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Voice-Controlled Wheelchair with Heart Rate and Location Monitoring

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Abstract: Nowadays, various control methods have been implemented to the existing electric-powered wheelchair (EPW). For example, controllers using joysticks, hands, and heads are already available at a high cost. Unfortunately, disabled people with upper limb disabilities do not benefit from these control methods. The risk of injury to wheelchair users while navigating the wheelchair alone is very concerning as they exposed to a high risk of injuries or health issues. Therefore, a voice-controlled wheelchair system aims to provide independent and self-guided mobility for people with disability (PWD) who suffered limited freedom of movement while using a wheelchair. This thesis presents a prototype of a voice-controlled wheelchair with a heart rate and location monitoring system, where users can navigate their wheelchair using voice commands. The general health status and real-time location of the wheelchair user can be tracked via mobile phone application via Wi-Fi. Voice recognition module V3 is used to detect the user's command. It will direct the motor driver to move the wheels in the desired direction. The joystick controller is also available as an option to navigate the wheelchair's direction. The wheelchair system also offers obstacle avoidance using the ultrasonic sensor to ensure the wheelchair user's safety. The mobile phone application also has been developed using Blynk IoT, which offers a remote monitoring system that allows the user and caregiver to monitor the general health status and real-time location from mobile phone and website. Based on the experimental results, the voice recognition control system shows promising results, with the wheelchair navigation responding accurately to voice commands 96.69 % under ideal conditions with minimal noise interference. The monitoring system's heart rate sensor results indicate an average accuracy of 99.22 % when compared to a pulse oximeter and 97.07 % when compared to a Garmin smartwatch. When compared to the built-in phone GPS tracker, the GPS sensor used for the GPS-based location and route monitoring system showed acceptable precision results when operating under optimal conditions. The development of an actual wheelchair prototype-controlled system that utilises an ECG sensor to monitor heart rate will be considered for future work, since an ECG sensor can provide a more accurate diagnostic of the heart signal.

Keywords: Electric-powered wheelchair, People with disability, Voice Recognition module V3, Arduino Uno, Heart Rate, Location, Voice command

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1. Introduction

In Malaysia, there were around 30,070 people with disabilities (PWDs) over the age of 50 years who had difficulties to walk due to chronic diseases, for example, peripheral arterial disease [1] and osteoporosis [2]. An approximation of 50.00 % of the patients with chronic diseases are incurable and struggle to live independently [2] and need assistance from the caregiver. Along the line, around 20 million (10.00 %) of PWD's population in the world required a wheelchair in daily life for mobility [3].

In the last two decades, a wide range of support and care equipment has been developed to help the elderly and disabled use wheelchairs. However, although most wheelchairs are manually operated, electric wheelchairs (EPW) have received positive user feedback [4]. EPW is widely used and developed, especially for disabled persons who live freely, because it allows users to maneuver wheelchairs without assistance [5], [6].

There are various methods to control the EPW. For example, joysticks [7],[8], hands [9],[10] and heads [11] are already expensive. Sadly, upper limb impaired patients do not benefit from these control approaches [5]. The existing EPW interface may not allow genuine autonomous mobility for many PWDs [12]. The survey indicated that after receiving electric wheelchair training, 10.00 % of users could not or only very difficultly utilize their electric wheelchair for daily activities [12]. Many wheelchair users live independently.

Wheelchair users are nonetheless at risk of injury from pedestrian incidents in urban settings [4]. Thus, the EPW control system required to be thoroughly evaluated and designed to give users independent and self-guided mobility. This project will develop an innovative wheelchair control system for severely disabled people.

The voice-controlled wheelchair [5],[6],[11],[13],[14], has been developed to promote the mobility of the elderly and the disabled who are completely dependent on the wheelchair. This function is widely used in patients with spinal injuries and is easy to use [15]. However, this function requires clear pronunciation to activate and control the directions of the wheelchair [15].

An improved smart wheelchair with voice-controlled system is required, especially for PWDs and the elderly with severe upper and lower limb limitations [16]. This study intends to aid disabled people with motor or cognitive impairments who have sufficient sensory abilities to control the wheelchair independently. Its target users are the elderly and disabled who live alone. the elderly and disabled who live alone.

1.1 Objective

The objectives of this project are as follow:

- To develop prototype of electrical voice-controlled wheelchair with GPS system, obstacle detection and avoidance system.
- To develop mobile application for real-time monitoring of the user's wheelchair location andheartbeat.
- To analyze the accuracy and sensitivity of the voice recognition sensor, GPS and heartbeat sensor.

1.2 Scopes

- A prototype of wired voice-controlled wheelchair will be developed to control wheel directions of forward, backward, left and right.
- Real-time user's wheelchair GPS location and heartbeat will be updated wirelessly on the phone application to provide information for the user's caregiver.

