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Empowering the Disabled and Elderly: A Voice Control Unit for Assistive Technology

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Abstract

The vast development of the technology of embedded systems has had a great impact on the healthcare field. Using low-cost, robust parts, this research proposes an innovative technology and design that enables paralyzed patients or elderly individuals to have a smart room with a voice recognition control unit that works like a joystick for various purposes. The aim is to create an environment that meets their needs and increases their independence, thereby improving their quality of life. The research will show the design of the control unit and present the various applications that can be programmed using voice commands, such as a wheelchair, bed, temperature, lights, TV, and alarm. The voice recognition module will be trained using the patient's voice, for example, to change the movement direction of a wheelchair. The system is based on training the Voice Recognition Module v3 with the use of Arduino and Node MCU. The results of the commendable accuracy of the English word response in a quiet environment ranged between 90% and 100% at the 0.2-meter distance and 50% and 100% at the 0.5-meter distance. While in a noisy environment, it ranged between 40% and 100% at the 0.2-meter distance and 10%–90% at the 0.5-meter distance. As for the Arabic-pronounced words, they ranged between 60% and 100% at the 0.2-meter distance and 30% and 100% at the 0.5-meter distance in a quiet environment. And, in a noisy environment, it ranged between 30% and 100% at the 0.2-meter distance and 10% and 100% at the 0.5-meter distance.

Keywords: Disabled; Elderly, voice control, Assistive technology, IOT, Node MCU, Arduino.

تمكين المعوقين وكبار السن: وحدة التحكم الصوتي للتقنية المساعدة

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الخلاصة

كان للتطور الهائل للتقنية فيما يخص الأنظمة المدمجة تأثير كبير على مجال الرعاية الصحية. باستعمال أجزاء متينة ومنخفضة التكلفة، يقترح هذا البحث تقنية وتصميمًا مبتكرًا يمكّن المرضى المصابين بالشلل أو كبار السن من الحصول على غرفة ذكية مع وحدة تحكم في التعرف على الصوت تعمل مثل عصا التحكم

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لأغراض مختلفة. الهدف هو خلق بيئة تلبي احتياجاتهم وتزيد من استقلاليتهم، وبالتالي تحسين نوعية حياتهم. سيُوضح البحث تصميم وحدة التحكم ويقدم التطبيقات المختلفة التي يمكن برمجتها باستعمال الأوامر الصوتية، مثل الكرسي المتحرك ودرجة الحرارة والسرير، والأضواء، والتلفاز، والإنذار. سيتم تدريب وحدة التعرف على الصوت باستعمال صوت المريض، على سبيل المثال، للتحكم في حركة الكرسي المتحرك في جميع الاتجاهات. يعتمد النظام على تدريب وحدة التعرف على الصوت 3v باستخدام Arduino وnode MCU. وتراوحت دقة النتائج لمدى الاستجابة للكلمات باللغة الإنكليزية في بيئة هادئة بين (90%–100%) على مسافة 0.2م و(50%–100%) على مسافة 0.5م. بينما تراوحت في البيئة الصاخبة بين (40%–100%) على مسافة 0.2م و (10%–90%) على مسافة 0.5م. أما بالنسبة للكلمات العربية المنطوقة فقد تراوحت بين (60%–100%) على مسافة 0.2م و(30%–100%) على مسافة 0.5 متر في البيئة الهادئة. وفي البيئة الصاخبة تراوحت بين (30%–100%) على مسافة 0.2م و(10%–100%) على مسافة 0.5م.

1. Introduction

Assistive technology for people with disabilities or the elderly has become a topic of growing research interest, with a specific emphasis on developing voice-controlled devices. The World Health Organization published a study that found that assistive technology will play a substantial role in letting people with disabilities join society and overcome barriers to communication, mobility, and independence [1]. According to the report by the WHO and UNICEF, over 2.5 billion people need assistive products, such as hearing aids, wheelchairs, or cognitive support apps. However, access to these products is limited, with almost one billion people lacking availability, especially in low- and middle-income countries, where accessibility is only 3% of the demand [2]. Speech recognition technology has occupied a vital role in many fields of science and has the potential to advance with the elimination of speaker variability, context, and surrounding noise. In speech recognition, machines detect and respond to voice commands, allowing for hands-free access and control of equipment using voice as data. The internet, which has made it easy to connect to any part of the world, has also played a major role in the development of this technology, along with other consumer electronics such as fans, lights, and heaters [3]. This paper aims to design a voice control unit by training it according to the user language and voice tone, taking into account the appropriate environmental conditions, as well as connecting all the devices the elderly or paralyzed person needs to the internet cloud to show the states of devices and control their mobility.

