Wireless Voice-Based Wheelchair Controller System

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***Abstract*—In this paper, we present our work called wireless voice-based wheelchair controller system, which consists of an Android device and a control system that controls the movement of wheelchair using a DC motor. This project is aim to ease the burden for wheelchair user especially for elderly people to move around. The control system is build using the Yo-Yo (IOIO) platform that controls the DC motor, communicates with the Android phone application using RF receiver through a Bluetooth communication protocol and RF signal. The Android application is developed using Basic-4-Android (B4A) rapid development tool connected with one main control interface using voice command, D-pad and joystick to control the motor driver MD30C direction and speed through IOIO platform based on four conditions; forward, backward, right and left. The speed movement is controlled by Pulse Width Modulation (PWM) signal while the direction movement for Qibla' is generated by the control interface and guided by an electronic compass in the Android device. While there are some limitations in the cost and direction movement, the concept developed in this project are proven convenience innovation and provides better benefits to the targeted market and public interest.**

***Index Terms*—Wheelchair; Android; IOIO Platform; Voice Control; Bluetooth.**

I. INTRODUCTION

Since past 20 years, electric-powered wheelchairs (EPWs) have been frequently deployed and developed because it has a pivotal role to improve the quality of life for the elderly and disabled people. Recent developments in smart wheelchair have heightened the need for smart control system such as hand-propelled wheelchairs, electrically controlled wheelchairs and automated-guided wheelchairs. For this reason, [1] had developed an autonomous robotic wheelchair controller using embedded system that includes the techniques of obstacle sensing and avoidance, local path navigation and user friendly interaction compare with the conventional powered wheelchair [1]. [2] had developed a Nintendo Wiimote controller wheelchair to facilitate impaired people, which they need an additional attention by people around them while bridging the gap between human-computer interaction and embedded software engineering [2].

[3] designed a system that operated with digital wheelchair controller that depicts an information flow between the driving commands and wheel speed constructed through the following steps; command decoding, speed estimation and speed serving [3]. A controller using parameter self-adjusting fuzzy PID developed in 2009 to control wheelchair speed deviation and changes in the rate of deviation which is applied to DC motor speed control system to achieve optimal control for the wheelchair [4]. An ultrasonic sensor combined with fuzzy controller wheelchair for obstacle avoidance is proposed [5] in order providing more autonomous navigation in unknown environments. [6] had developed the Qibla' smarts wheelchair to find the Qibla' direction, guided by electronic compass in Android device besides controlling two home electrical appliances; lamp and fan.

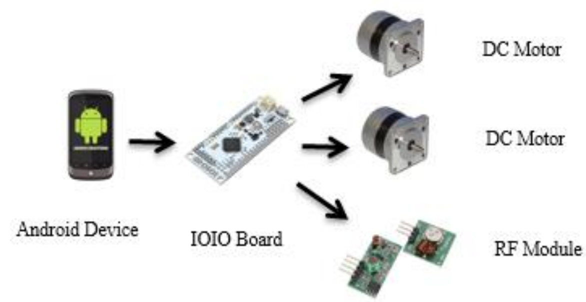

Figure 1: Project Flow Diagram

This project is developed as an assisted technology in wheelchair development that provides a new method to control the movement of wheelchair using main voice control and two back up control; D-pad and joystick [7]. Low cost DC motor, motor driver module and microcontroller; Yo-Yo (IOIO) platform used in this project instead of digital or fuzzy PID controller to minimize overall project cost with predicted good control movement performance as shown in Figure 1. This control system are integrated with Android control interfaces. There are four movement conditions designed in this controller system; going forward, going backward, going to the right and going to the left. Two type of communication protocol used in this design; Bluetooth and Radio Frequency (RF) where the Bluetooth protocol used to communicate between the Android device and the control system while RF used as communication between IOIO platform and home electrical appliance features [7]. The rest of this paper is organized as follows. Section 2 describes the methodology of this project. Section 3 elaborates the result and discussion. Section 4 concludes and suggests a few new ideas in the development of electronic wheelchair.

II. METHODOLOGY

There are four phases in voice-based wheelchair control system; 1. Circuit design, 2. Software development for

Android controller interfaces, 3. Hardware development for IOIO platform and DC motor, 4. Project analysis and evaluation.