2. Methodology

2.1 Block diagram of the system

Figure 1 shows the block diagram of the proposed system. The voice recognition module detects the customized voice command signals that has been pre-set in advanced via the mic. These signals were used to lead the direction and speed of the wheelchair. Other than that, the joystick is also available as a second option to control the direction of the wheelchair. An ultrasonic sensor is used for obstacle avoidance by detecting and calculating the distance between a wheelchair and obstacles. Then, the sensor will automatically stop the wheelchair system to avoid a collision from occurring. Arduino Uno majorly controls this system as the system controller.

At the same time, the ESP8266 Wi-Fi Module Node MCU use as standalone to control the monitoring system. Node MCU, well-known as an IoT platform's open-source, includes firmware that runs on the module. In monitoring system, the heart rate sensor model SEN0203 is connected to analog pin of the Node MCU and GPS Neo-6M to the digital pin of the Node MCU. The data signals from the sensors were processed by the Node MCU and stored in the Blynk Cloud through Wi-Fi. These data were uploaded and displayed in a graphical analytical form on a website and mobile phone application, Blynk.

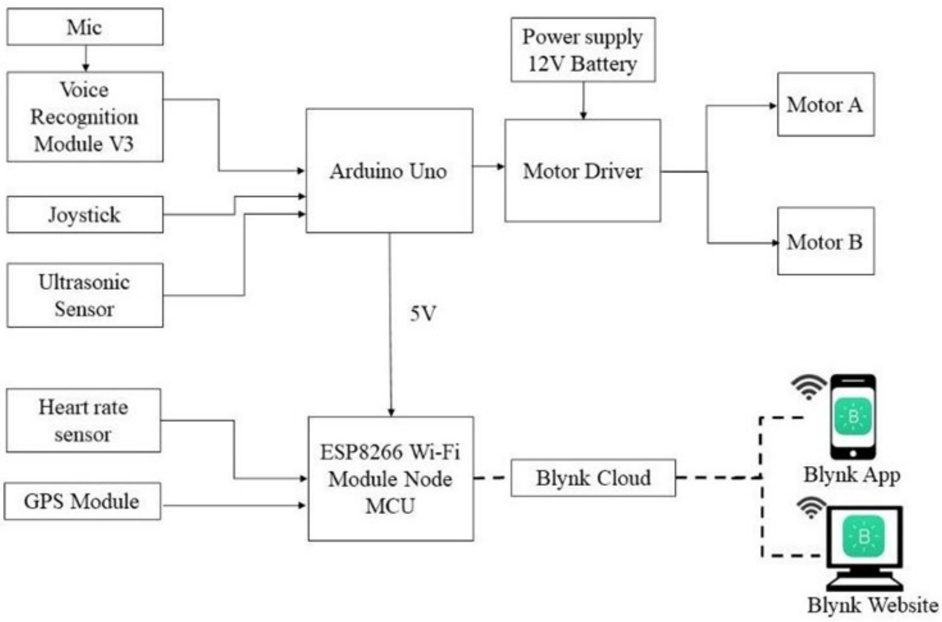


Figure 1: The block diagram of the system

2.2 Flowchart of the system

The flowchart of the operational system is divided into part which is wheelchair prototype control system and the IoT based monitoring control system as shown in following figures:

- Wheelchair prototype control system.

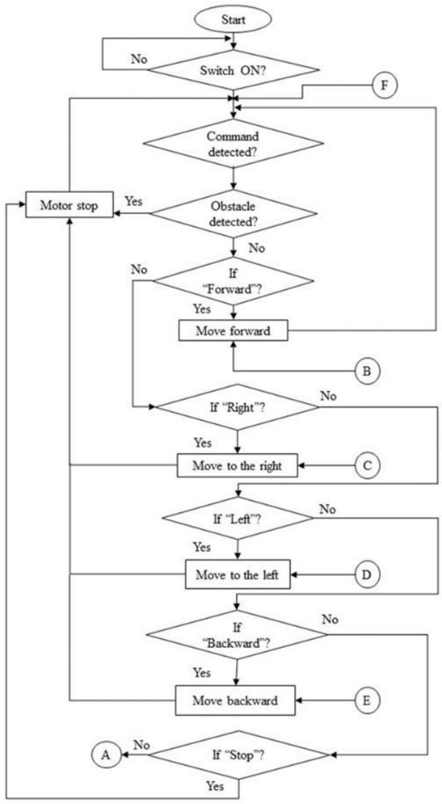


Figure 2: The Operational system flowchart for control system (i)

