Development of a Voice-controlled Intelligent Wheelchair System using Raspberry Pi

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***Abstract*—This paper proposed a voice recognition-based intelligent wheelchair system for physically disabled people who unable to control the wheelchair by their upper and lower limbs. This development employs voice command to controls the movement of the wheelchair in different directions. The android device is used as microphone to be connected to the Google Assistant prior to data processing by the Raspberry Pi. The Raspberry Pi will then command the servo motors to act accordingly. This system offers automatic obstacle detection via the use of an infrared sensor which aids the user to apply momentary brake button upon the obstacle detection. The proposed development has been evaluated in terms of movement accuracy and system responsiveness upon the commands given, in both control mode i.e., voice controller and joystick controller. For the movement accuracy, the results indicate that the minimum accuracies are 90% and 95% for the voice recognition controller and joystick controller, respectively. For the system responsiveness, the system response in less than 1.2 seconds for the voice recognition controller and less than 0.65 seconds for the joystick controller. With this noticeable performance, the intelligent wheelchair enables users with limited control over their limbs to maneuver the wheelchair using voice commands.**

Keywords- voice command; Intelligent; Android devices; Infrared sensor; Google Assistant; Raspberry Pi.

I. INTRODUCTION

Paralysis is a losing strength or control over the muscle or any group of the muscle in a part of the body. Most of the time, it may not a problem with the muscle themselves but it more likely a problem somewhere along the chain of nerve cells that runs from the part of the body to the brain. This kind of disease can be categorized into many conditions of paralysis. One of them is partial type of paralysis, it is the type of paralysis that it still can control the muscle and in other word it calls “paresis” for the partial type of paralysis. Second, a complete type of paralysis when there is no strength at all to move all the muscle on the body. Paralysis can occur in any part of the body either at one part of the body or at a several of the body part.

One of the significant constraints occur to the paralysis patient is they barely move and need to use a wheelchair to move from one place to another. Nowadays, there is a wheelchair that incorporates a controller to control the wheelchair. This kind of wheelchair able to help paralysis patients to move around especially who have limited control over their lower limb but have a functional upper limb. However, the use of this kind of wheelchair remains a remarkable limitation to those who had problem with both of their limbs. Consequently, the voice recognition based intelligent wheelchair system is proposed. This intelligent wheelchair is designed in such a way that it can be controlled with voice commands as well as provides safety feature from obstacle collision.

The main aim for this system is it able to recognize speech with highest possible accuracy. Speech recognition is the conversion of the speech words in spoken language into machine-readable form. Speech recognition incorporate in this intelligent wheelchair is performed in which when a command is acted verbally (forward/reverse/left/right/stop), the system will follow the command accordingly [1]. The notable innovation done in this system is it integrates both voice-controlled and controller-controlled to maneuver the wheelchair. The development of the system using infrared sensor, joystick control, Raspberry Pi, Google Assistant, servo motor and android device as microphone is discussed in this paper. The system performance between voice controlled and controller controlled is also examined.

II. RELATED WORKS

The development of assistances tool that able to aid disable people in their daily routine has gradually rising interest among the researchers with numerous approaches have been explored. In 2019, Gulati et al. has innovated an intelligent car as a personal assistance to the disabled people by using the Raspberry Pi [2]. The development employs Alexa as a speech system. The speech signal that came from the Alexa will give the necessary signal to the nodeMCU, which will control the relevant machine. Meanwhile, M. Nishimori et al. has developed an intelligent wheelchair using Raspberry Pi [3]. Google API (speech to text) has been used for voice recognition. The system uses the speech synthesis as a vocal response that sent to the Raspberry Pi.

On the other hand, in 2012, Ismail et al. has developed an innovation to set the qibla for the people to do their salah (prayer) [4]. Global Positioning System (GPS) and also digital compass are used as an input to set the direction of the qibla. Ishak et al. has developed the qibla determination by using the vector algebra [5]. In this development, a comparison between vector algebra and the spherical trigonometry has been conducted. Vector algebra has been discovered to offer more accurate result and easier to understand without require any high mathematical knowledge. The outcomes from both [4] and [5] enlightens the authors to incorporate sensor as safety feature in the proposed project.

III. System Overview

This section is dedicated to the development of intelligent wheelchair system. Each of the phase involved in the system development is thoroughly discussed.