2. Related work

Shehu et al. (2018) [4] highlighted the use of a microcontroller to control the wheelchair and merged a voice recognition module and obstacle detection sensors with it to enhance safety and ease of use. The research achieved an accuracy of 91% for real conditions and 99% for ideal conditions.

Dutta et al. in 2020 [5] showed a simple design to control a wheelchair that is controlled by a microcontroller (Arduino) and uses sound commands through mobile by sending radio signals to the Arduino using a Bluetooth module to control the wheelchair's movement. As a result, the design will allow the patient to move freely using a wheelchair and independently from others' assistance.

Gayatri Haritha et al. in 2020 [6] designed a cost-effective smart wheelchair and bed health monitoring system by using the SMS GSM module so that all the parameters will be updated to the concerned user when the range is reached, as it can transform from chair to bed and the other way around by using the lever, recliner, and a battery-operated linear actuator. At the same time, it monitors some health parameters, like heartbeat, body temperature, and weight, using sensors. The system mostly focuses on cost-effectiveness for needy people.

Zanwar et al. in 2021 [3] designed a voice recognition-based device control system using a smartphone application. The main focus of this project is to use mobile applications and MATLAB for speech recognition. The system responds to voice commands and verifies the user's identity by comparing the stored voice samples using MATLAB. Additionally, the devices can be controlled remotely. MATLAB is employed for speech recognition and displaying voice signals. This allows for convenient and hands-free usage of voice commands to toggle the devices on and off.

Y. Iliev et al. (2022) [7] designed a voice recognition wireless room automation system. The project contains three standalone embedded systems that can be connected to each other over wires or wireless media. A voice recognition module includes an encoder and transmission component, along with a decoder and receiver module. The system uses the HM2007L IC to recognize an intended user's voice, speech, or commands.

3. The proposed system

The proposed system depends on a direct command from the user or through the application interface, which can be accessed remotely via the Wi-Fi network.

3.1 System Design and Implementation

The block diagram shown in Figure 1 describes all the parts of the system, its method of operation, and its connection via the Wi-Fi network.

3.1.1 Hardware Requirements

The proposed system depends on all of the listed components:

1- Node MCU: A quick and efficient way to develop an IoT application with minimal additional circuit components is to use the NodeMCU circuit. This open-source firmware and development equipment is a crucial element in designing a suitable IoT product using a limited number of codes. The NodeMCU module is primarily built on the ESP8266, a low-priced Wi-Fi microchip that includes a TCP/IP stack and microcontroller capabilities. The ESP8266 NodeMCU is a versatile device that combines some features of an Arduino board with the capability to connect to the internet, and it is manufactured by Espressif Systems [8].

2- Arduino UNO: The Arduino Uno is an open-source platform that utilizes simple hardware and software. It features a microcontroller board based on the ATmega328p microcontroller, developed by Arduino. cc. The board has six analog pins and fourteen digital pins that can be programmed by using the Arduino IDE and a USB cable. It can be work by an external voltage battery [9].

3- ESP8266 Wi-Fi Module: The ESP8266 Wi-Fi is a System-on-Chip (SOC) that integrates with a TCP/IP protocol, allowing the microcontroller to access any Wi-Fi networks. It is mostly used as an end-point for Internet of Things (IoT) applications and is considered a standalone wireless transceiver offered at an affordable price. The ESP8266 enables the connection of embedded systems to the internet. It can function as a slave or a standalone device. Also, when it works as a slave to the microcontroller host, it can act as a Wi-Fi adapter for the microcontroller through UART or SPI, but when it is used as a standalone application, it will provide the roles of both a microcontroller and a Wi-Fi network [10].

