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REAL TIME SPEECH RECOGNITION BASED BUILDING AUTOMATION SYSTEM

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ABSTRACT

A smart home is a residence in which technology has been applied to expect and respond to the occupant's needs and commands, which can be used to enhance the everyday life at home. The main objective of this paper is to design an embedded system to detect and recognize human voice commands, which is in turn used to toggle respective loads. The entire design is accomplished using a speech recognition system along with an 8051 microcontroller kit and relays. The system is initially in standby mode waiting for an input from the user. Once an input is detected, it is analyzed by the speech recognition module. If a known command is detected, the speech recognition system sends respective digital representations to the microcontroller. The microcontroller then interprets these data signals, compares them with a database and thus identifies the referred load and its desired state. The processing results are then displayed on the LCD which is primarily used to display the system states. According to the load state identified, control signals are sent to respective relay circuits, thus actuating the appropriate loads. The original goals are the same i.e., to control the electrical appliances using voice commands and they have been achieved.

Keywords: speech recognition, microcontroller, spectrograph, automation, sensor, relay.

INTRODUCTION

From the remote system, we can adjust the whole home appliances like music and video system, heater and air conditioning, security cameras, lighting, even individual electrical outlets. Gone are the racks of black-faced components with digital displays and bouncing equalizer bars. Remote controls are reduced from dozens to a single master.

Home Automation is conveniences installed and designed to perform chore in your living place. Smart homes are often referred to as intelligent homes as they perform services that become part of our life. Many of the automated systems that silently perform their jobs unnoticed this is automation at its best.

Automation takes many shapes and it plays a major role in our daily life and homes. When you forget to lock a door in your car, the dome light comes on. Your favorite jewelry shop's door opens as you approach. A smart home system knows to turn off the air conditioning when a casement is opened, calls you when your children come home from school unscheduled or tells you the car port door was left open. One press of a button and your Home Theater lights dim, the blinds close and your TV turns on including all the right associated A/V components Call to check the indoor/outdoor temperatures, change your thermostat or close your blinds. Other automated system may include to set the air conditioning to an energy saving mode when the house is unoccupied, and restore it to the normal setting when an occupant is about to return. In simple applications this may be designed to turn on the lights when a person enters the room. In advanced systems, it not only sense the presence of a person inside but also identify who is that person and perhaps set appropriate cooling level, lighting, music levels or television channels, taking into account mind set of that person and other factors. Most of the sophisticated systems can maintain their own details like inventory date, their usage by bar codes, or RFID tag, and maintain their database.

To build an automated system that is truly efficient, easy to use, the designer must be able to assemble disparate bits of technology into a streamlined whole. A home automation system integrates all home appliances in a house with each other. With the help of the microcontroller, the cost of electronic control systems fell down rapidly. Smart control technologies were adopted by the building services in the worldwide, as they are user friendly to the end user. The elements of a demotic system are:

- Software or Hardware controllers
- Actuators
- Sensors

Goal

To build a robust hardware design model to aid the control of home devices using speech recognition.

Objectives

- To develop a hardware model to control home devices.
- To accept control signals from users in the form of speech.
- To process the voice signals for identifying speech and to generate corresponding control signals.
- To transfer the control signals to the corresponding device to perform the required task.

Need for automation

Home automation is also known as demotic. It is automation of the housework, home, or household activity. Home automation may include centralized control of

lighting, and other appliances, to provide improved convenience, energy efficiency and security. Home automation for the disabled and elderly can provide increased quality of life for persons who might otherwise require caregivers or institutional care.

Many of the household jobs were automated by the development of special appliances. For instance, water heaters reduced the labour necessary for bathing and automatic washing machines were developed to reduce the manual labour of cleaning clothes. As the number of controllable appliances in the home increases, the ability of these devices to communicate with each other digitally becomes a useful and desirable feature. The consolidation of monitoring or control signals from appliances, basic services or fittings is an aim of home automation.

