino board. The module is loaded with voice commands as illustrated in Fig. 12.

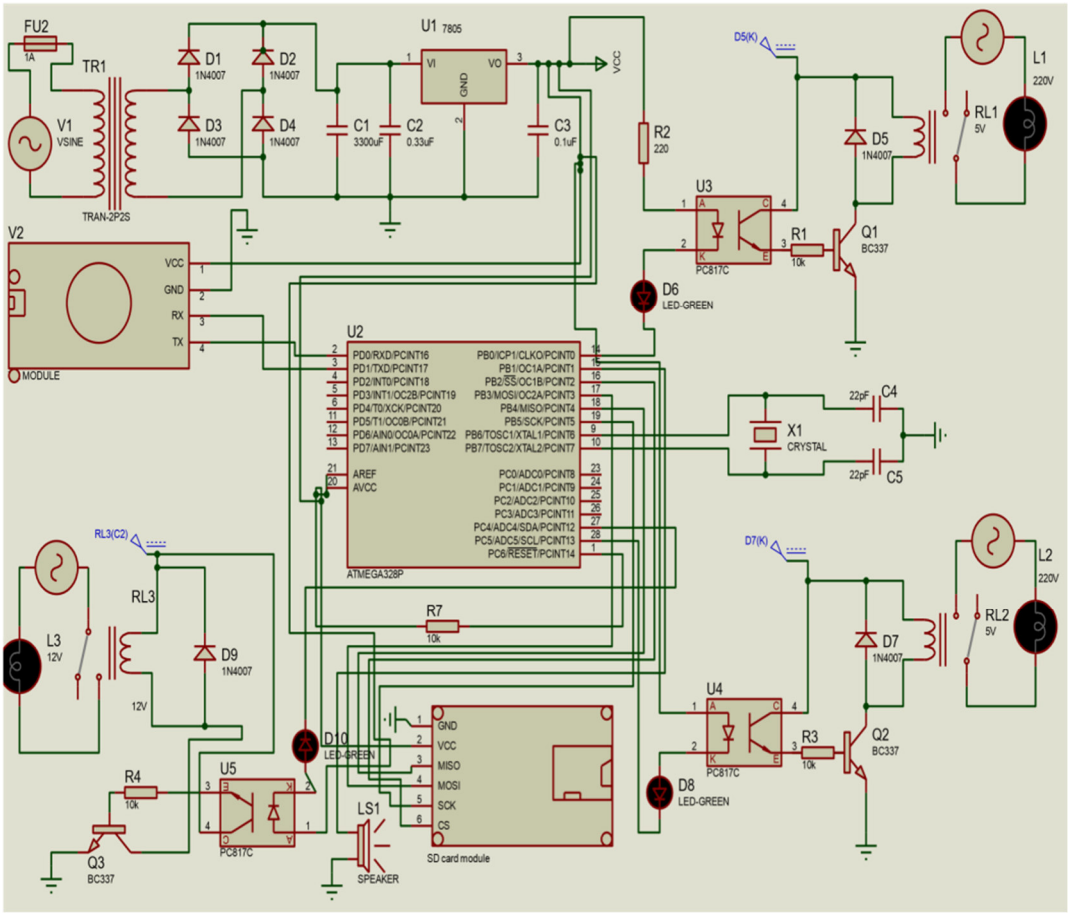

Fig. 10 The circuit illustrating only three relays

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

Fig. 11 Complete hardware package for control of four devices

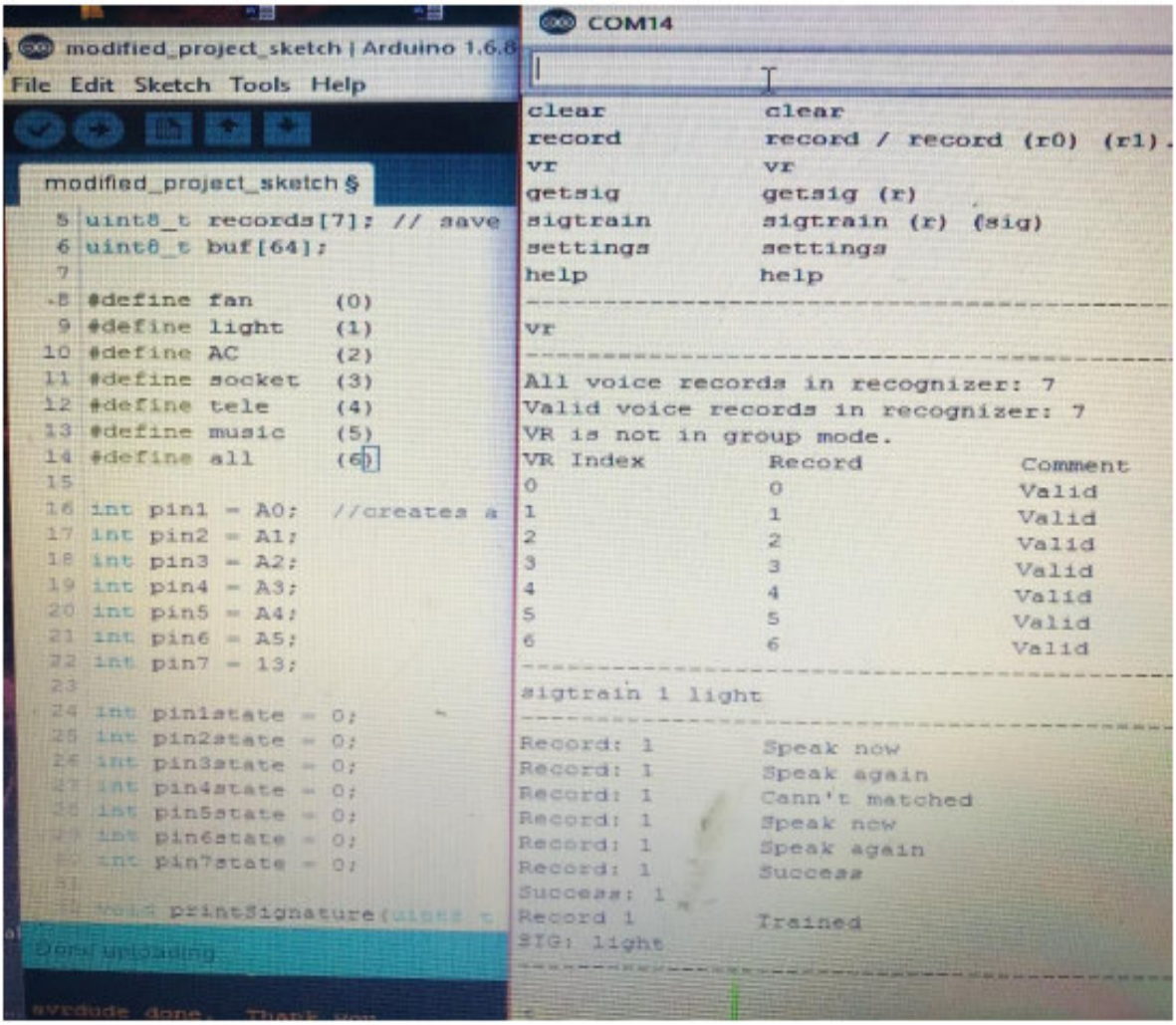

Fig. 12 Loaded 7 groups of voice command

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

3.2 Operation

After training the system, there arise the need to test and observe the performance of the system as expected. The system was tested modularly. The performance of the sub-circuits were found to be satisfactory.

A user whose voice command was previously loaded into the voice recognition module issued one command after the other, the states of the devices under control were observed.

The microcontroller changed the state of the corresponding pin which is connected to a relay circuit and according to incoming command ID, the load is toggled ON/OFF by the relay driver circuit.

When the command "Fan" was issued by the user, the relay changed its initial state which enabled the fan to turn ON. When the command "Fan" was repeated, the relay changed its state and the fan turned OFF. When the "ON all" command was given, all the four loads in the prototype system were turned ON. All the four loads were turned OFF after the "OFF all" command was issued. The LCD showed the change of status of the devices under control and the speaker also notified the user by voice.

4. CONCLUSION