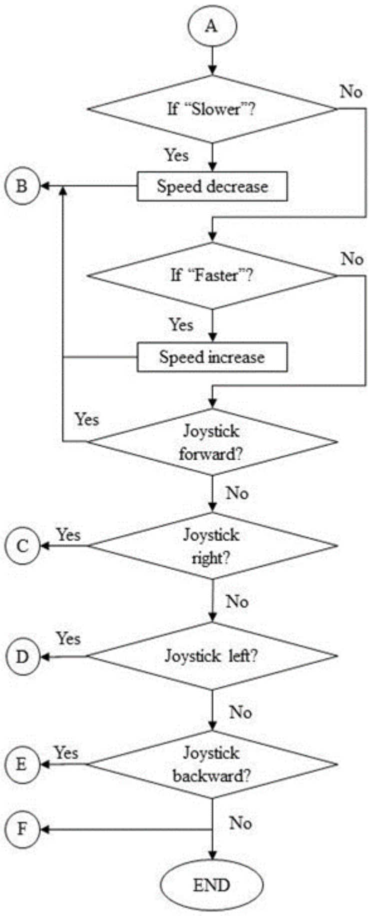


Figure 3: Operational system flowchart for control system (ii)

• IoT based monitoring system.

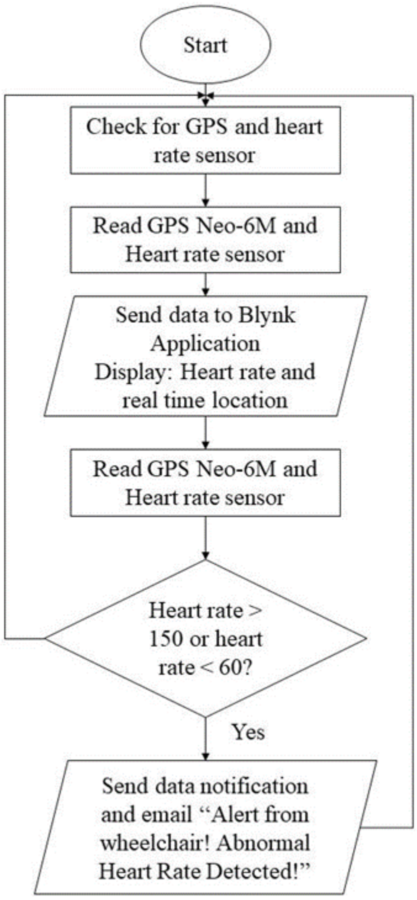


Figure 4: Operational system flowchart for monitoring system

2.3 Hardware Development

2.3.1 Circuit Diagram

The schematic circuit for the proposed system designed in Fritzing software is shown in Figure 5. This circuit consist of Arduino Uno, voice recognition module V3, analog joystick, ultrasonic sensor (HC-SR04), DC geared motor (SPG30HP-30K) and L298N motor driver, ESP8266 Wi-Fi Module Node MCU, and GPS Neo-6M and heart rate sensor model SEN0203.

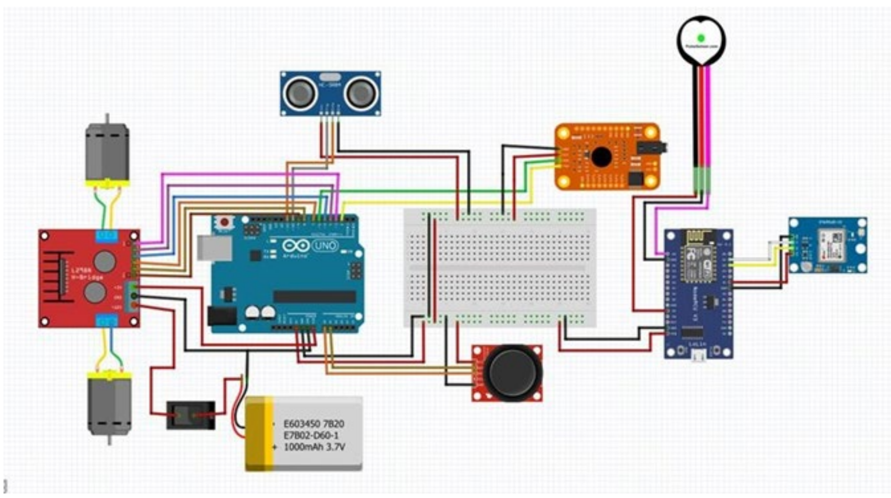


Figure 5: Circuit diagram of the project

2.3.2 Prototype Development

Figures 6 and 7 show the prototype of the electric voice-controlled wheelchair that has been developed. The prototype model is equipped with two DC motors and three wheels. The joystick and voice recognition controller are placed in one casing and directly connected to the wheelchair prototype using wire, as shown in Figure 6. Meanwhile, in Figure 8, circuit connection of the heart rate sensor and GPS module to the Node MCU for IoT monitoring system is shown. Furthermore, most components are connected to the breadboard using jumper wire for the circuit connection, as shown in Figure 7 and 8.

