

Smart Wheelchair with Dual Control Using Touchpad and Android Mobile Device

Yna Victoria P. Paulite, Neil Jerome C. Carandang, Edwin R. Arboleda*

Department of Computer and Electronics Engineering, College of Engineering and Information Technology, Cavite State University, Indang, Cavite, Philippines

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ABSTRACT

The general objective of the design was to develop a touchpad controlled Android-based electronic wheelchair. It aimed to construct the Android-based circuitry and program for the path finding mechanism of the drive system and interface the Arduino-based circuit to the electronic wheelchair setup. It was designed to evaluate the system in terms of the speed of the electronic wheelchair, reliability of the sensors to avoid obstacle, and ease of use of the wheelchair. C Programming Language was used by the system to control and manipulate the microcontroller, Gizduino AtMega644. The Android application was programmed using the Java Language and Eclipse as the IDE. Its ports were used to interface input and output devices such as the ultrasonic sensors, infrared proximity sensor, touchpad, Bluetooth module, motor and motor driver. There was a satisfactory rating for the evaluation of the system while the Android software was rated excellent as a navigational controller.

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Corresponding Author:

Edwin R. Arboleda,

Department of Computer and Electronics Engineering,

College of Engineering and Information Technology, Cavite State University,

Indang, Cavite, Philippines.

Email: edwin.r.arboleda@cvsu.edu.ph

1. INTRODUCTION

Technology is the present world. It affects people's daily lives. A list of the benefits of technology would be very long indeed and this includes the medical field [1]. This wheelchair project offers people with disabilities [2-3], people who with various degrees of paralysis [4] a chance to navigate. The degree of the paralysis must only be limited either from the lower body, the upper body, except from the fingers, the wrist and the hand [5-6]. Otherwise, the person cannot control it.

The person uses a touchpad to maneuver the wheelchair independently [7-8]. On the other hand, the helper can remotely control the wheelchair via smart phone, using an application that is powered by the Android Operating System. The wheelchair is also equipped with sensors [9-10]. It can maneuver through incoming walls, people, stairs, or any obstacle that it comes in close contact with [11]. When detected, the wheelchair automatically selects the best path to the selected course.

Romero et al. [12] presented the design, implementation and experimental platform of a low-cost intelligent wheelchair for the motor-disabled. A cheaper electric power wheelchair, which cost one third of the commercial ones was the first prototype developed. The said prototype can do both manual and autonomous operations. Manual types depend on a joystick and are made for people that have the capability of controlling the wheelchair despite their disability. Autonomous operation on the other hand leans on a mobile robotics inspired computer vision system used to navigate through corridors, halls, indoors/outdoors,

among other structured environments. It is purposely devised for severely impaired persons, such as tetraplegics.

The development of autonomous mobile robot systems has become a current interest in the area of artificial intelligence. Autonomous robots are attracting more attention all over the world due to the recent improvements in technology. In both industry and academia, there are research and development activities that are now ongoing. For obstacles' positions that are uncertain, path finding for robots in complex ground environment is being searched. Consequently, a new path finding method integrating line tracking and obstacle avoidance algorithms is proposed and implemented according to Wu et al. [13]. He presented the design and implementation of a multi-sensor based path finding autonomous exploration robot system, 2RE, with the VEX robotics design system. The robot system with the new path finding algorithm can effectively solve path finding problem in complex ground environment and it avoid collision with the obstacles as shown on the results of the project [14].

The design and realization of the mobile application for the Android operating system is focused on manual control of mobile robot using wireless Bluetooth technology [15-16]. The application allows the robot control interaction with the display, or voice. When graphical interface is used, the current distance of the robot from obstacles can be monitored [17]. The measurement of distance is carried out by ultrasonic sensor placed in front of the robot. It is necessary to build a prototype of a mobile robot for the development of the application. The prototype of the mobile robot is based on the differential gear.

A mobile robot system suitable for performing various tasks for the physically disabled has been then developed. The mobile robot uses ultrasonic range finders for detection and mapping in order to prevent collision with various obstacles [18]. An obstacle avoidance strategy used for this robot relies vitally on the performance of the ultrasonic range finders although the sensors have limitations on the obstacle avoidance algorithm [19-20].

