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Practical Design of a Home Appliance Control System Using Audio Signals

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ABSTRACT

In this paper, the design of a system that controls home appliances using voice commands is considered. This system may be utilized by people with special needs and the elderly. By using just their voice, they can control the lighting of their room, and turn on or off their television, air conditioner, or fan with safety and security and without needing someone else's assistance. This may be achieved by passing their voice commands to a microcontroller, (Arduino), through a device that uses voice or speech recognition technology. Herein, the system is designed at the lowest possible costs. Two basic ways are discussed to build this system, a wired system that does not depend on wireless technologies and the other depends on Bluetooth technology. Each of them has advantages and disadvantages. The hardware parts utilized in the design process are the Arduino Uno, Relay Module, and voice recognition module. The latter could be replaced by a Bluetooth module and a smartphone with an application that uses voice or speech recognition technology. The proposed wired system proved to be advantageous in terms of privacy, security and reliability. A comparison between the two systems is concluded at the end of this paper.

KEYWORDS: Speech Recognition Technology, Recognition Module V2, Home Appliances, Arduino Uno, Bluetooth.

1. INTRODUCTION

The demography of the world population shows a trend in which the number of elderly people is increasing rapidly in recent years as a result of the increase in the average lifespan [1]. In addition, the number of amputees in the world specifically in Libya has increased due to the wars in recent years. There are no accurate statistics for the number of local amputees, but the last statistic was in 2018, and the number of amputees was approximately 120,000 according to the Ministry of Social Affairs. This increase in the number of elderly, amputees, and people with special needs is the main purpose of the proposed system.

There are numerous studies on the subject of household appliance control using voice recognition techniques [2]-[8].

In [2], the authors suggested a control system, which is composed of three parts, Arduino Uno, Ethernet controller, and a relay module. A similar system was proposed in [3], but the ATMEGA2560 microcontroller is used instead of Arduino. The system in [4] utilized the Android platform as a control system, which may take advantage of the features that are already available in smartphones.

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Therein, the fast Fourier transform method is applied to the received voice to match it with the previously stored ones. If there is a match, the microcontroller will execute the command accordingly.

The system proposed in [5] is composed of a microcontroller and a voice recognition system. The system is utilized to control the light, fan, water pump, and safety deposit box. The average rate of successful commands is about 65%, with the minimum rate is about 58% and the maximum is around 85%. Therefore, some commands need to be repeated.

In [6], the authors proposed a system that is composed of a microphone to be used as a sound sensor to control various devices such as fans, lamps, laptops, and TVs. The voice signal is transferred to a digital signal, which is the input to the Arduino microcontroller to be processed and yield the proper control signal to the actuator. To make the system more reliable, a converter-battery set was utilized to store energy and reuse it in an emergency. Several tests were performed on the proposed system to evaluate the system's performance and sensitivity to surrounding noise.

In [7] and [8], similar systems were proposed as tools to aid visually impaired people in handling some of their daily activities, such as controlling password-protected safety box which is used to store their personal belongings.

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The system proposed in this study is composed of a microcontroller (Arduino) device connected to a voice recognition module, which captures an audio signal and compares it with the stored voice signal in the recognition module. This is in the case of the first design, and as for the second design, which depends on Bluetooth technology, the spoken word is compared to a word stored on the Arduino board. The two systems rely on two different technologies that are similar at the same time, namely, voice recognition technology and speech recognition technology. Speech recognition and voice recognition are not quite the same thing. Speech recognition recognizes only the words (WHAT was spoken). Voice recognition, on the other hand, recognizes only the voice and identifies an individual user's voice (WHO is speaking) [9].

Arduino-c-software is used as a monitoring and control section. In addition, an access port program is used to record the voice of the person speaking. Another program is utilized which is the Android voice controller. These are the main three programs used in this system.