A. Control System Circuit Design

In the first phase, the circuit for this controller system is designed based on the combination of IOIO microcontroller with two motor drivers (MD30C). The Pulse Width Modulation (PWM) output configuration in IOIO microcontroller is connected with the MD30C motor drivers PWM input for the speed movement along with the DIR pin that used for wheelchair direction. There are three types of power supply used in this system. This control system is designed to use power supply range from 5V to 15V based on IOIO platform voltage input. The ideal power source for the IOIO platform voltage input is the LIPO battery 7.4V 900mAH due to it is lightweight battery and it can supports low ampere supply, suitable for any mobile and low power application. The second power source is the power supply for DC motor using rugged 12V sealed acid lead battery connected to the input power pin of motor drivers. The third power supply is used to operate the RF receiver using external 12V DC power supply.

B. Android Controller Interfaces

The second phase of this project is the software development to develop the user interfaces and control interfaces on the Android device using Basic4Android. Basic4Android is a rapid application development tool for native Android applications. B4A is used to develop Android application to control the movement of wheelchair and to turn on or off electrical appliances. Figure 2 shows the B4A user interface desktop view. The voice control interface is developed with implementation of Google voice API. Google Voice is a free service that brings a number of telecommunication features such as voice messages can be recorded and transcribed to a text [8], which it is becomes an important feature in voice control interface. The wheelchair will move forward, backward, to the right and to the left as according to the voice command that we set in the voice setting. Figure 3 shows the sample code of voice command in B4A.

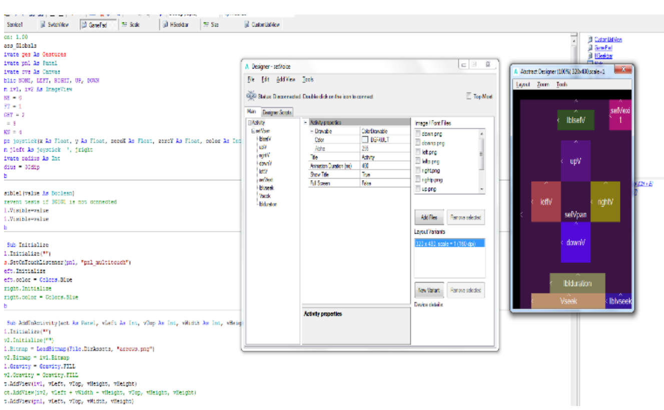

Figure 2: B4A software

```
Sub    btnV_CheckedChanged(ProgressButton2    As    ProgressButton,
IsChecked As Boolean)

        If IsChecked Then
        btnV.CircleColor = Colors.Gray
        btnV.Progress = 0
        VR.Prompt = "Voice Control"
        VR.Listen
        vcheck = 0
        btnV.Checked = False
        btnV.Max = vcount
        End If

End Sub
```

Figure 3: Voice command in B4A

In the Android device, the D-pad and Joystick control have been developed as a backup controller for voice. These controllers built with a speed controller. The Android device also controls the home electrical appliances based on ON or OFF button to control the lamp and fan. In this part, IOIO platform is using the 434MHz RF transmitter and receiver connected with the relay circuit. By sending command of "AR+FCMT" and "AT+FSCT" to the controller wireless module, the module will be working in toggle mode. The configuration of the RF module is shown in Table 1.

Table 1
RF module configuration

Input	Output	Operation
0	0	Initial State
0	1	Toggle
0	0	Toggle
0	1	Toggle

The switch works independently, we can turn ON switch one and switch two together or switch one ON and switch two OFF. Table 2 shows the switch button icon when the switch is pressed and when it is not pressed. The color is black when the switch is not pressed and it will become green when the switch is pressed.

Table 2
Icon to indicate switch that is active and inactive

Inactive	Active
① ②	① ②

In Qibla' compass, the scale ranges from 0 to 400, but the reading in our orientation ranges from 0 to 360. Thus, calculation is required to obtain the Qibla' direction in degree.

$$Qibla'\ (degree) = 360 - \left(\frac{360^0}{400}\ x(State\ in\ Qibla'\ Division)\right) \tag{1}$$

Example calculation for Johor State:

$$Johor\ Qibla'\ (degree) = 360 - \left(\frac{360^\circ}{400} \times (80)\right)$$
$$Johor\ Qibla'(degree) = 288^\circ \tag{2}$$

288 are the initial value used as the reference value in the program. Table 3 below shows the list of Malaysia's state and its corresponding in Qibla' direction in calculated degrees.