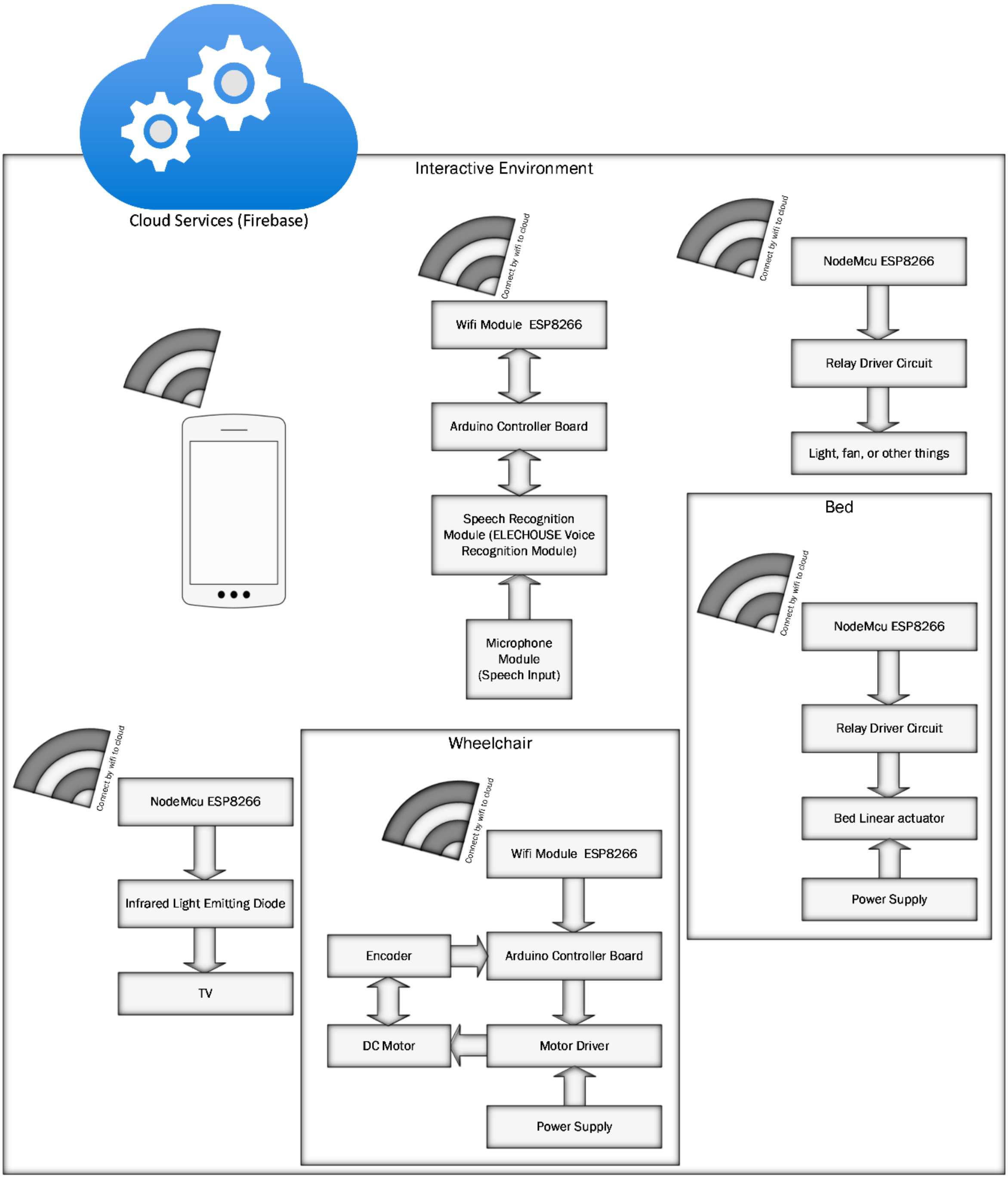


Figure 1: block diagram of system design.