Home automation can also provide a remote interface to home appliances or the automation system itself, via telephone line, wireless transmission or the internet, to provide control and monitoring via a smart phone or web browser. A good example of a remote monitoring in smart home automation could be when a smoke detector detects a smoke or fire, and then all lights in the house will blink to alert any occupants of the house to the possible fire. If the house is equipped with a home theatre, an intelligent system can shut down all audio and video components to avoid distractions, or make an audible announcement. The system could also call the house owner on their mobile phone to alert them, or inform it to the alarm monitoring company or the fire department.

Types of home automation

The implementation of home automation can be divided into the following application categories:

HVAC

Heating, Ventilation and Air Conditioning (HVAC) solutions include humidity and temperature control. This is generally one of the most important aspects to a house owner. For example, an Internet-controlled thermostat can both save money and help the environment, by allowing the house owner to control the building's heating and air conditioning systems remotely.

Lighting

Lighting control systems can be used to control household electric lights. Natural lighting control involves controlling LCD shades, window shades, awnings and draperies.

- Replace manual switching with Automation of on and off signals for any or all lights
- Change the ambient colour of lighting via control of electronic dimmers or LEDs
- Regulation of illumination levels according to the level of ambient light available
- Extinguish all the lights

Audio and video

It includes audio and video switching and distribution. Multiple sources can be selected and distributed to one or more rooms.

Security

With Home Automation, the consumer can select live video streams to watch their home or business. Security cameras can be controlled by the user to observe the activity around a house or business right from a touch panel or Monitor. T will give the intimation to the user through alarm or cell phone while identifying unauthorized entry by motion sensors. This system also has control and distribution of security cameras.

- Detection of possible intrusion

- sensors for detection of movement
- sensors for magnetic contact of door/window
- sensors for glass breaking
- sensors for identifying change in pressure

- Simulation of presence.
- Detection of gas leaks, water leaks, fire
- Medical alert via Tele-assistance.
- Precise and safe closing of blinds.

Control methods

A multiple intelligent devices or centralized controller can be used around the home. Besides the upcoming standardization of home automation hardware, there is also the issue of the control software. In older systems (and some contemporary ones), the control of each home automation system needed to be done separately, and there was thus no central control system. This sometimes led to a great amount of remote controls, one being needed to control each individual part of the system. However, with the new generation of home automation systems, central control can be foreseen.
The control can be achieved by the following ways:

a) Centralized control
b) Voice control
c) Predefined user profiles
d) Independent sensors

Centralized control

A centralized control is an autonomous control of the home devices aided by a central home server. A central home server is a server located in a private residence providing smart-living services to the user with the help of intelligent home devices. The devices are interfaced directly with this central controller and are independent from each other. Also multiple devices can be added or removed without any disruption of the entire system. The smart home network can be established by either wired or wirelessly connecting all the devices and sensors to this central server, which can also be networked to provide online control services. Thus this control method grants a

centralized and flexible network in which multiple home modules and sensors directly link to a central unit thus forming a deeply integrated system.

Voice control

This control method offers a more user interactive approach in delivering control commands. The principle of voice/speech recognition is employed as the basic concept. The term "voice recognition" means the systems t must be trained to a particular speaker's voice. Speech recognition applications include voice user interfaces such as call routing, domotic appliance control, voice dialing, search, simple data entry, preparation of structured documents, speech-to-text processing, etc. The concept of speech recognition involves the study of speech patterns of various individuals. All the patterns contain basic similarities, which can be grouped together into quantities called 'Phenomes'. Phonemes are described as semantic units. They are the sounds that group together to form our words, although quite how a phoneme converts into sound depends on many factors including the surrounding phenomes, speaker accent and age. Here are a few examples:

Table-1. Phenomes.

Aa	Father
Ae	Cat
Ah	Cut
Ao	Dog
Aw	Foul
Ng	Sing
T	Talk
Th	Thin
Uh	Book
Uw	Too
Zh	Pleasure

Phenoms are extracted from the waveform by running it through a Fourier Transform. It analyzes the waveform in the frequency domain. It is easier to understand this concept by using spectrograph. It is a 3D plot of a waveform's frequency and amplitude versus time. The amplitude of the frequency can be expressed by colour (either gradient colour or greyscale). Figure-1 shows the spectrograph Generation.