Table 3
Icon to indicate switch that is active and inactive

State	Degree (°)
Johor, Melaka, Negeri Sembilan & Selangor	288
Kuala Lumpur, Pahang, Perak, Terengganu, Kelantan, Perlis, Kedah, Pulau Pinang & Sarawak	283.5
Sabah	279

The Android device orientation sensor must first to be calibrated, by swinging the phone in number 8 direction two or three times before it can be used to determine the direction of the Qibla'.

C. IOIO and DC Motor Implementation

There are two parts in this phase; IOIO firmware and DC motor. The IOIO firmware is installed in the development control board with two on-board motor drivers and the RF transceiver module as shown in Figure 4. The IOIO firmware needs to be upgraded using the MPLAB X software in order to communicate with Android device using Bluetooth protocol.

Figure 4: Voice control wheelchair

After the firmware has been loaded, changes must be verified. The Bluetooth and the IOIO platform have been plugged and powered ON. In Bluetooth manager, IBRAHIM (BF: EB) BF: EB can be seen by referring to the last Bluetooth mac address. Then, the device pin has been inserted and clicked. Figure 5 shows that IOIO platform has been successfully connected. Then, test.apk of B4A is installed into the Android device to test run the application. When the IOIO LED is turned on, it shows that the Bluetooth has been paired with the IOIO platform.

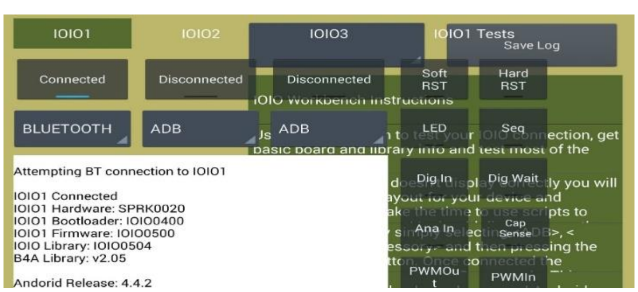

Figure 5: Bluetooth has been paired

The RF transceiver module and relay output have been developed to control the home electrical appliances from the Android device. It is tested within the 30-meter range and working well without any faulty. Relay will acts as a switch to TURN ON or OFF for the home electrical appliances. The 12V 7AH sealed acid battery has been placed into the designated battery box, connected with motor drivers using high ampere 2.5mm multi-core wire. PWM signal has been configured in the IOIO platform so that the speed of the motor can be controlled.

D. Analysis & Evaluation

In order to validate and verify this project meets the requirement and the design, a number of test mechanisms have been applied which are the Design Verification and Performance Test.

a) *Design Verification*: The objective is to ensure that an application conform to its original design that outline the original requirement which are the UI design, control interfaces and Qibla' movement direction.
b) *Performance Test*: It is needed to ensure that this project is durable and does not experience related issues or problems when the wheelchair operated. The performance tests include the movement of the motor, the truth table for motor drivers, IOIO platform PWM output, battery performance analysis and ultrasonic sensor analysis.

III. Results and Discussion

A. Design Verification

Figure 6 shows the control type successfully added into the Android application which are Voice command, D-pad and Joystick. Voice command is the main control that lets to move the wheelchair based on voice message while in D-pad and Joystick controls, user needs to touch the button or slide the circle to move the wheelchair.

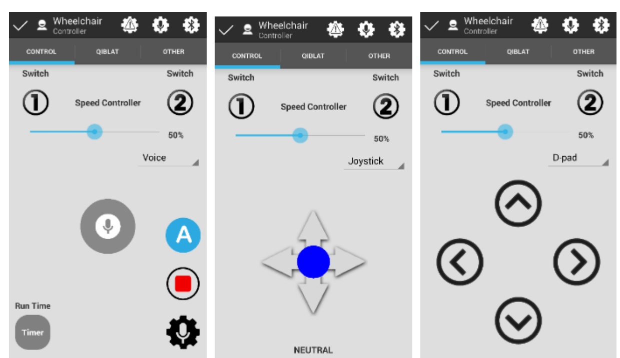

Figure 6: Voice, D-pad & Joystick control

The Qibla' application in the Android device builds the list of Malaysia states. The direction of Qibla' in Android device compared with the direction shown by the actual Qibla' compass to ensure the correctness of the direction of Qibla'. Android device with selected Johor state has been placed beside the Qibla' compass as shown in Figure 7. The Android device shows a value of 288.158140 with both needles of the Qibla' and Android device compass show almost the same direction.