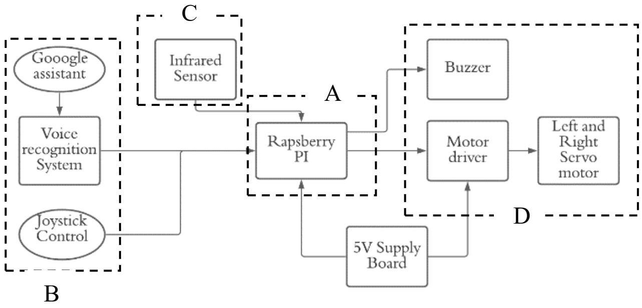

Fig. 1. Overall System Design

The overall system of the intelligent wheelchair is shown in Figure 1 above. Raspberry Pi is the main processor that act as an interface between the input and output. Smartphone application is used as the microphone where the received voice commands will be recognized and sent to the Raspberry Pi. Upon receiving the command, the Raspberry Pi will react to activate the corresponding motor such that the wheelchair can either go forward, backward, left, right or stop.

In addition to that, infrared sensor is employed to sense the obstacle that located 2 feet from the wheelchair. If obstacle distance is more than 2 feet, the wheelchair moves according to the initial command. Otherwise, the wheelchair will stop. The ultrasonic sensor will stop working upon the command "stop" by the user. This is the safety feature of the project to avoid the user from obstacle collision. Last but not least, the use of buzzer is to give the signal to the users that the command has successfully been processed in the system.

A. Main controller of the system

From Figure 1, the main controller of the system (i.e., Raspberry Pi) is labelled as A. Raspberry Pi is one of the devices that have a similarity with a computer's capability. This credit card size computer possesses a CPU of 700MHz, 512 MB RAM with 4 USB Ports, Ethernet, WIFI, Audio output and also HDMI for display purpose.

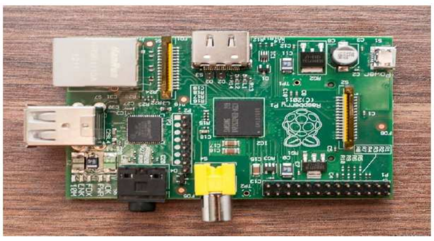

Fig. 2. The Raspberry Pi Model B [3]

In this project, Raspberry Pi is used to execute the output coming from speech recognition system (B) as well as the obstacle detection (C). Speech recognition can be performed by various platform such as CMU Spinx, Iphone SIRI and also by using Google API [3]. As for the proposed project, Google API has been chosen. Furthermore, the external GPIO pins of the Raspberry Pi are connected to infrared sensor and H-Bridge. GPIO is used as communication with the external device.

B. Controller

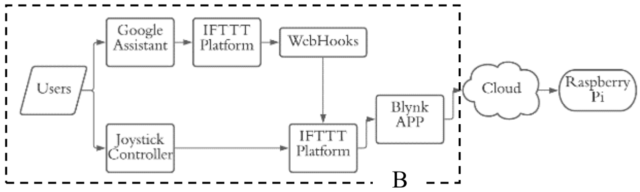

Fig. 3. The overall system of the controller

From Figure 1, the controller is labelled as B and the block details is illustrated in Figure 3. Note that the recognized speech is one of the inputs to the Raspberry Pi. The execution of this system begins with the verbal command from the user (either forward/reverse/ left/right/stop) to the Google Assistant and this command will be passed to IFTTT (IF This, Then That). IFTTT offers a platform where a number of services can be assimilated to provide solution in the realm of IoT [2]. Then, from the IFTTT, it will go to Webhooks. It is a service that will translate the previous uttered command stored in the Google Assistant into a https protocol request. A WebHooks is the services that can called back the Hypertext Transfer Protocol (HTTP) whenever there is an action triggered in it [2].

The https protocol request is directed to the Blynk cloud's Internet protocol address. Blynk cloud is the fastest and the lightweight service cloud which is secure and scalable. This service able to manage any request from the IFTTT to be interpreted. In addition, this service also can run any server in term of environment, dedicated business and also locally for being in open source [8].

C. Safety Feature

From Figure 1, the safety feature is labelled as C. It uses infrared (IR) sensor to detect the object within the distance of its radiation. The detection initiated when the transmitted beam detects the object and this beam being reflected to the receiver. The received signal then will be fed to the Raspberry Pi. The working principle of the IR sensor is known as triangulation method as depicted in Figure 4 [6].