The contributions of this study are as follows: first, this study proposes a comparison between two systems, wired and wireless systems. On one hand, the wired system is less susceptible to noise, protects someone's security and privacy, and consumes less energy. The wireless system, on the other hand, is more flexible and can easily cover a larger area. A comparison that highlights the difference between the two systems is presented at the end of this paper. Secondly, this system provides a great service for society since it may be manufactured locally, thus it can be customized for each specific disability case based on its need. In addition, there are no extra costs required such as international shipping costs.

2. HISTORY AND BACKGROUND

A. History of Voice Recognition Technology

Voice recognition technology has become very popular in recent years and the great development of this technology is evident. However, this technology is not very recent as it has its roots go back to the 1950's. A review of the beginnings of this technology is in the following points [10]:

- In 1952 Audrey was invented by Bell Laboratories which could only understand numbers.
- In 1962, the shoebox technology was able to understand 16 words in English.
- In 1990, the first speech recognition software in the world was released by the company Dragon.
- In 2001, Google invented an application called Google Voice Search.
- In 2010, Google introduced personalized recognition on Android devices, which can recognize 230 billion English words, and Apple's Siri was invented too.

B. What is the voice recognition

Vocal communication between humans may be explained as follows: the sound starts from the vocal cords and then travels to the air through the mouth, air is the medium that transmits sound. Then the signal is received by the ear in order to be sent to the brain. It follows that the information is interpreted and translated. In the same principle, communication is made between humans and machines.

This process can be summarized in the following steps: The first step, the person's voice begins as vibrations in the throat and then is transmitted to air. This causes pressure changes in the air (waveform). Then the audio input unit (microphone) converts the pressure changes into electrical voltage changes (an analog signal). The next step, the analog signal is converted to digital by using an A/D converter and is stored in memory [11]. The final step is the processing of the digital signal by a speech recognizer in order to be used in a specific program. The program contains the input template and matches this template with the actual input. The block diagram of the process is shown in Fig.1.

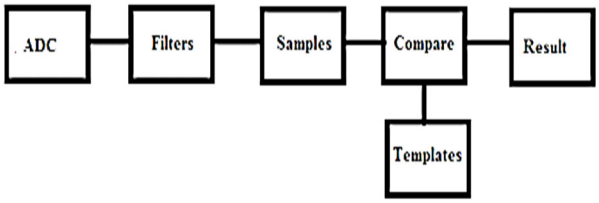


Fig. 1. Block diagram of the speech recognition process.

C. Different between voice and speech recognition

The difference between voice and speed recognition may be summarized in the following points:

- Voice recognition is a technique that focuses its attention on who is the speaker. Voice recognition has two types, one that does not depend on the text (**Text Independent**), which is who is the speaker regardless of what he is speaking, and another type that depends on text **(Text Dependent)**, that the text cares about who and what he is speaking [12].
- Speech Recognition is a technique that focuses its attention on what you speak (speech). It also has two types, one that does not depend on the speaker

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(Speaker Independent), meaning that the word is important only regardless of who spoke, and the second type depends on the speaker **(Speaker Dependent)** and is interested in the word and who is the speaker at the same time [13].

However, one may consider both as one technology that differs as follows:

1. Recognizes WHO is speaking (voice recognition Text-independent*)*.
2. Recognize WHAT was spoken (speech recognition Speaker independent*)*.
3. Recognize WHO is speaking and WHAT was spoken at the same time (voice recognition Text-Dependent or speech recognition Speaker independent).

D. Smart home

In smart homes, all home devices together are connected as a big network and controlled by remote control, smartphones, or microphones as depicted in Fig. 2. There are several benefits of smart homes, such as convenience, entertainment, safety, security, energy savings, and healthcare for elderly and disabled people[11].

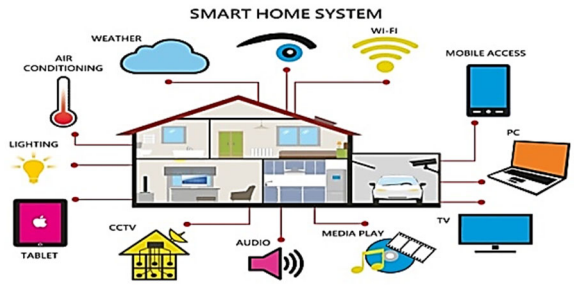


Fig. 2. Smart home.