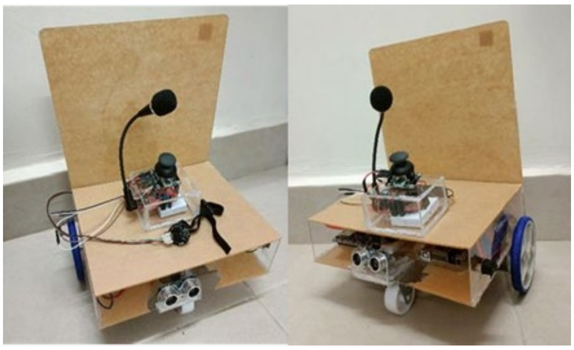


Figure 6: Design of the wheelchair prototype (i)

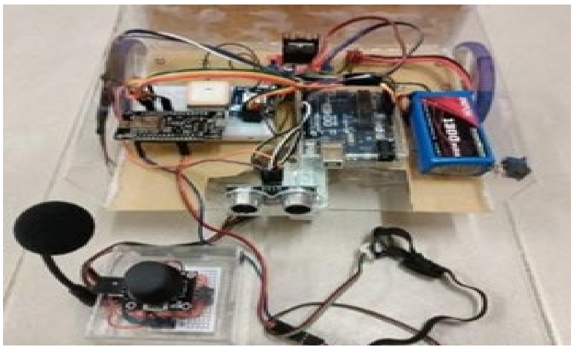


Figure 7: Circuit connection of the wheelchair prototype

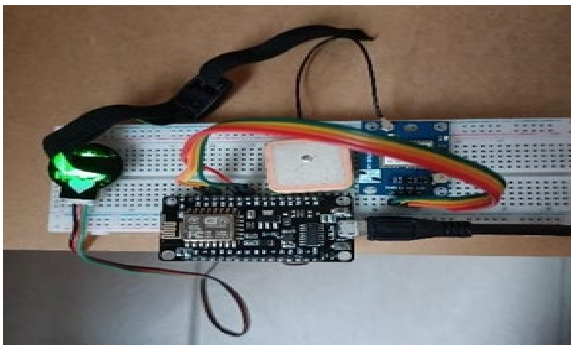


Figure 8: Circuit connection of the heart rate sensor and GPS module to the Node MCU

2.3.3 IoT based monitoring application development.

This project develops a mobile phone application based on IoT for wheelchair users' real-time location and heart rate monitoring purposes as shown in Figure 9. Blynk IoT App is used to create and develop an app interface that can provide access and display real-time heart rate data and a wheelchair user's location via a Wi-Fi connection.

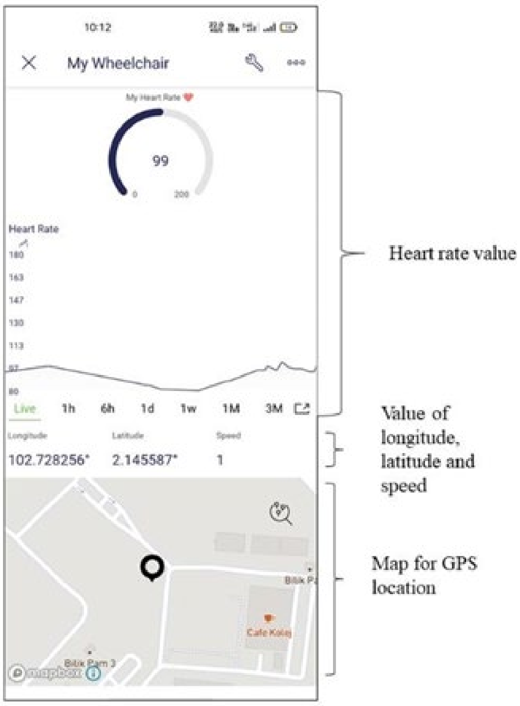


Figure 9: Graphical user interface for Blynk App

This proposed app's interface design, heart rate value, heart rate graph, longitude, latitude value of user's location and real-time map are displayed on one page. First, this monitoring application is connected to the sensor via a Wi-Fi connection—the transmitted data from the Wi-Fi module Node MCU to the Blynk Cloud. Then, from the Blynk Cloud, the data is uploaded to the created app. Then, the data received by the application will be displayed on the app. This feature allowed the caregiver to monitor and analyse the movement of the wheelchair user and notify the caregiver of the wheelchair user's health status. This monitoring system can also be accessed through the Blynk website.

3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Determining the motor condition.