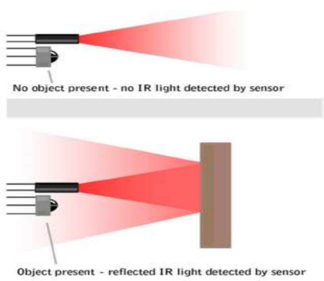

Fig. 4. The working of IR sensor [6]

The infrared sensor is used as the distance measure sensor in this project.

D. Visible Output of the system.

From Figure 1, the visible output of the system is labelled as D. This part consists of three components which are motor driver, servo motor and also the buzzer. Each of them has their own task according to the input fed to the Raspberry Pi. The servo motor cannot be connected directly to GPIO pins of Raspberry Pi. Hence, the use of motor driver (H-Bridge) is essential as an interface between Raspberry Pi and the servo motor. Lastly, the buzzer used to send a signal to the user that the command has been successfully process.

I. Motor Driver (H-Bridge)

The H Bridge motor driver (as shown if Figure 5) is a 16 pin IC which can control a set of two DC motor to operate simultaneously in any direction. This motor driver has a maximum current rating 14A continuously with 5.5-16 Volts and the maximum frequency is 20KHz. This motor driver is connected with the Raspberry PI GPIO by using the Opto-coupler and this Opto-coupler circuit acts as protection to the Raspberry Pi [3].

The motor driver has two enables pins that can be connected to the motor [7]. Pin 1 and Pin 9 are the pins that need to be connected to the motor so those pins need to be high. If one of the pin turns to low condition, it will suspend the current flow to the motor.

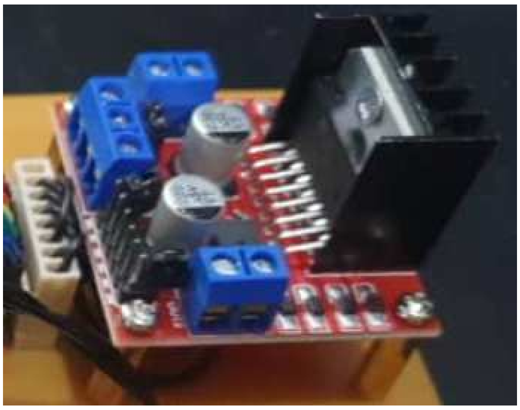

Fig. 5. The motor driver (H Bridge)

II. Servo Motors

In this project, two servo motors are used to move the wheelchair. They were mounted to the left and right of rear wheel to control its direction. Each motor (as shown in Figure 6) can handle maximum weight up to 5 -8 kg which is fit as prototype development. The output of the motor is 300 rpm, and the input is 6-12 volts. Meanwhile, the stall currents are 500-600 mA [7].

Fig. 6. The Servo motors that connected to the wheels [7]

IV. EXPERIMENTAL AND RESULT

This section focuses on the series of experiment that have been conducted throughout the development of intelligent wheelchair. The experiment includes an investigation on the accuracy and responsiveness of the system towards the command given by the user, in both control mode i.e., controller and voice command. Thenceforth, comparison between the proposed project and other related project is also conducted to emphasize the attribute of each system. The final product of the developed prototype is also presented in this section.

A. The action accuracy and the responsiveness of the development.

The accuracy of the system is measured on how fast and adhere to does the wheelchair toward the commands from the user. Therefore, several tests had been conducted to the intelligent wheelchair to access its responsiveness.

TABLE I. TABLE FOR AVERAGE TIME FOR 30 TIME TEST VS THE COMMAND DIRECTION

Direction\Method	Voice Recognition (Sec)	Joystick Controller (Sec)
Forward	1.193	0.637
Reverse	1.124	0.558
Left	1.169	0.427
Right	1.121	0.576
Stop	1.134	0.328

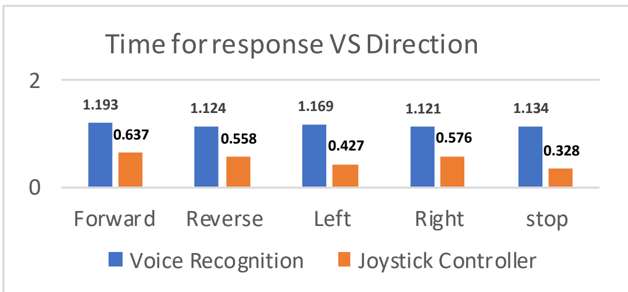

Fig. 7. The average time taken to response VS the direction command

Table I and Figure 7 shows the time taken by the wheelchair to follow the commands in both control mode. The system is tested for 30 times in various direction and average duration is calculated. It is found that the voice recognition mode takes longer times to respond to the command compared to the joystick controller. Nevertheless, the voice recognition mode can be deemed as reliable system as the average duration taken is less than 1.2 second. In addition, the measurement obtained in both Table I and Figure 7 also demonstrates high precision of the data.