3. SYSTEM COMPONENT

The following devices are utilized to configure the wired system.

A. Arduino Uno

The Arduino board is an open-source board founded by the Arduino company in Italy that can be programmed easily using the Arduino IDE which is based on the C language. There are several types of this product, and one of which is commonly used, is the Arduino Uno, depicted in Fig.3. Arduino Uno is a very suitable board for starting projects as it is inexpensive. It contains several components, the most important of which is the microcontroller, which contains the CPU, RAM of 2KB (this is runtime memory), and Flash memory of 32 KB. The program loaded from the Arduino IDE is stored in the flash memory. It contains 14 digital input/output pins, 6 of which can be used as PWM outputs. In order to operate them, a DC source equal to 5 V is required.

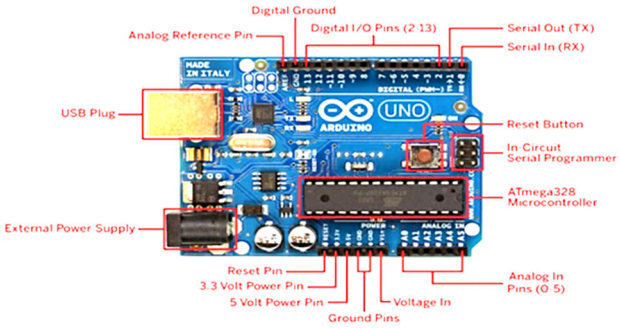


Fig. 3. Arduino UNO.

B. Voice recognition module v2

The module, depicted in Fig.4, could recognize the speaker's voice. It receives voice commands and compares them with pre-stored voice commands. The Access Port program is utilized to store voice commands. This module (v2) can store up to 15 pieces of voice. It stores 15 voice commands in three groups, and each group contains 5 voice commands. When storing voice commands, they are recorded in each group separately. This module is characterized by a high accuracy of 99% so that it can identify even the person who is speaking. It works at a voltage of 4.5-5.5 V. There is a new version of this module that can store up to 80 voice commands.



Fig. 4. Voice recognition module.

C. Relay module 4× 4

A relay is an electrically operated switch that can be turned on or off. It can be used to control various appliances with large current and yet it can be controlled directly by a microcontroller. It works at a voltage of 5 volts, similar to the Arduino. The module illustrated in Fig. 5 has four channels, each channel needs a 15-20 mA driver current.

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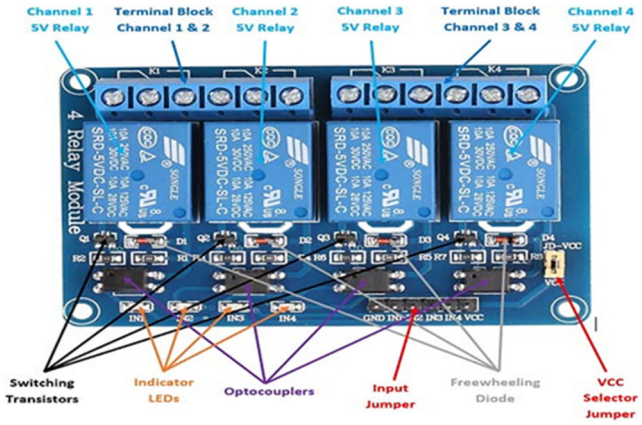


Fig. 5. Relay module 4×4.

D. USB and ttl driver

As shown in Fig. 6, USB and ttl driver is the mediator that is used to download the sounds that are generated to control the devices. It is used to connect VRV2 to the computer.



Fig. 6. USB and ttl driver.

It may be worth mentioning that this system could be converted into a wireless system only by replacing the voice recognition module with a Bluetooth module and linking it to a smartphone with a voice recognition application installed on it.