In reference to the current innovations mentioned above, this paper presents the design and implementation of a touchpad controlled android-based path finding automated wheelchair intended for physically disabled people. It primarily focuses on the avoidance of obstacles through sensors and the distance the wheelchair had travelled as indicated by the Android application used.

2. RESEARCH METHOD

2.1. Design Considerations

The materials used for this study are available in the local market and not more expensive than that of the commercially available electronic wheelchairs. The materials that were used in the project are the following: the manual wheelchair is a standard wheelchair that weighs 20 kg and capable of carrying a maximum load of 120 kg. The wiper motors that were used were second hand because a new one would be very costly and hard to find. The motor drivers, the sensors, the microcontrollers, and the modules that were used for the main circuit are available at electronic shops and hobby shops locally. There was a lot to consider for the modification of the manual wheelchair. The following were taken into consideration: the size and position of the sprocket and chain ring for maximum efficiency; the extension of the axle; and the placement and weight of the battery. As for the main circuit, it was taken into account that it must not be easily removed and must be protected from dust and the weather.

2.2. Selection of Motor and Motor Driver

A DC motor with permanent magnet connected field [21] was used since the application range of this motor includes the electric wheelchair because of its high torque and power density [22-23]. A windshield wiper motor which uses permanent magnet field was applied in the design. The Toyota wiper motor used has an output rating of 50 W and has a load current of 4 A - 6.5 A from a weight range of 40 to 90 kg. Additionally, to allow the motors to run forward and backward (reverse), an H-bridge electronic circuit was utilized. The H-bridge was designed depending on the current rating of the battery that will not limit the maximum operation of the wiper motors.

2.3. Selection of Battery

One 12 Ah 12 V battery was used. It has a weight of 7 kg. It was estimated that an average of 1 A is consumed in every hour of use of the entire system. Thus, the 12 Ah battery is compatible for 10-12 hours of use. It is a type of lead acid battery used for cars and motorcycles. It was used since it is intended to provide a steady amount of current over a long period of time and can withstand being deeply discharged over and over again.

2.4. Design and Construction of a Navigational Controller Circuit

The design focused on users who can operate the electronic wheelchair using their hands. A capacitive touchpad was used because it is similar to Android-based phones that use capacitive touch panel [24]. It is also easy to use.

2.5. Interfacing the Navigational Controller and Sensors, and Bluetooth Module to the Arduino Circuit

Figure 1 shows the block diagram of the Android-based electronic wheelchair [25]. The navigation controller pins, sensors, and Bluetooth module were all connected to the microcontroller.

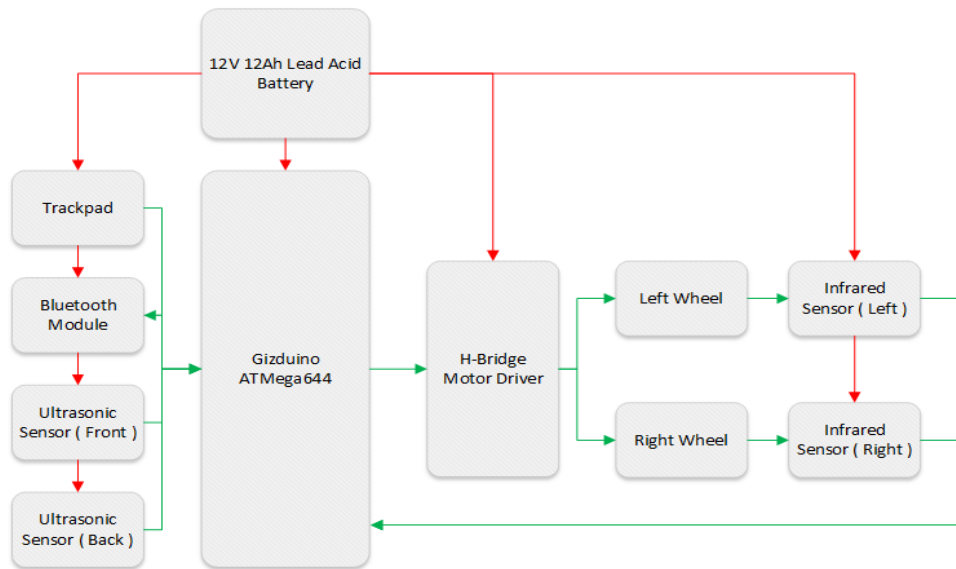


Figure 1. The block diagram of smart wheelchair with dual control using touchpad and android app