4- Voice Recognition Module: This is a speaker-dependent technology that can identify up to 80 voice commands, with a maximum of seven commands working simultaneously. To use it, the module must first be trained to identify exact voice commands, each of which can be a maximum of 1500 ms of speaking. It requires a voltage range of 4.5V to 5.5V [11].
5- Relay: A relay is an electronic switch that can turn devices on and off, like lights and fans. It is composed of an electromagnet and a contact package [3].
6- Linear Actuator: is a device that generates motion in a straight line and is used for precise, reliable movement. It is typically powered by an electric motor [12]. It will be to adjust the bedback position by the microcontroller.
7- DC motors: DC motors are the most widely used actuators among all others, largely due to their high efficiency, impressive speed torque capabilities, and wide availability in the market.

Additionally, there is a vast range of DC motors available, making them ideal for various applications [7].
8- Encoder: The magnetic encoder counts the pulses produced during the rotation of the DC motor [7]. It will be used to measure the rotational speed, angle, and acceleration.
9- L298N Motor Driver: The L298N motor driver is a high-power module for controlling DC motors and can work with up to 4 DC motors or 2 DC motors with directional and speed control. It contains an L298 motor driver IC and a 78M05 5V controller [7].

3.1.2 Software Implementation

The software application that is used in the proposed system is:
1- MIT App Inventor: MIT App Inventor is a user-friendly, visual programming platform maintained by the Massachusetts Institute of Technology (MIT) that allows users to make fully functional applications for Android/iOS phones [13]. With its graphical interface, users can construct apps by simply dragging and dropping visual elements, making testing and debugging immediate and effortless.
2- Firebase: Firebase is a hosting service for different types of applications, such as Android, iOS, JavaScript, and more. It provides real-time hosting for databases. Firebase Arduino is a library that makes it easy to connect to the Firebase database from Arduino devices. The library provides a full abstraction of Firebase's REST API through C++ calls and takes care of all JSON parsing. It makes it possible for users to deal with pure C/Arduino data types [14].

3.2 Operation of the Proposed System

The proposed design that is illustrated in the algorithm, which is shown in Figure 2, begins with waiting for the voice order from a patient. As a start, the first command represents the chosen device that the patient wants. Directly When the command is received, the system will recognize and compare the command with what it has been previously trained on (stored words). Then, the system will have access to that device according to the patient's voice (e.g., a wheelchair). Now, the system will wait to take the next order from the patient to apply the type of control to the device (such as front, back, left, or right). Also, the patient can change to another device by calling 'Hi Kan' (if he uses English words). The flowchart shown in Figure 3 explains the method of operation of the control unit based on voice commands, which have been programmed using both Arabic and English.

Algorithm 1 A Voice Control Unit for Assistive Technology

```
function OPERATION
    while True do
        take_voice_order ← inputsound()
        if take_voice_order is not null then
            if take_voice_order == HiKanWord() then
                take_voice_order ← inputSound()
                Delay(3000)
                if take_voice_order == WheelChairWord() then
                    while True do
                        take_voice_order ← inputSound()
                        Delay(3000)
                        if take_voice_order == OnWord() then
                            WheelsOnPin()
                        else if take_voice_order == OffWord() then
                            TurnWheelsPinOff()
                        else if take_voice_order == frontWord() then
                            RunWheelsForwordPin()
                        else if take_voice_order == HiKanWord() then
                            break
                                ▷ Add other conditions for different commands...
```

Figure 2: The algorithm for the proposed system.

4. Results and Discussion

4.1 Propose model

The suggested system will be activated and controlled according to the user command that has been previously trained using the Voice Recognition Module, as shown in Figure 1. The Arduino board will act like the brain by connecting it to an ESP8266 Wi-Fi module, which in turn will be connected to all of the nodes, establishing a Wi-Fi network to provide access to several devices, such as the wheelchair, bed, TV, lights, fan, and bell. The system provides another option to control devices through the use of mobile applications. The training command will be recorded based on the tone of his/her voice, the way of pronunciation, and the language. The system is programmed in both Arabic and English. By using the keyword (Hello Kan), the system will start running, and then the user will choose or pronounce the name of the wanted device. for example, changing the bed angle, whether it's horizontal, inclined, or vertical, and if the user desires to switch devices, it is done by simply resaying the keywords (Hello Kan) in either Arabic or English. Table 1 shows the ten trials that are taken for each voice command, two distances (0.2m and 0.5m), and under quiet and noise conditions.