A low-cost prototype of a voice controlled smart home system controlling four devices by an Arduino microcontroller via a four-channel relay has been developed. The microcontroller changed the state of the corresponding pin which is connected to a relay circuit and according to incoming command ID, the load is toggled ON/OFF by the relay driver circuit. The status of the devices is communicated to the user via an LCD and a speaker. This system will support independent living of people at old age and people with disabilities. These people will not need the help of others to turn ON or turn OFF an appliance at home. Voice or Speech Processing has been applied for the control of energy supply to home appliances.

REFERENCES

[1] J. H. Choi, Sy. Choi, D. Shin, and D. Shin, Research and Implementation of the Context-Aware Middleware Based on Neural Network, in T. G. Kim (Ed.), *Artificial Intelligence and Simulation. AIS 2004. Lecture Notes in Computer Science*, (Berlin: Springer, 2005) 3397, 295-303.

[2] C. Suh, and Y. Ko, Design and implementation of intelligent home control systems based on active sensor networks, *IEEE Transactions on Consumer Electronics*, 54, 2008, 1177 - 1184.

[3] R. Kango, P. R. Moore, and J. Pu, Networked smart home appliances - enabling real ubiquitous culture, *Proc. of the 2002 IEEE 5th International Workshop on Networked Appliances*, Liverpool, 2002, 76–80.

[4] P. Lalanda, J. Bourcier, J. Bardin, and S. Chollet, (2010). Smart Home Systems, M. A. Al-Qutayri (Ed.), *in Tech*, Available from: http://www.intechopen.com/books/smart-home-systems/smart-home-systems

[5] C. Felix, and I. J. Raglend, Home automation using GSM, *Proc. International Conference on Signal Processing, Communication, Computing and Networking Technologies (ICSCCN)*, Thuckafay, 2011, 15- 19.