E. Bluetooth module

It is the device that is used to connect the Arduino board to the smartphone which contains any application that uses speech recognition technology such as Android Voice Controller.

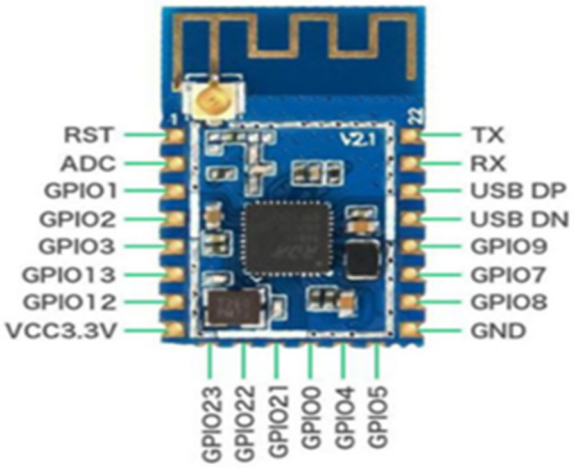


Fig. 7. Bluetooth module.

4. METHODOLOGY AND RESULT

A. Wired System based on voice recognition module

The speech input from the microphone is given to the voice recognition module where the speech signal is compared with the previously stored trained voice samples. Upon successful recognition of voice command, the Arduino microcontroller actuates the corresponding electrical device like turning on lights or adjusting bed elevation using the relay module. In Fig.8, the block diagram sets the principle of the system's work.

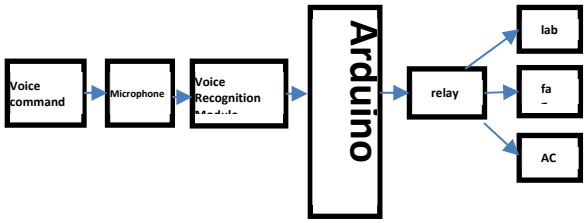


Fig. 8. Block diagram of the proposed system.

The working principle of the system is as follows:

First, we connect the voice recognition device to the computer (connection is shown in Fig.9).

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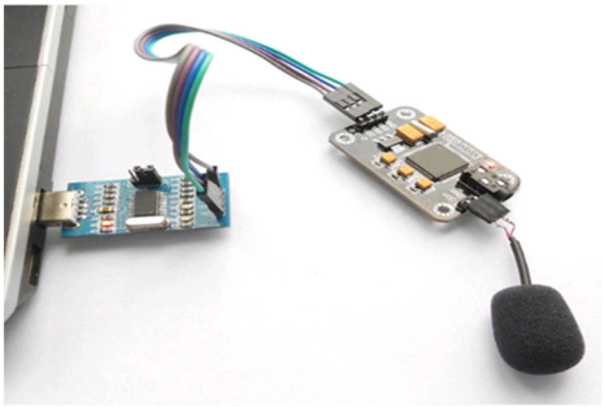


Fig. 9. Voice recognition system.

Then the voices are recorded and stored on it, with the help of the (Access Port) program as demonstrated in Fig.10. In order to connect the voice recognition device to the computer, the USB and ttl driver are used. The maximum number of voice commands that can be recorded is 15 voices.



Fig. 10. Access port window.

To set the stage for this case study, the voice commands with their descriptions are presented in Table 1. Herein, only five commands are used as a demonstration to evaluate the performance of the system.

Table 1. System Commands

Command number	Command words	Description
Commomd1	On	To turn on the lighting
Commomd2	TV on	To turn on the TV
Commomd3	Charger	To turn on the charger
Commomd4	Off	To turn off the lights and the charger
Commomd5	TV off	Turn off the TV

Secondly, we define the Arduino device to the computer, and through the Arduino C program, all the codes for the project can be written and then sent to the Arduino microcontroller.

Finally, we connect the Arduino to the voice recognition model and the relays which are used to connect home devices to the Arduino. The hardware connection of this system is shown in Fig. 11.