2.6. Modification of the Manual Wheelchair

The following materials or components were installed on the manual wheelchair: two wiper motors, battery, battery, capacitive touchpad, two ultrasonic sensors, three IR sensors, and the main circuit. Figure 2 shows the modified manual wheelchair.

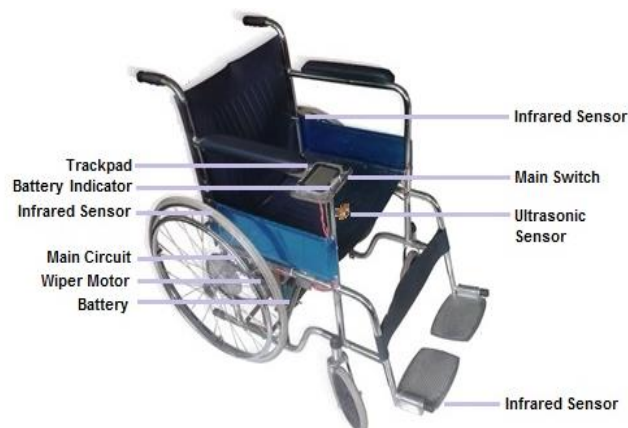


Figure 2. The modified electronic wheelchair

2.7. Software Development for the Electronic Wheelchair

The software that was used for the programming of the system is C Programming Language and was uploaded to the AtMega644 Arduino.

2.8. Developing the Software for the Android-Based Device

The Android application was programmed using the Java language and Eclipse as the IDE. The application was not created by the proponents themselves. The Android application created and developed by the proponents of the design project “Design and Development of Android Based Path Finding Mobile Robot” was the same application used in this design project. The name of the application is Arobot. The application was just modified to become compatible with higher Android versions. The application is an input device that will serve as an interface for the navigation controller, and auto pathfinder. Figure 3 shows the Arobot android apps.



Figure 3. The Android application interface

2.9. Testing and Evaluation

For technical evaluation, the electronic wheelchair was tested in different distances several times per mode of operation. The capability of the transmission was recorded since it uses a Bluetooth connection to connect the Android application to the wheelchair. The maximum weight that the wheelchair could carry was also recorded. Figure 4 show the actual testing of the developed wheelchair wherein it is controlled from a distance by the Arobot Android apps.



Figure 4. Using an android mobile device to remotely control the electronic wheelchair

For the user evaluation test, 30 people tested the device. Among these were Cavite State University students and two PWDs. The students were categorized into four weight ranges: 40-56 kg, 57-73 kg, and 74-90 kg. The authors set marks from 1 m to 10 m to measure the time travelled of every respondent. The speed was computed by dividing the distance travelled by the total time travelled in seconds. The proponents prepared a survey questionnaire to examine the user's perception about the specific functions of the Android-based touchpad controlled electronic wheelchair. Five questions were prepared to evaluate the touchpad controlled android based electronic wheelchair, namely: (1) the touchpad controller is easy to use; (2) the Android software is easy to use; (3) the sensors work properly; (4) the path finding system works properly; (5) and the electronic wheelchair is easy to use. Each question was rated on how the respondents find the electronic wheelchair efficient and user-friendly using Table 1 as reference.

Table 1. Reference for Rating the Accuracy of the Project

RATING	DESCRIPTION
5	Excellent – Exceeds the expected function of the project
4	Satisfactory – Meet all the functions of the project
3	Fair – Good enough for its use
2	Needs improvement – Did not meet all the functions of the project
1	Poor – Not effective and efficient

Table 2 shows the mean range weight interpretation of the Likert scale used in the survey questionnaires.