Table 1: Motors condition and wheelchair prototype direction

Motor Condition		Wheelchair Prototype Direction
Motor A	Motor B	
ON	ON	Forward
OFF	ON	Turn left up to 90 degree
ON	OFF	Turn right up to 90 degree
OFF	OFF	Stop
ON	ON	Backward
ON	ON	Forward with low speed at 256.4 rpm
ON	ON	Forward with high speed at 344.2 rpm

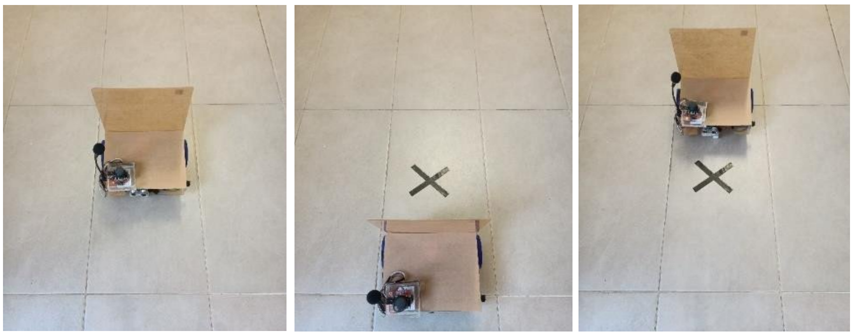


Figure 10: Wheelchair prototype moves forward and backward from initial position

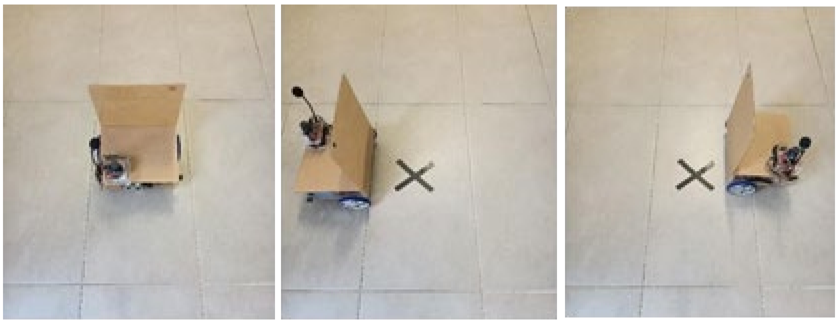


Figure 11: Wheelchair prototype moves to the left and right from initial position

According to Table 1, the motor condition determines the wheelchair's direction, with the motor rotating in response to the motor driver L298N's signal. The table above shows that the wheelchair prototype moves forward when both motors are ON. Both motors are ON and rotate at the opposite polarity in the reverse direction. The direction of the wheelchair prototype moves forward and backward from the initial position is shown in Figure 10.

In the case of a left or right turn, only one motor (A or B) will be turned on. For a wheelchair prototype to turn left at 90 degrees, as shown in Figure 11, only motor right will be turned on while motor left is stopped, and vice versa. The wheelchair prototype can also move at low and high speeds when motors A and B are turned on. Both motors will rotate at an average of 254.1 rpm (low-speed case) and 344.2 rpm (high-speed case).

3.2 Analysis of voice recognition system.

Table 2 shows the data analysis to test the accuracy of the voice recognition control system.

Table 2: Analysis of voice recognition system

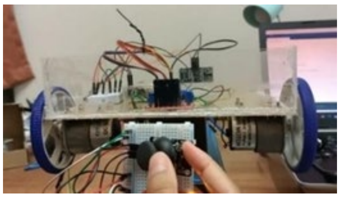
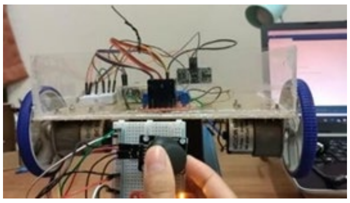
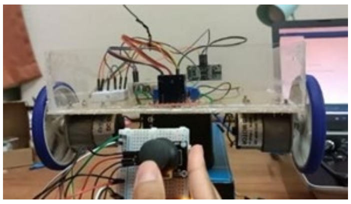
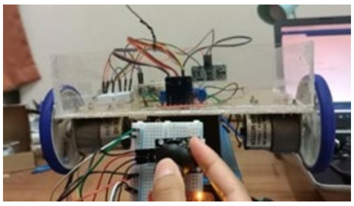
Individual	No. of successful Outcomes (30 trials)	Accuracy (%)	Error (%)
A	29	96.66	3.34
B	25	83.33	16.67
C	27	90.00	10.00
Average		89.90	10.01

According to the data collected, the average accuracy of the speech recognition system is 89.99 % theoretically and 99.99 % theoretically for the voice recognition module V3 [22]. The data received shows a 5.15 % difference in accuracy, with a 30.01 % inaccuracy. Mispronunciation in providing commands throughout the testing method is one of the aspects that caused errors. Thus, the way they uttered the command can be a factor in inaccuracy. So proper vocalization and pronunciation are essential to ensure accurate speech recognition module V3.3.4 Analysis of joystick orientation.

3.3 Analysis of joystick orientation.

As shown in Table 3, is the data collected for the joystick control motor. The joystick orientation, analog value of the x and y-axis, and motor A and B were determined.