[6] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, Wireless sensor networks: a survey, *Computer Networks*, 38(4), 2002, 393-422.

[7] A. R. Zubair and O. K. Atusiuba, O. K. (2016). Microcontroller based Signal Processing for Multi-Source Energy Flow Control and Voltage Regulation, *International Journal of Engineering and Technology,* 6(12), 2016, 455-468.

[8] M. Tomita, and S. Nochajski, Using Smart Home Technology and Health-Promoting Exercise, in I. Söderback, (Ed.) *International Handbook of Occupational Therapy Interventions* (Springer, Cham, 2015).

[9] T. Zarina, M. Som, Z. Tukiran, and M. H. Abd Wahab, Remote Control Home Electrical Appliances System for People with Physical Disabilities, *Proc. 3rd International Conference on Innovation, Design and Articulation (I-IDeA 2016)*, Shah Alam, Malaysia, 2016.

[10] M. M. A. Jamil, and M. S. Ahmad, (2015). A pilot study: Development of home automation system via raspberry Pi, *Proc. 2nd International Conference on Biomedical Engineering (ICoBE)*, Penang, 2015, 1-4.

[11] V. Singhvi, A. Krause, C. Guestrin, J. H. Garrett, and H. S. Matthews, Intelligent light control using sensor networks, *SenSys '05,* 2005.

[12] S. Kumar, and S. R. Lee, Android based smart home system with control via Bluetooth and internet connectivity, *Proc. The 18th IEEE International Symposium on Consumer Electronics (ISCE 2014)*, JeJu Island, 2014, 1-2.

[13] M. F. Woishe, T. Z. Bristy, N. Sultana, S. K. Chaity, and M. T. Ahad, Optimizing IoT Based Parallel Server in a Low Power Operational Environment, *Int. J. Advanced Networking and Applications*, 13(04), 2022, 5069-5075.

[14] NIH, World's older population grows dramatically, *National Institutes of Health News Releases Monday,* March 28, 2016 Available at: World's older population grows dramatically | National Institutes of Health (NIH) [accessed November, 2016.]

[15] D. Pant, S. Bhattarai and S. Poudel, Smart Care: Body Area Sensor Network Conceptual Architecture for Elderly and Non-Critical Patient Care, *Int. J. Advanced Networking and Applications*, 12(5), 2021, 4706 - 4713.

[16] J. Murugadhas, A. M. Al-Aamri, and M. S. Al-Sabahi, Smart Home Automation System for Elderly and Handicapped People Using Mobile Phone, *Int. J. Advanced Networking and Applications*, 12(4), 2021, 4616 - 4620.

[17] A. R. Zubair and A. O. Ogunware, Telediagnosis: Interfacing Biomedical Diagnostic Devices with Internet of Things (IoT) using ThingsSpeak Web-

Volume: 13 Issue: 05 Pages: 5134-5142(2022) ISSN: 0975-0290

Based Platform, *Proc. of the 13th ISTEAMS Cross-Border Conference,* Accra, 2018, 141–150.

[18] Arduino, n.d. Arduino Uno. [Online] Available at: http://arduino.cc/en/Main/ArduinoBoardUno [accessed November, 2016.]

[19] Atmel, n.d. Atmel AVR 8-bit and 32-bit Microcontrollers. [Online] Available at: http://www.atmel.com/products/microcontrollers/avr/default.aspx?tab=documents [accessed November, 2016.]

[20] P. Ranjeet, T. Prakash, S. Amruta, and S. Monali, Automatic Speech Recognition System, *Areview, Imperial Journal of Interdisciplinary Research (IJIR)*, 2(3), 2016, 165-169.

[21] R. Paul, R. Beniwal, R. Kumar, and R. Saini, A Review on Speech Recognition Methods, *International Journal on Future Revolution in Computer Science & Communication Engineering*, 4(2), 2018, 292 – 298.

[22] M. Saundade, and P. Kurle, Speech Recognition using Digital Signal Processing, *International Journal of Electronics, Communication & Soft Computing Science and Engineering*, 2(6), 2013, 31-34.

[23] S. Karpagavalli, and E. Chandra, Review on Automatic Speech Recognition Architecture and Approaches, *International Journal of Signal Processing, Image Processing and Pattern Recognition*, 9(4), 2016, 393-404.

[24] I. Gupta1, P. Raibagkar, and A. Palsokar, Speech Recognition Using Correlation Technique, *International Journal of Current Trends in Engineering & Research (IJCTER)*, 3(6), 2017, 82 – 89.

[25] A. Bala, A. Kumar, and N. Birla, Voice Command Recognition System Based on MFCC and DTW, *International Journal of Engineering Science and Technology*, 2(12), 2010, 7335-7342.