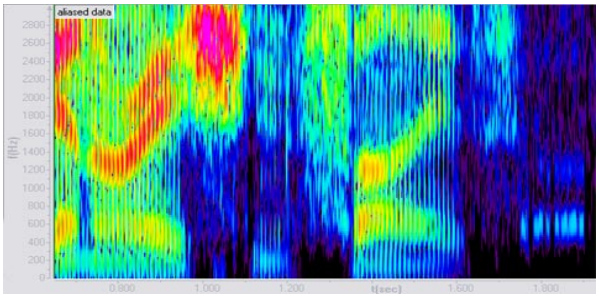

Figure-1. Spectrograph of 'ion' bit of generation.

For assurance, another spectrograph of the "ss" bit is shown here (this is a phoneme):

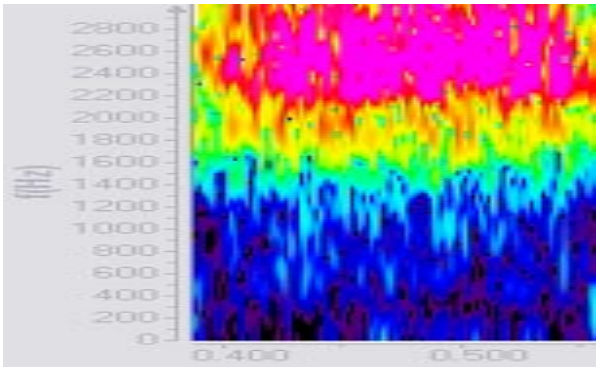

Figure-2. Spectrograph of the "ss" bit of assure.

Using this, we can identify the location of the "sh" Generation in the spectrograph. The timescales are slightly varying on the two spectrographs. We can easily match up the amplitudes and frequencies of a template phoneme with the corresponding phoneme in a word.

Predefined user profiles

The occupants define various settings of the entire system into 'profiles'. These profiles can be selected to be different for every user and contain settings of various devices such as room lighting levels, air conditioning, ambient music, etc. , all of which can be customized based on the users mood levels. For example, a profile 'SLEEP' can be made which would switch off all the room lighting, adjust air conditioning to a mild level, and switch off any unwanted running appliances.

Independent sensors

Due to availability of multiple automation standards in the market, a smart home can also comprise of smart devices which have their own proprietary standards. In such a case the setup would consist of independent sensors which aid and respond only to a few selected devices. This kind of installation does not form a network, but forms multiple independent modules, modules comprising of a set of sensors corresponding with a smart device. An example can be of a lighting system which automatically detects the presence of people in a

room and switches on the lights, this system of detection aids only the lighting system and does not actuate any other device.

METHODOLOGY

We intend to give a voice/speech input command to the system which has an in-built microphone that captures the input and transmits it to the speech recognition module. The speech sample is then analyzed after which a command is sent by the speech recognition circuit to the 8051 microcontroller. The command received by the microcontroller is then displayed on the LCD. The command signal that goes to the 8051 microcontroller is also made to toggle the bits/pins on an output port which are in turn connected to the relay circuit. The relay circuit consists of an isolation system and the relay along with the loads. Thus when the microcontroller sets on output bit to activate a load, the relay circuit triggers the respective relay to actuate the load. And the optocouplers present in the circuit isolate the main system from these high voltage loads.

Thus the system successfully isolates and controls loads based on an input speech command

Block diagram

The following block diagram describes the pattern we have followed to obtain the desired goals.