Table 3: Joystick control test result.

Joystick Orientation	Analog Value		Motor Condition	
	x-axis	y-axis	Motor A	Motor B
Joystick navigates to the left 	0	512	OFF	ON
Joystick navigates to the right 	1023	513	ON	OFF
Joystick navigates upward 	526	0	ON	ON
Joystick navigates downward 	526	1023	ON	ON

When the value of the X-axis increases to 1023, the only motor B will be turned ON, and the wheelchair will move to the right. When the joystick travels left or right (x-axis) or forward or backward (stick moves along the y-axis). Each axis' analogue value can range from 0 to 1023. This value changes from 0 to 1023 as the joystick goes along each axis.

Motors A and B will turn on as the joystick moves up or down the y-axis. Nevertheless, the analogue value determined the motor's spin. When the analogue value is 0, the motors rotate forward, whereas the motors rotate backwards when the value is 1023s.

Then turn on motor A while motor B is off, and shift the wheelchair prototype to the left. Only motor B is energized when the X-axis reaches 1023, and the wheelchair prototype moves to the right.

3.4 Analysis and comparison of the heart rate sensor and heart rate sensor data.

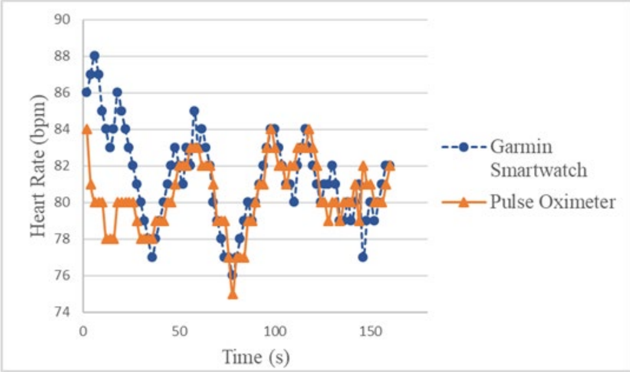


Figure 12: Comparison graph heart rate data using Garmin smartwatch and pulse oximeter in first trial

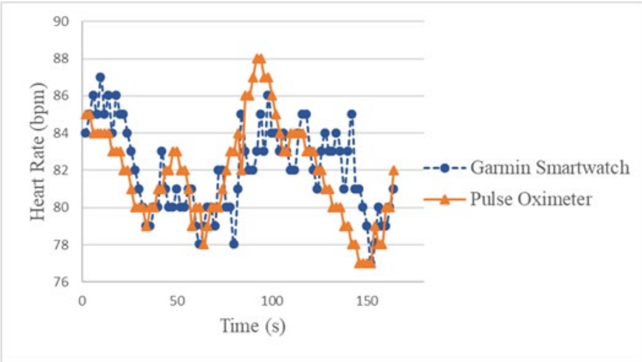


Figure 13: Comparison graph heart rate data using Garmin smartwatch and pulse oximeter in second trial

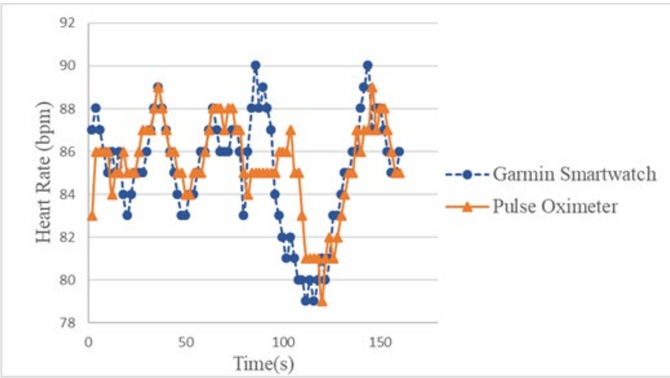


Figure 14: Comparison graph heart rate data using Garmin smartwatch and pulse oximeter in third trial

Table 4: Average value and percentage of error for Garmin Smartwatch.

	1st trial	2nd trial	3rd trial
% Error	1.150498	0.223514	0.29283

Figure 12, 13, and 14 compare the heart rate values acquired by Garmin watches and pulse oximeter sensor. According to the comparison graphs, it is estimated that the Garmin smartwatch has 99.44 percent accuracy compared to a pulse oximeter sensor in each trial. As indicated in Table 4, the overall percentage error for each trial ranges from 0.22 % to 1.15 %. The Gamin smartwatch required some time to stabilize. Therefore, the heart rate value fluctuated early in the testing period, around 0s to 30s. The device's positioning also contributes to the error, as the Garmin watch was placed on the person's wrists while the pulse oximeter was placed on the person's fingertip.