Table 2. Mean Range Weight Interpretation

RANGE	DESCRIPTION
4.50-5.00	5 – Excellent
3.50-4.49	4 – Satisfactory
2.50-3.49	3 – Fair
1.50-2.49	2 – Needs Improvement
1.00-1.49	1 – Poor

During the testing and evaluation period, the authors recorded the measurements made from the wheelchair and the participants were given an evaluation form to rate the effectiveness of the electronic wheelchair operation.

3. RESULTS AND ANALYSIS

3.1. Principle of Operation

The electronic wheelchair was designed to provide a mobility device for people with disabilities. The design project consists of the following: wheelchair, touchpad, two ultrasonic sensors, two infrared sensors, two wiper motors, battery, motor drivers, Bluetooth module and Gizduino ATmega644 microcontroller which controls the whole operation of the system.

The electronic wheelchair automatically moves or transports the user to the direction indicated by the user, either touchpad or Android-based controlled. It is supplied by a 12 Ah 12 V lead acid battery. Once the main switch of the electronic wheelchair is switched on, the battery will start to supply power to the main circuit of the system which consists of Gizduino ATmega644, Hybrid Motor Driver, Bluetooth RxTx Module, regulators, and amplifier. The infrared sensors are placed at both sides of the wheelchair near the wheel. It serves as an improvised tachometer by detecting the black marks placed at every 45 degrees on the wheel [26]. The touchpad placed at the right side of the wheelchair or the joystick-mode of the Android application via Bluetooth connection can navigate by tapping the right coordinates for forward, backward, left rotation and right rotation. Upon forward or backward navigation, the 12 V wiper motors will rotate forward or backward together, respectively. But in the event that the ultrasonic sensor in front of the wheelchair detects that the wheelchair is heading towards an obstacle with distance of 1.2 m in front and 0.6 m at the rear, the electronic wheelchair will automatically stop. Upon left and right navigation, the main circuit will only allow the forward movement of the right and left motor, respectively. While, the left and right wheels will remain stationary respectively, this makes the wheelchair move going to the left and to the right. The electronic wheelchair has also an additional feature of path finding. This works through Android application via Bluetooth. The settings of the application are configured from joystick mode to auto-path

mode by creating a map. One tile in the map is equivalent to 0.304 m by 0.304 m. The starting point is set by long pressing a tile of choice then another tile is tapped for the destination point. It is important to take note that the map is always due north of the wheelchair. The wheelchair will automatically find its way from the starting point to the destination point and avoid obstacles along the way.

3.2. User-Acceptance Data Analysis

Table 3 presents the data gathered from the 28 Cavite State University students. It shows the time each respondent travelled using Android software and auto-path finding system with different routes in 10 m. Their speed using different modes of operation were computed and recorded. It also shows that the weight of the user affects the speed of the electronic wheelchair. Heavier users moved slower in all modes of operation.

Table 3. Speed of Electronic Wheelchair at 10 m (Cavite State University students)

WEIGHT (kg)	TIME	TIME	TIME	SPEED	SPEED	SPEED
	TRAVELLED (s) Android Software	TRAVELLED (s) Auto-Path (Route 1)	TRAVELLED (s) Auto-Path (Route 2)	(m/s) Android Software	(m/s) Auto-Path (Route 1)	(m/s) Auto-Path (Route 2)
40	48	42	46	0.21	0.24	0.22
45	68	50	56	0.15	0.20	0.18
45	63	48	53	0.16	0.21	0.19
45	73	51	55	0.14	0.20	0.18
45	61	48	56	0.16	0.21	0.18
46	69	49	55	0.15	0.20	0.18
47	67	49	57	0.15	0.20	0.18
47	80	51	57	0.13	0.20	0.19
48	83	53	59	0.12	0.19	0.17
48	76	53	58	0.13	0.19	0.17
48	86	51	58	0.12	0.20	0.17
48	58	52	57	0.17	0.19	0.18
48	71	51	59	0.14	0.20	0.17
49	108	53	58	0.09	0.19	0.17
49	68	54	60	0.15	0.19	0.17
49	66	54	61	0.15	0.19	0.16
49	52	52	60	0.19	0.19	0.17
50	66	54	62	0.15	0.19	0.16
51	68	55	60	0.15	0.18	0.17
52	116	57	63	0.09	0.18	0.16
55	103	56	64	0.10	0.19	0.16
55	60	57	63	0.17	0.18	0.16
55	82	57	65	0.12	0.18	0.15
61	47	59	65	0.21	0.17	0.15
67	119	63	68	0.08	0.16	0.15
75	117	69	73	0.09	0.14	0.14
75	137	68	75	0.07	0.15	0.13
90	123	79	83	0.08	0.13	0.12