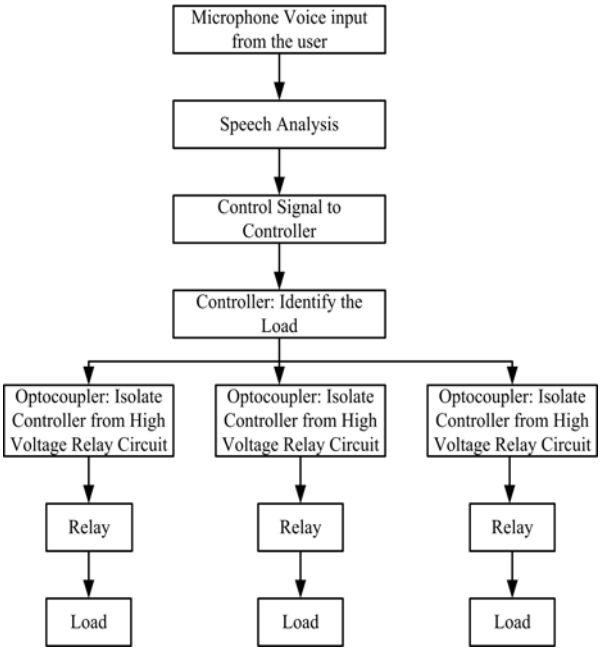

Figure-3. Block diagram.

Flow chart

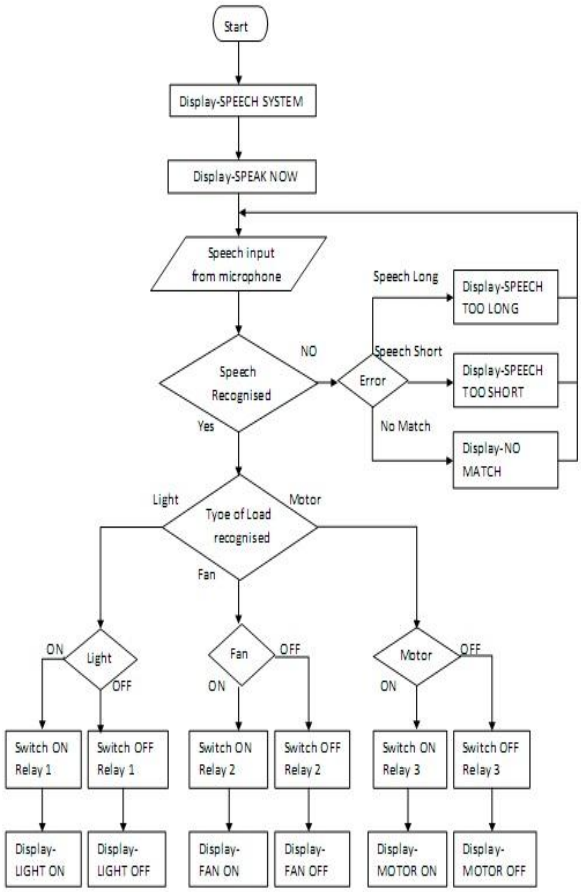

Figure-4. Flow chart.

Algorithm

a) The speech Kit is continuously monitored for voice samples through input port.
b) When data is got from the voice kit, it is checked if it is a new data or old one.
c) If old, then data is not considered.

If new, then the data is compared with the preset values assigned to each speech sample.

d) Thus by knowing the sample number, we get to know the command spoken.
e) Then according to the number, the respective command shows up on the LCD screen
f) Then the respective pin/bit on the output port used to control the relay is made 1 for the on commands and made 0 for the off commands accordingly.

Choice of components

HM2007 Speech recognition system

The above mentioned module was chosen to perform the function of receiving and analyzing the voice input. The selection was based on its following onboard features:

- Built-in microphone
- Direct 8-bit interfacing with any microcontroller 8 pin port
- Easy to train speech samples
- Onboard 64KB memory, capable of storing 20 speech samples of 1.92 seconds each.

P89V51RD2 microcontroller kit

For the implementation of the circuit functions, the low-power processing capabilities of an 8051 based system were found to be the most suitable. Thus the 80C51 based microcontroller development board NXP P89V51RD2 was chosen based on the following features:

- 80C51 CPU
- Easy to flash program via ISP tool 'Flash Magic'
- Four 8-bit I/O ports accessible onboard through 10-pin FRC connectors

Optocoupler (MCT2E)

Optocoupler is used to isolate the controller circuit from the any short circuit or instantaneous high current generated in high voltage devices. The MCT2E opto isolators consist of a gallium arsenide infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package. Its specifications are found to successfully isolate a 220v high voltage source.