TABLE II. PERCENTAGE OF THE SUCCESSUL COMMAND IN 30 TIMES TESTING

Direction\Method	Voice Recognition (%)	Joystick Controller (%)
Forward	90	95
Reverse	95	100
Left	98	99
Right	98	99
Stop	99	100

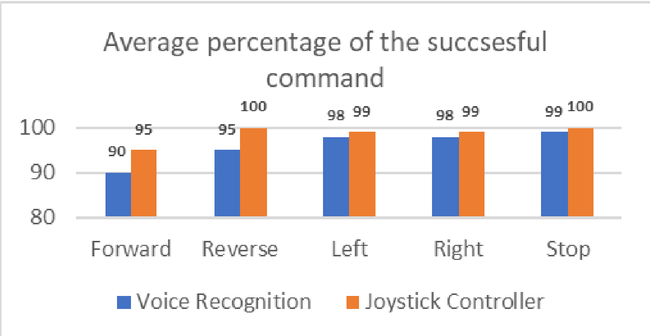

Fig. 8. Percentage of the successful command in 30 times testing

On the other hand, Table II and Figure 8 shows the percentage of the successful command for both control mode. The system is tested for 30 times in various direction and the responses of the wheelchair towards the commands are recorded. The measurement shows that the voice recognition mode unable to surpass joystick controller performance, with slight discrepancy. The joystick controller possess better accuracy due to direct communnication between the transmitter and receiver. In addition, the performance of joystick controller is independent of the surrounding environment i.e., noise etc.

The response of each motor toward the user command for each direction is tabulated in Table III. Both motors will move forward upon the command “Move forward” by the user. Both motors acted accordingly upon the command “Stop” where they will be in the static condition. Meanwhile for “Move right” command, the right motor will move reverse and the left motor will move forward to direct the wheelchair to the right. “Move Left” command utilize the same working principle as “Move Right” with alternate condition of each motor. This time, left motor will move reverse, and the right motor will move forward. Hence, the wheelchair will turn to the left. Besides, the motors will immediately stop when the infrared sensor detects the obstacle in the wheelchair’s pathway. The wheelchair remains in static state until the obstacle has been removed or new command is uttered.

TABLE III. THE COMMAND AND THE RESPONSE OF THE PROJECT

User command to the google assistant	Left-motor condition	Right-motor condition	Result
Move forward	Move forward	Move forward	Move forward
Move right	Move forward	Move reverse	Move right
Move left	Move reverse	Move forward	Move left
Stop	Static condition	Static condition	Stop
Move reverse	Move reverse	Move reverse	Move reverse

B. Comparison between development

The comparison between the proposed system, voice controlled intelligent wheelchair and joystick controlled intelligent wheelchair is conducted to point out the attribute of each system as shown in Table IV.

TABLE IV. COMPARISON BETWEEN INTELLIGENT JOYSTICK-CONTROLLED WHEELCHAIR AND THE VOICE CONTROLLED INTELLIGENT WHEELCHAIR USING RASPBERRY PI [8]

	Intelligent Joystick Controlled wheelchair	Voice Controlled Intelligent Wheelchair
Main Controller of the system	Arduino	Raspberry Pi
Type of controller used	Joystick Controller	Voice Recognition and Joystick controller
Safety feature	No	Yes
Type of motor used	DC Motor	Servo motor
Costing	Moderate	High

From the comparison conducted, the cost incurred for the proposed system is higher compared to the joystick-controlled wheelchair. Nevertheless, the proposed system offers better features such as dual-mode controller and also safety protection via the use of infrared sensor.

C. Prototype

Figure 9 shows the final product of the prototype for the voice controlled intelligent wheelchair system.

Fig. 9. The developed prototype of the wheelchair.

V. Conclusion

In this paper, the voice controlled intelligent wheelchair with obstacle detection feature is developed. The experimental results of more than 90% accuracy and less than 1.2 second of response supports that it is a reliable system to be used by disable people. The dual-controller mode also emphasizes its significance to the user with limited control over their lower limb or both limbs. This wheelchair also a user-friendly system as it can be controlled without any prior training and limitation of user.

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