3.5 Analysis and comparison of the heart rate sensor data.

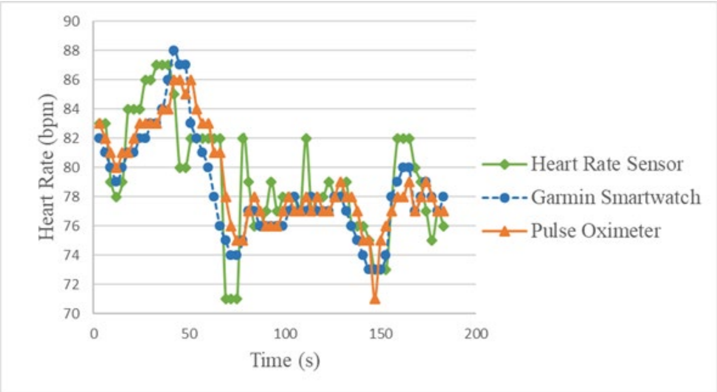


Figure 15: Comparison graph heart rate data using heart rate sensor, Garmin smartwatch and pulse oximeter in first trial

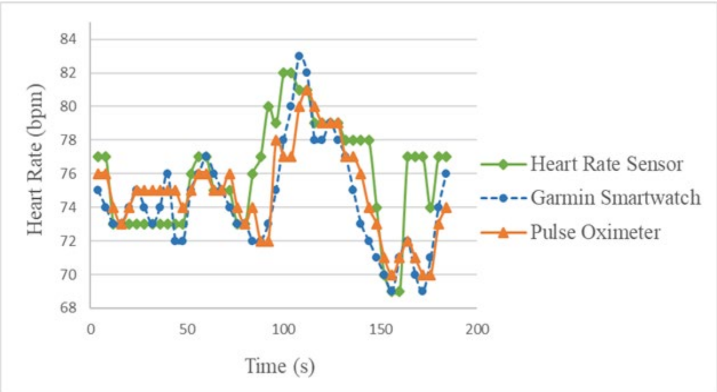


Figure 16: Comparison graph heart rate data using heart rate sensor, Garmin smartwatch and pulse oximeter in second trial

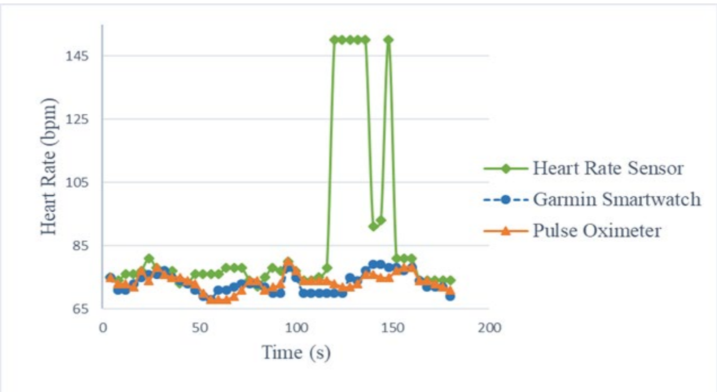


Figure 17: Comparison graph heart rate data using heart rate sensor, Garmin smartwatch and pulse oximeter in third trial

Table 5: The percentage of error for heart rate sensor

% Error	1st trial	2nd trial	3rd trial
HR VS PO	0.165803	1.393728	17.8281
HR VS GW	0.876644	2.045587	18.5073

Based on Figure 15, 16, and 17, compare the heart rate measurements from three different devices. Assistive devices such as pulse oximeters and Garmin smartwatches are used in this process. The accuracy of heart rate sensors may be validated by comparing them to a pulse oximeter and a Garmin smartwatch.

The average percentage of accuracy for each comparison was 99.22 % (heart rate versus pulse oximeter) and 97.07 % (heart rate sensor compared to Garmin smartwatch). Table 5 compares the average percentage error of the heart rate sensor to the pulse oximeter in the first and second trials. The average inaccuracy obtained for each testing phase is 0.87 % for the heart rate sensor and 2.04 percent for the Garmin smartwatch.

However, as shown in Figure 17, the heart rate sensor's percentage error soared to 18.51 % at one point in the graph. The heart rate sensor recorded a few out-of-range data at 120 s to 136 s and 148 s. The sensor's circuit's voltage supply and signal instability generated this type of error to the heart rate sensor, causing data signal noise. The heart rate sensor has a great sensitivity to hand movements.

As seen above, the pulse oximeter's heart rate measurement is more accurate than the Garmin smartwatch's heart rate sensor because the sensor's positioning influences the measurement's quality. PPG sensors work best when placed in efficiently accessible anatomical locations, such as the fingertip. So, PPG signals can be detected more precisely.