Table 1: voice command testing result using English and Arabic words

Environment	Quiet		Noise			Environment	Quiet		Noise	
Distance Voice Commands (Arabic)	0.2 M	0.5 M	0.2 M	0.5 M		Distance Voice Commands (English)	0.2 M	0.5 M	0.2 M	0.5 M
Hallo Kan	10	10	10	8		Hi Kan	10	9	10	7
Kursi	6	3	5	3		Chair	10	10	10	8
sareer	10	10	10	10		Bed	10	8	10	7
Telfaz	10	4	8	2		TV	10	9	9	9
dhwaa'	10	10	10	7		Light	10	5	10	5
Tshgheel	9	9	9	5		On	10	10	10	8
Etfaa'	10	8	7	3		Off	10	9	9	8
Amam	10	8	7	2		Front	10	6	4	2
Khlf	10	10	6	2		Back	10	10	5	1
Yassar	10	9	5	1		Left	10	9	6	1
Yameen	8	6	6	1		Right	10	8	5	1
Tali	10	10	3	3		Next	10	7	5	2
Alli	10	10	6	2		High	10	10	5	4
Nasi	10	8	6	3		Low	10	10	7	7
Amoodi	10	10	8	4		Stand	10	10	6	4
Maell	10	10	6	6		Tilt	10	8	4	2
Afoqi	10	9	3	1		Recline	9	9	5	2

The testing was done by taking into consideration the following aspects: the sensitivity of the devices to voice commands, the distance of the microphone, the surrounding noise, and the language used. Tests showed that the response decreases as the distance from the microphone increases, as well as when ambient noise increases. As for the matter of choosing the command words, the shortest the better, either for Arabic or English, this will increase the sensitivity of the response, as shown in Figure 4. Therefore, using common words with the patient will give better results. For example, as an alternative to saying (horizontal), (vertical), and (tilted) to control the bed's angle, the words (one), (two), and (three) can serve the same purpose for adjusting three levels.

4.2 Comparison System

The proposed system was compared with previous work [5] to test its efficiency as well as to clarify the new things that were added to the proposed model. Table 2 displays the advantages that the proposed model has over previous work, and Figure 5 displays the percentage response to words, indicating that the proposed model responds to words better. As for the "forward" word ("front" in the proposed model), this can be addressed as previously explained in 4.1.

Table 2: The advantages of the proposed model over previous work

	Propose system	Previous work
Support many languages	Yes	No
The number of words trained on	17 words for English 17 words for Arabic	Just 4 words for English
Supports controlling many devices	Yes	Just wheelchair