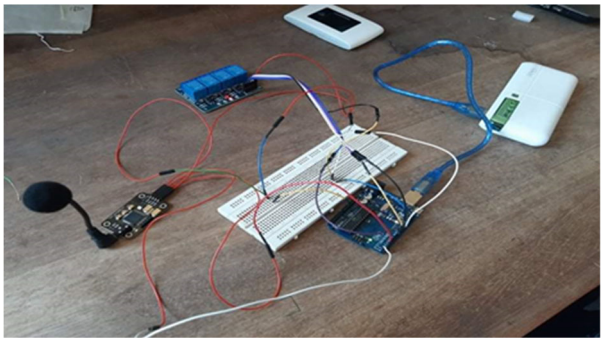


Fig. 11. Connection of the system.

B. Wireless system using bluetooth module

The composition of this system is the same as the installation of the previous system with the difference is in replacing the voice recognition module with the Bluetooth module. The block diagram in Fig.12 illustrates the wireless system.

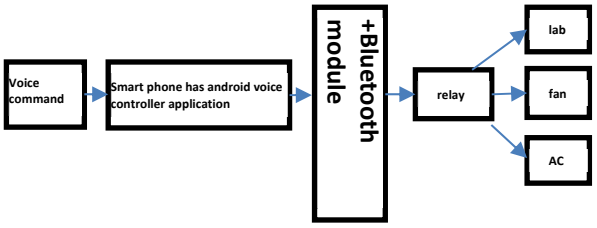


Fig. 12. Block diagram of the system.

The working principle of the system is as follows:

First, the code for the system is written using the Arduino IDE, and it is sent to the Arduino board as in the first system. Secondly, the Arduino, Bluetooth module l and the relay are connected to each other and the relay is used to connect home devices to the Arduino. The connection of the Arduino with Bluetooth module is shown in Fig.13.

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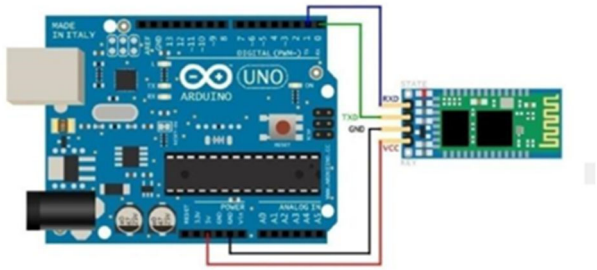


Fig. 13. Connection of the arduino with Bluetooth module.

Finally, the application that uses voice recognition technology is downloaded from the App Store, such as the **Android Voice Controller** application. Then it is connected to the Bluetooth module that is connected to the Arduino board application.

5. RESULTS

This system has been tested in terms of accuracy, speed of response, and the effect of distance from the system on its response, and the evaluation of the system performance with the results are presented in the following subsections.

A. System Accuracy

In this section, we will test the accuracy of the system, as mentioned earlier is approximately 95%. Table 2 illustrates the voice commands which are tested five times for each command. As shown, '0' indicates that the system has not responded to the command while '1' indicates that the system has responded to the command.

Table 2. Wired System Accuracy

Commands	Successful Responses					Total Responses	Accuracy
	1	2	3	4	5		
ON	1	1	1	1	1	5	100%
TV ON	1	1	1	1	1	5	100%
CHARGER	1	1	1	1	1	5	100%
OFF	1	1	1	1	1	5	100%
TV OFF	1	1	0	1	1	4	80%

Here we measured the response at a fixed distance of one meter, we calculated the accuracy for each voice command, and it is as shown in the table. If we want to calculate the system accuracy for all commands we get an average accuracy of 96%, which is close to the previously mentioned value.

One may argue that this is a random process that is affected by surrounding circumstances. For instance, if we measure the response in a noisy environment, the accuracy rate is estimated to be about 60%. However, in our experiment, the accuracy is found to be as low as 44% as shown in Table 3.