3.6 Analysis and comparison of the GPS data.

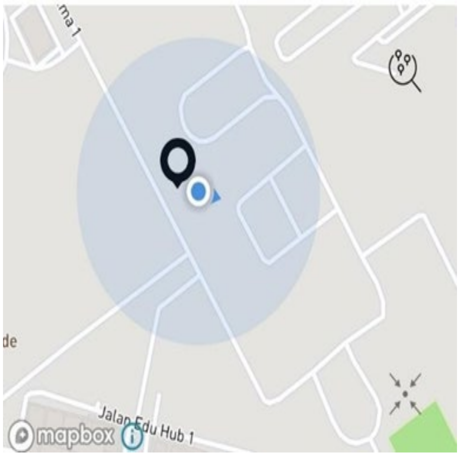


Figure 18: Comparison of location pinned based on GPS module and phone's location at location A

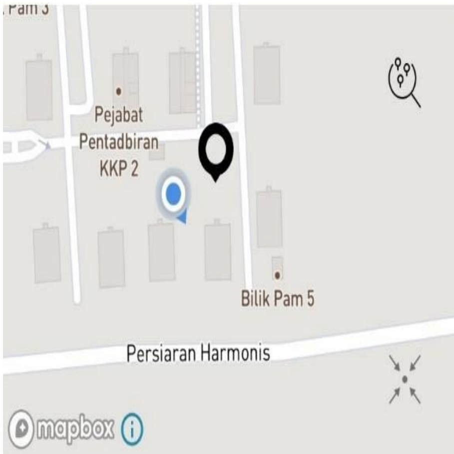
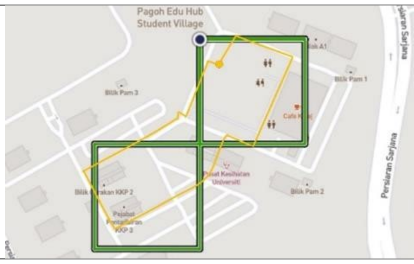


Figure 19: Comparison of location pinned based on GPS module and phone's location at location B

Figure 20: Comparison of location pinned based on GPS module and phone's location at location C

Figures 18, 19, and 20 display three separate locations, each representing a pinned position depending on the GPS module and the user's phone location. In the images above, the GPS-pinned location differs from the phone's actual location. The distance between the GPS pinned location and the phone's location for A and C is reasonable. However, position B appears to be different from the pinned location. This error is caused by the environment affecting the signal. The data were gathered from locations A and C, which were not surrounded by buildings or trees. However, data were obtained at site B in a tall building far from the ground. Buildings, walls, trees, and other impediments blocking or reflecting the signals can reduce GPS accuracy.

Table 6: Comparison of path tracking between GPS and actual path taken

Location	Path based on GPS (green)	Actual path (yellow)
A		

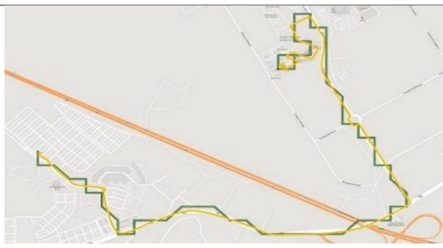
B	
C	

Table 6 compares the GPS tracked journey to the actual path followed by the user. This comparison was intended to assess the GPS Neo-6M module's performance. Location, A path tracking data, was collected by walking. Comparing the GPS path recorded with the actual path taken during the test shows faulty distances, and the path mapping reported is not as exact as the actual data. Because large buildings and trees surround point A, the satellite signal tends to obstruct and reflect, causing positioning mistakes and path tracking delays.

For locations B and C, data were acquired while driving. The path recorded by the GPS is slightly accurate. However, there are slight delays in the signal for location placement, which creates some error distance in path tracking.

4. Conclusion

A motorized wheelchair prototype, controlled by voice recognition and a joystick, was successfully implemented in this study, demonstrating its feasibility. Sophisticated technology is used to process the voice and control the motors in this proposed wheelchair prototype. For the vast majority of the orders, the voice recognition system performed at or around 89.99 %. Only when a word was not correctly vocalized and spoken did the algorithm fail to identify it as such. The prototype wheelchair has also been developed offered a joystick as a second option to navigate its direction. This wheelchair prototype has been developed to provide an assistive system for a physically disabled person who is unable to move with their wheelchair independently. The system offers the movement of wheelchair-using voice command and joystick.

Furthermore, an IoT-based monitoring system application has been built, and it is reliable enough to give users information about their general health and location status. The caregiver and the intended set of individuals may be quickly and readily accessing the developed app through mobile phone applications and websites.

In the future, this wheelchair prototype-controlled system can be integrated into an actual wheelchair and operated in a real-world environment. A personalized user's voice recognition detection can be added to the system to increase the system's accuracy and to improve the wheelchair's safety. It is feasible to improve the hardware by adding automatic battery charging using any renewable energy source, such as a solar energy system. Furthermore, the PPG heart rate sensor can be replaced with a more accurate sensor, such as an ECG sensor, for use in the monitoring system.

Acknowledgement

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