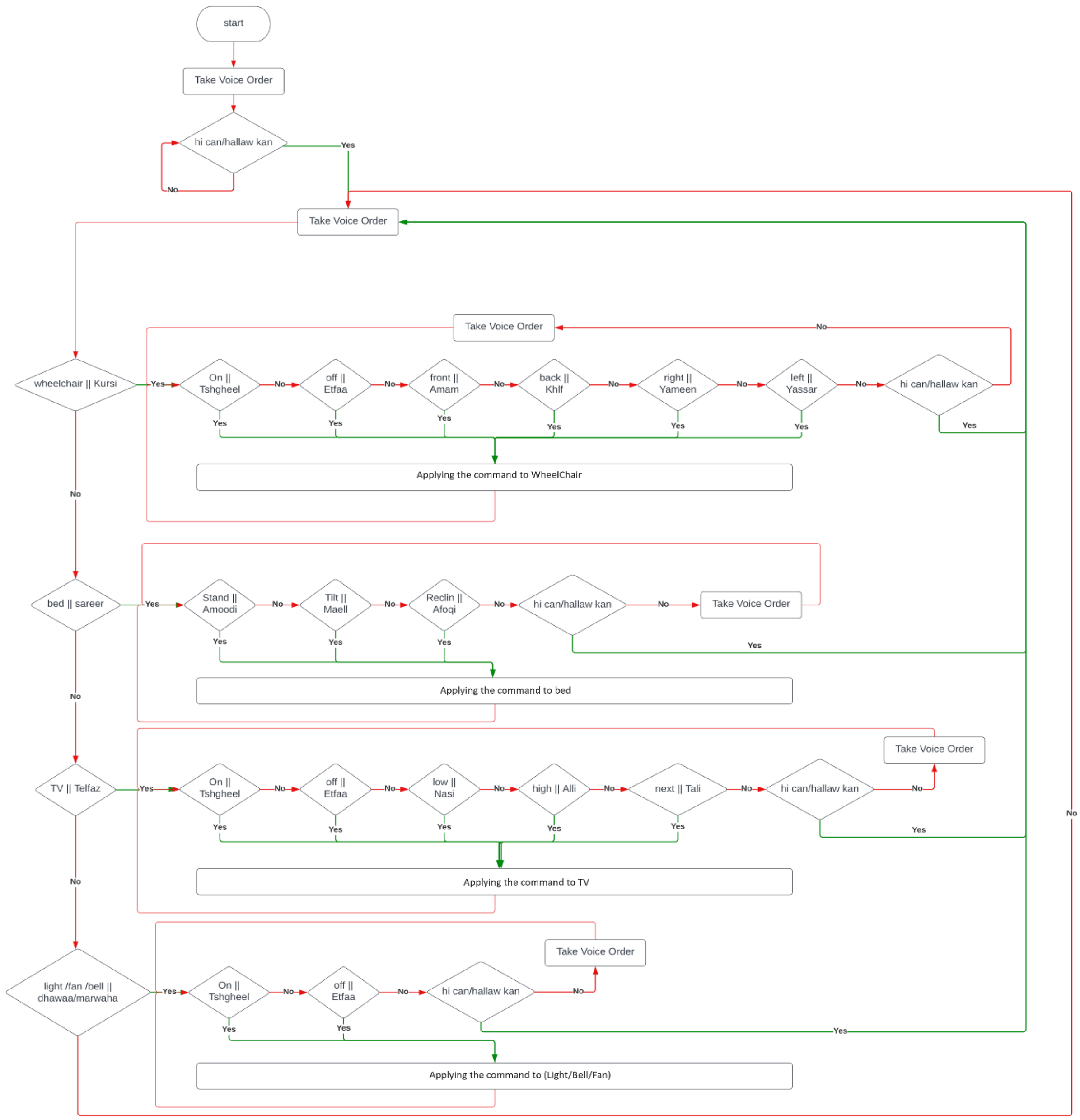
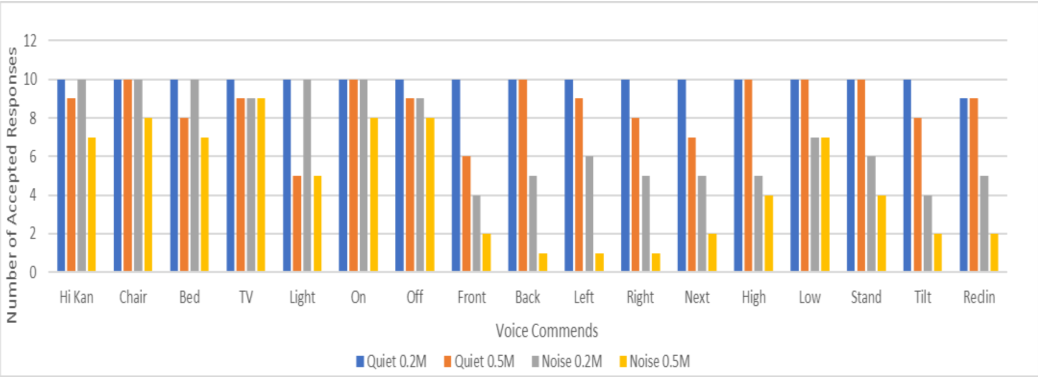
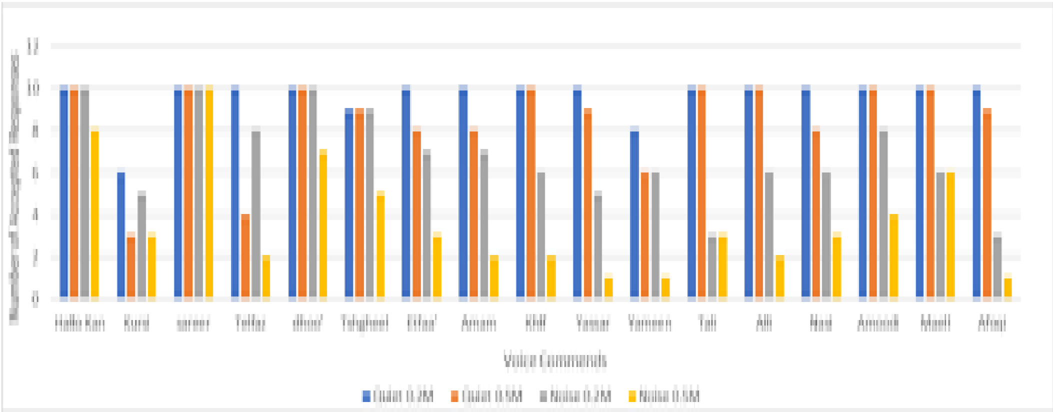