Table 3. System Accuracy, Noisy Environment

Commands	Successful Responses					Total Responses	Accuracy
	1	2	3	4	5		
ON	1	1	0	0	0	2	40%
TV ON	1	0	0	1	1	3	60%
CHARGER	0	1	0	0	1	2	40%
OFF	0	0	0	1	1	2	40%
TV OFF	1	0	0	0	1	2	40%

B. The effect of distance on the system

The system is tested at three different distances which are measured between the system and the source of the voice command which are 'one' meter and 'two' and 'three' meters.

We notice that the system's response to commands decreases if the distance between the speaker and the system is increased. That means, increasing the distance has a negative effect on the accuracy of the response. As depicted in Table 4, the further the distance, the lower the accuracy which is intuitively should be the case.

The system's average accuracy for all commands at a one-meter distance is about 96%. The system's average accuracy for all commands at a two-meter distance gives an accuracy of 72%. Finally, the system average accuracy for all commands at a three-meter distance is about 48%.

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Table 4. System Accuracy At Different Meter Distances.

Voice commands	At 1 Meter Distance		At 2 Meter Distance		At 3 Meter Distance	
	Total Responses	Accuracy	Total Responses	Accuracy	Total Responses	Accuracy
ON	5	100%	4	80%	3	60%
TV ON	5	100%	4	80%	2	40%
CHARGER	5	100%	3	60%	2	40%
OFF	5	100%	4	80%	3	60%
TV OFF	4	80%	3	60%	2	40%

C. System speed response

Here, we will test the speed of the response to the voice command. After issuing the command, the response time is recorded as displayed in Table 5.

Table 5. Time Response Of Commands.

Voice commands	Response Time (seconds)					Average Response Time (seconds)
	1	2	3	4	5	
ON	0.47	0.48	0.41	0.54	0.41	0.462
TV ON	0.47	0.53	0.48	0.54	0.34	0.472
CHARGER	0.41	0.60	0.47	0.43	0.54	0.49
OFF	0.40	0.54	0.48	0.47	0.54	0.486
TV OFF	0.41	0.60	0.51	0.35	0.35	0.44

Finally, the comparison between the wired technology and the Bluetooth technology is presented in Table 6.

Table 6. Comparisons Of Wired Technology and Bluetooth Technology

Technology / Comparisons	Wired technology	Bluetooth technology
Range of the distance that can be covered	3 meter Suitable for smart room	More than 10 mete Suitable for smart home
The ability to exchange the voice recognition model for mobile phone	We cannot exchange the a voice recognition model for mobile phone	We can exchange the a voice recognition model for mobile phone
Usability by the elderly	More Suitable	Suitable
Usability by amputees	More Suitable	Suitable if we use VRV2or VRV3. Is not suitable if we use mobile phone.
Number of commands	15 commands if we use VRV2,If we use VRV3 are 80 commands	15 commands if we use VRV2, If we use VRV3 are 80 commands. Infinite number if we use mobile
Accuracy	Very High accuracy	Very High accuracy if we use VRV2. High when we use mobile
Flexibility and simplicity of the system	Simple and flexible if we use it for smart rooms, but if we use it for all home, it can increase the complexity.	Simple and flexible for smart home

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It can be shown from the results that the response is within 0.35 to 0.6 seconds. That means that the system has a relatively rapid response to voice command. These tests are conducted on the wired system, which prove to be much more accurate than wireless technology for this specific case study.

6. CONCLSION

This paper discusses two systems that have a high response speed and high efficiency, yet they are relatively simple systems and reasonably inexpensive. The cost of the first system is only 300 L.D, and you only need an extra 20 L.D to convert your system into a wireless system (the second system).

The first system has a high accuracy at ideal conditions approximately 95%-99%. This accuracy is achieved using the voice recognition module. The proposed system can distinguish between people's voices, because it uses voice recognition technology. For the second system, the application used in it uses speech recognition technology that only needs the correct word to execute the command. One advantage of the second system is that it is not required to be close to the system to execute commands. On the other hand, you need a distance of less than three meters for the first system to respond. In terms of security, however, the first is better because the voice is considered as a fingerprint for a specific person.

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