Figure 7: Qibla' direction comparison

Magnetic field level in nature is about 49uT. If there are metals near the device, the value will be increased. Figure 8 sand Table 4 show the result when a metal is around the device, thus the value of magnetic field level increased to 132.81µT.

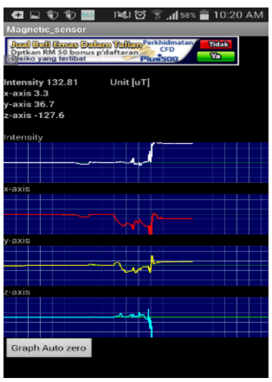

Figure 8: Reading when there is a metal near to the device

Table 4
Status of magnetic field

Value of Magnetic (µT)	Status
0-49	Magnetic field level in nature within tolerance
50-69	Phone is heating
More than 69	There is metal nearby

The application will shows a warning message to notify the user, the direction of Qibla' is inaccurate. The warning will be appeared when the magnetic level reached more than 50.

B. Performance Test

Wheelchair movement control test has been tested using a truth table analysis to represent the functionality of MD30C motor drivers. Pin 31 until pin 34 are used as DC motor controller pin. Table 5 shows the truth table configuration for MD30C.

The condition of wheelchair movement is checked based on the control button command where the result shows the condition is the same as assigned button command. The PWM analysis has been made to evaluate the motor driver performance. Figure 9 shows the measurement of 40% duty cycle of PWM using oscilloscope. The measurement result is 40.53% which is near to 40% value taken from the range of 10% to 90% indicates that the generated PWM duty cycle is within the specification.

Table 5
The truth table of motor driver MD30C

Command Button	Left Wheel Pin 13 (PWM)	Left Wheel Pin 17 (DIR)	Right wheel Pin 14 (PWM))	Right wheel Pin 18 (DIR)	Wheelchair Condition
	Duty cycle of PWM	0	Duty cycle of PWM	0	Forward
	Duty cycle of PWM	1	Duty cycle of PWM	0	Reverse
	1	1	1	1	Right
	1	0	1	1	Left
 Inactive button	0	0	0	0	Neutral

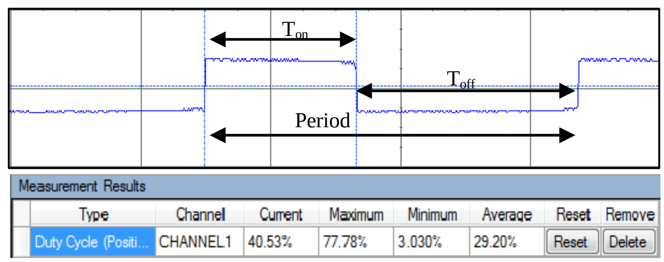

Figure 9: IOIO PWM duty cycle

In a battery performance test, a voltage divider circuit has been implemented to transform a large voltage into a smaller voltage. The input voltage of 50V to 0V is transformed to the output voltage of approximately 3.3V to 0V. Diode Zener used to prevent the output voltage from exceeding 3.3V in order to protect the IOIO analog pin from excessive voltage damage. The IOIO analog pin capabilities only measure voltage levels between only 0-3.3V.

Figure 10 shows the output voltage from simulation and test measurement comparison. It is observed that the voltage output from test measurement is slightly higher than the voltage output from the simulation. However, the trend line equation from the test measurement can be used in the B4A program as both voltage output vary linearly with voltage input.

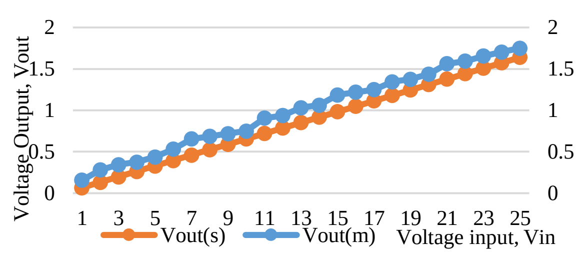

Figure 10: Vout test & Vout simulation vs. Vin

Three samples of voltage have been tested by using IOIO measurement. These results were compared with the voltage that had been obtained by using digital multimeter. It is observed that the result from the measurement that used IOIO measurement and the results obtained from the multimeter are almost identical.