HRS4 relay

A standard relay with a contact rating of 10A 120V ac/24V dc and 15A 120Vac/24V dc was chosen for its easy availability and durability.

Circuit diagram

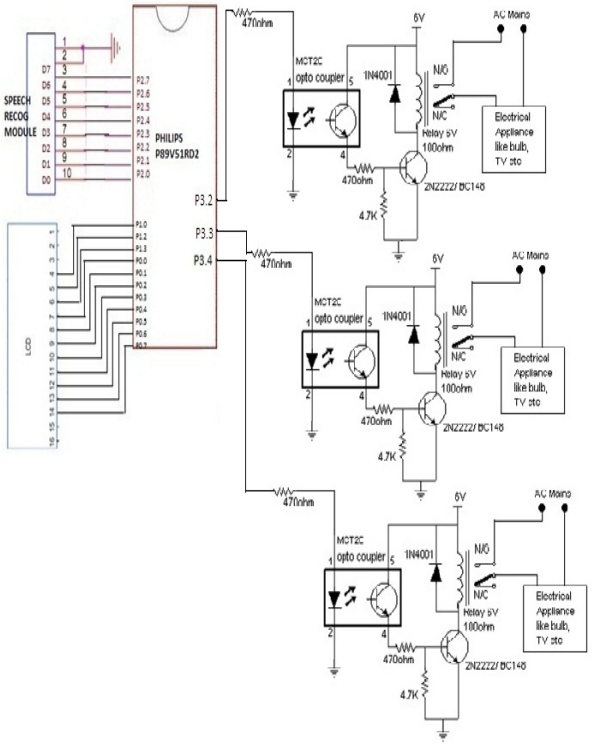

Figure-5. Circuit diagram.

Circuit function

The basic function of the circuit can be stated as:

a) To accept and recognize voice commands.
b) Analyze them to identify the load and its next state.
c) Send control signals to the corresponding relay circuit to actuate the load.

Modules

Voice recognition system

The function of accepting and recognizing the voice commands is done by the HM2007 voice recognition system. It is a standalone module with a built-in microphone. The basic function of the onboard HM2007 chipset is to analyze and compare the input speech sample with a database of pre-recorded samples. The board has 64KB SRAM capable of storing 20 speech samples of 1.92 sec each. Initially the system is trained by prerecording the voice command samples. These commands are stored in memory locations which are denoted by two hexadecimal digits. The board is explained in detail in the component description section.
The voice commands used in our project are:

- Load-Fan

a) Fan ON
b) Fan OFF

- Load-Light

a. Light ON
b. Light OFF

- Load-Motor

1) Motor ON
2) Motor OFF

These samples serve as a database, which is used to compare the input voice commands. It contains the following system status denotations:

- Load-Fan

A. Fan ON - 41
B. Fan CLOSE - 42

- Load-Light

I. Light ON - 43
II. Light CLOSE - 44

- Load-Motor

a. Motor ON - 45
b. Motor CLOSE - 46

- Error Codes

(i) Word too long - 55
(ii) Word too short - 66
(iii) No match - 67

Corresponding to the input detected, respective hexadecimal digits are displayed on the built-in segment display; also data signals in the form of these hexadecimal digits are transmitted across the 8-bit data out. This is connected to the port 2, initialized as an input port on the P89V51RD2 controller board.

Controller

The input on the microcontroller board consists of hexadecimal digits which are then compared with a database to determine the associated commands. Accordingly, the system status is transmitted to the LCD display in the form of a text-string. The LCD is connected to the controller board through port 0 and port 1, where port 0 acts as the data port and port 1 is used to send control signals. The port 3 is used to interface the controller board with the relay circuit. If the command is to switch 'ON' a relay, the bit on port 3, connecting to the corresponding relay is set. But the current level of this output signal is low and is not enough to energize the relay.