Figure 3: Flowchart of the control unit.



a)



(b)

Figure 4: The chart of the command testing result using (a) English and (b) Arabic words.

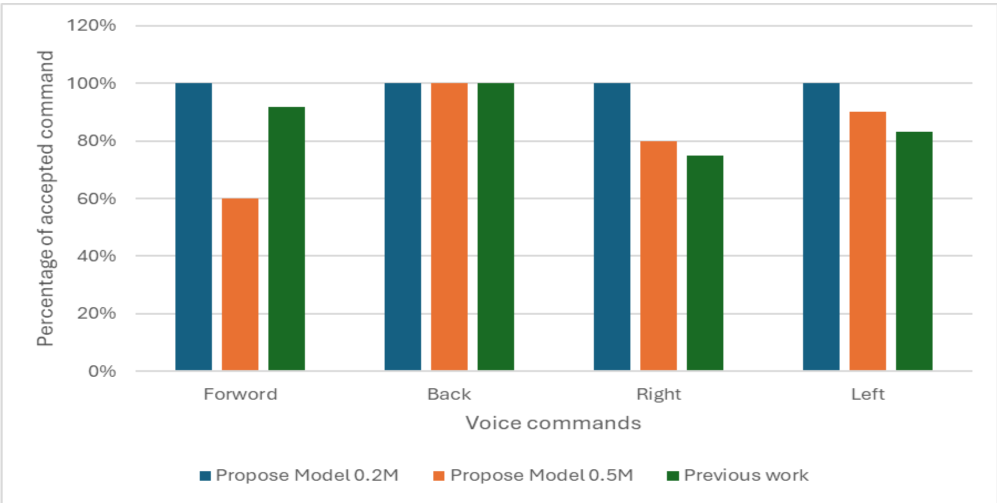


Figure 5: the percentage response to words between the proposed system and previous work

5. Conclusions and Future Scope

The suggested system in this research focuses on the software design and programming aspects in such a way that it creates an easy yet efficient control unit by testing the sensitivity of the patient's voice and the language used according to the surrounding environment. The sound unit is also trained and connected in a way that allows the user to easily control several devices according to his needs. As for the mechanical and electronic aspects of the hardware, more exact research is needed, especially for the matter of moving the electric wheelchair. Taking into account all the technical parts that are needed, the test of the responsiveness of the voice unit showed that the voice control tool is more acceptable and suitable for controlling devices such as televisions, fans, lighting, and the angles of the hospital bed. However, safe wheelchair movement necessitates a more advanced and precise voice unit, as well as the identification of the appropriate size and type of actuator, all of which require a more thorough investigation. This is what is proposed as a future study of this system in a practical way by building an integrated model.

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