An ultrasonic sensor has been used to detect obstacles ahead to prevent collision. The further away the distance of an object from the sensor, the higher the output voltage becomes mean while the closer an object is from the sensor, the sensor will produces a lower voltage. A distance test has been made for a measurement between 6 inches to 15 inches as shown in Figure 11.

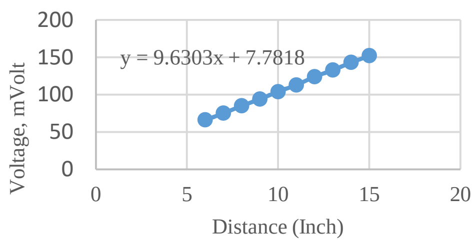

Figure 11: Voltage ultrasonic vs distance

The range within 0 inch to 5 inches produced an unstable output voltage. The output voltage for the similar range varies unpredictably, due to the sensor limitations to sense nearer obstacles.

The main objective of this project is to develop a voice-based smart wheelchair control using an Android device. An IOIO microcontroller platform has been used to communicate between the Android device and wheelchair instead of using a fuzzy or PID controller as in previous research. There are four movements that are being considered; forward, backward, right and left. Voice control moves the wheelchair to the desired direction based on voice messages that have been inserted into the voice settings. The voice control feature is the new element in the wheelchair control system development compares with the conventional control system.

The speed of wheelchair can be controlled by using PWM signal that is connected to MD30C. Previous wheelchair [7] research unable to control the speed of wheelchair using the Android device due to the software limitations, bug in up and down events of button in B4A designer contribute to only one direction at one time movement. When user releases the button, the wheelchair automatically stops. The speed of the DC motor is controlled by PWM frequency. This result of PWM analysis indicates that the PWM duty cycles are within the specification.

Another improvement has been made in the wheelchair movement is to find the Qibla' direction. There are three buttons in Qibla' application which are manual turn left, auto-rotate and manual turn right. The direction of the Qibla' from a certain location can be changed via a button. The function of Qibla' application is not only to show the current Qibla' direction, but also to change the direction of the wheelchair to face the direction of the Qibla'. Auto rotate button measures which direction has the shortest distance to the Qibla' direction, and it automatically rotates the wheelchair [6]. A manual rotation has been developed as an alternative which is to the left or to the right, and the wheelchair stops once it faces to the Qibla' direction.

RF transceiver used in this project as a communication module between wheelchair, lamp and fan because the transmission of RF is better than the infrared (IR). Furthermore, the signal transmitted through the RF, travels through a larger distance even when there are obstructions between transmitter and receiver. In previous research [6], the RF transmitter and receiver have a shorter distance of switching which is about 5 meters and only one switch can be turned ON at one time. The current RF transceiver can switch ON/OFF up to 100 meters range and independently; turn ON two switches at one time or turn ONE switch at one time.

IV. Conclusion

A voice-based control system that controls the movement of a wheelchair by using the B4A in Android device has been developed. The wheelchair consists of two 350W scooter DC motor, two module MD30C, IOIO platform, two RF transceiver module with two output relay, two 12 inches bicycle tires with modified sprocket and material. It can controls left, right, forward and backward movement by using three control interfaces; Voice Command, D-pad and Joystick. The speed of wheelchair movement can be controlled by using PWM signal. The Qibla' direction movement, guided by electronic compass in the smartphone can be controlled by auto or manual button. The Android device also provides home electrical appliance buttons to control the lamp, fan and the entire electrical appliances using RF transceiver module. The limitations in this project are only four movement directions and the total battery capacity used to transport user in the wheelchair. A larger and costly battery capacity needed if the user weight above 100kg thus significantly increased the cost and total weight of the wheelchair. While there are some limitations in the cost and direction movement, the concept developed in this project are proven convenience innovation and provides better benefits to the targeted market and public interest.

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as $\mu_0 H$. Use the center dot to separate compound units, e.g., "$A \cdot m^2$.

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