Relay control module

Thus the controller output is given to an optocoupler which is used to isolate the controller from the high voltage source. The optocoupler outputs are then connected to the respective relay circuits. Thus the respective relays are energized to power the loads.

CODING ALGORITHM

a) Start
b) Initialse P3.2 as relay1 o/p, P3.3 as relay 2 o/p, P3.4 as relay 3 o/p and the output signals from the microcontroller are sent to these port pins.
c) Initialse two variables 'lastdata' and 'datanow'.
d) Port 2 is used as the input port to take in the data from the speech recognization module.
e) While continuously monitoring P2, data from P2 is put into 'datanow'.
f) If datanow!=lastdata, we know that new data has come at P2.
g) Lastdata is given the value of datanow.
h) The data in lastdata is now compared using a switch case.
i) If

lastdata=55,lcd displays 'speech long'.
lastdata=66,lcd displays 'speech short'.
lastdata=67,lcd displays 'no match'.

j) If
lastdata=41,lcd displays ''FAN ON" ,and OUT1 is set as 1 so the relay is switched on.
lastdata=42,lcd displays 'FAN CLOSE',and OUT1 is set as 0 so the relay is switched off.
lastdata=43,lcd displays 'LIGHT ON',and OUT2 is set as 1 so the relay is switched on.
lastdata=44,lcd displays 'LIGHT CLOSE',and OUT2 is set as 0 so the relay is switched off.
lastdata=45,lcd displays ''MOTOR ON" ,and OUT3 is set as 1 so the relay is switched on.
lastdata=46,lcd displays 'MOTOR CLOSE',and OUT3 is set as 0 so the relay is switched off.

k) End

Testing analysis

The core module of this project is the speech voice control, thus the system's overall efficiency is determined by the efficiency of the speech recognition system.

To test the efficiency of the speech recognition system, we have trained it with the 'user1' providing the speech samples. It was then tested over 5 experimental trials by two users - User1 (male) and User 2 (female) to recognize the previously mentioned speech commands and the following results were observed:

Table-2. Observation table.

LOAD	COMMAND	USER1- MALE					USER2- FEMALE				
FAN	F_{ON}	√	√	√	√	√	√	√	√	√	√
	F_{OFF}	√	√	√	√	√	x	√	√	x	√
LIGHT	L_{ON}	√	√	√	√	√	x	√	√	√	√
	L_{OFF}	√	√	√	√	√	√	√	x	√	√
MOTOR	M_{ON}	√	√	√	√	√	x	√	√	√	√
	M_{OFF}	√	√	√	√	√	√	√	√	√	√

Thus for the user training and operating the circuit, the success rate is found to be 100%. For a user of different gender and vocal patterns, the success rate is found to be as high as 83%.

The system was successfully built and tested before implementing any loads.

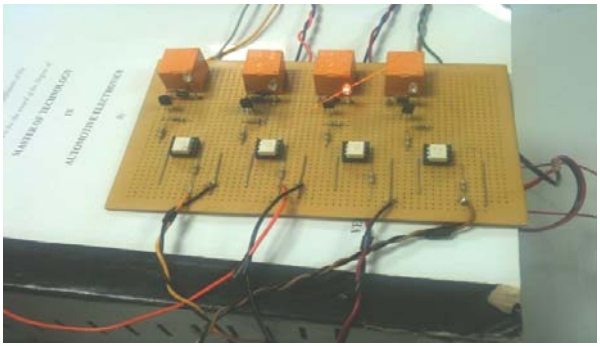

Figure-6. The relay circuit.

The complete system was then run to check if the microcontroller is successful in interpreting the input voice commands and activating loads:

When the system is started the LCD displays a welcome message 'SPEECH SYSTEM'. Followed by a message requesting the user to provide voice input 'SPEAK NOW'

Figure-7. System ready status.

When one of the commands, 'LIGHT ON' was given as speech input, the following results were observed:

Based on the input speech command the following results were observed:

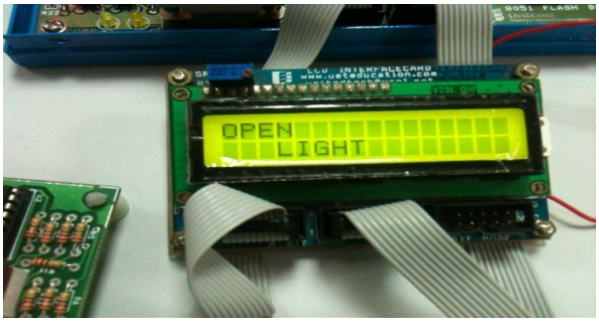

Figure-8. Light on speech command accepted.

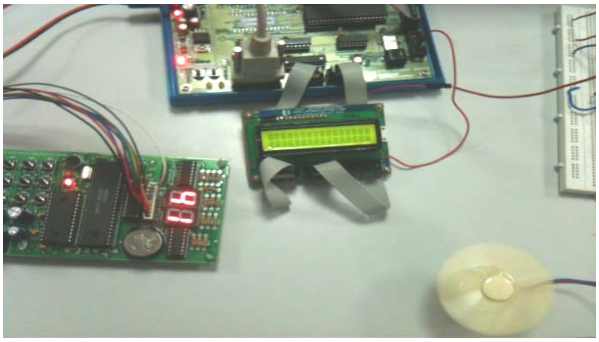

Figure-9. Load switching ON.

When the commands, 'LIGHT CLOSE' was given as speech input, the following results were observed:

Figure-10. Light close speech command accepted.

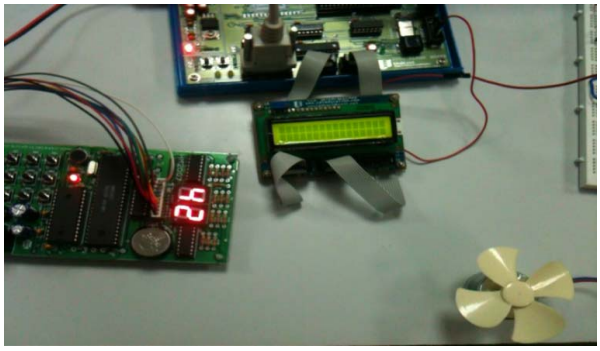

Figure-11. Load switching OFF.

A speech recognition error code signifying that the input speech was too short to be analyzed:

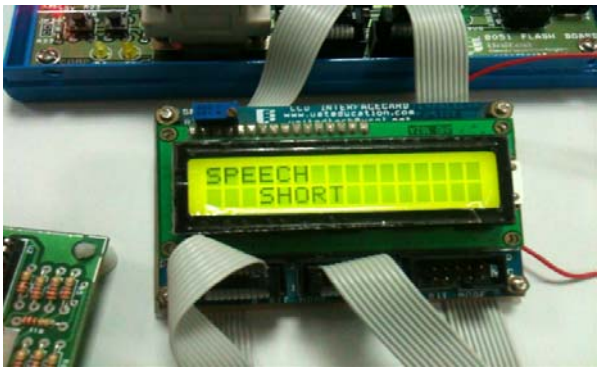

Figure-12. Speech short error message.

A speech recognition error code signifying that there was no match found:

Figure-13. NO Match error message.

CONCLUSIONS

We have presented a method for home automation. We have taken the voice command input from microphone. This electrical signal is processed to recognize the speech. Based on the recognition the microcontroller generates control signals for the relays which lead to many loads.

This working model has been tested on a variety of input patterns from people belonging to different age-group, gender. We have generalized the efficiency of our design by obtaining quantified data after every stage. This speech recognition system is very apt for the chosen words and identifies it efficiently with an overall success rate of 78.3%. The words used here are easy to speak and thus are used. Thus the drawback is eliminated.

This work can be extended to controlling the light capacity as well as the fan speed. By using regulators and more controllers, the amount of current sent to the load can be controlled, thus we can dim or brighten a room using only speech.

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