Table 4 presents the data gathered from two persons with disabilities. It shows the time each PWD travelled using Android software and auto-path finding system with different routes in 10 m. Their speeds using different modes of operation were computed and recorded. It also shows that the weight of the user affects the speed of the electronic wheelchair.

Table 4. Speed of Electronic Wheelchair at 10 m (PWDs)

WEIGHT (kg)	TIME	TIME	TIME	SPEED	SPEED	SPEED	
	TRAVELLED (s)	TRAVELLED (s)	TRAVELLED (s)	(m/s)	(m/s)	(m/s)	
	Android Software	Auto-Path (Route 1)	Auto-Path (Route 2)	Android Software	Auto-Path (Route 1)	Auto-Path (Route 2)	
PWD 1	50	60	55	63	0.17	0.18	0.16
PWD 2	72	90	67	74	0.11	0.15	0.14

3.2.1. Question 1. The touchpad controller is easy to use.

The mean of the ratings given by the respondents is shown in Table 5. There was a little difference in the answers of the respondents belonging to the three weight ranges, but the data computed still showed high rating for ease of use of the touchpad controller.

Table 5. Data Gathered by Weight Range for Question No. 1

WEIGHT RANGE (kg)	AVERAGE TIME (s)	AVERAGE SPEED (m/s)	MEAN	PERCENTAGE %
40-56	70.41	0.15	4.00	80.00
57-73	79.29	0.13	4.33	86.67
74-90	83.00	0.15	4.33	86.67

3.2.2. Question 2. The Android software is easy to use.

The mean of the ratings given by the respondents is shown in Table 6. There was a little difference in the answers of the respondents belonging to the three weight ranges, but the mean computed still showed high rating for ease of use of the Android software.

Table 6. Data Gathered by Weight Range for Question No. 2

WEIGHT RANGE (kg)	AVERAGE TIME (s)	AVERAGE SPEED (m/s)	MEAN	PERCENTAGE %
40-56	70.41	0.15	4.79	95.83
57-73	79.29	0.13	4.33	86.67
74-90	83.00	0.15	5.00	100.00

3.2.3. Question 3. The sensors work properly.

The mean of the ratings given by the respondents is shown in Table 7. There was a little difference in the answers of the respondents belonging to the three weight ranges, but the mean computed still showed high rating for the reliability of the sensors. During the technical evaluation, the reliability of the sensors was further tested.

Table 7. Data Gathered by Weight Range for Question No. 3

WEIGHT RANGE (kg)	AVERAGE TIME (s)	AVERAGE SPEED (m/s)	MEAN	PERCENTAGE %
40-56	70.41	0.15	4.21	84.17
57-73	79.29	0.13	5.00	100.00
74-90	83.00	0.15	5.00	100.00

3.2.4. Question 4. The path finding system works properly.

The mean of the ratings given by the respondents is shown in Table 8. There was a little difference in the answers of the respondents belonging to the three weight ranges, but the mean computed still showed high rating for reliability of the path finding system.

Table 8. Data Gathered by Weight Range for Question No. 4

WEIGHT RANGE (kg)	AVERAGE TIME (s)	AVERAGE SPEED (m/s)	MEAN	PERCENTAGE %
40-56	70.41	0.15	3.96	79.17
57-73	79.29	0.13	4.00	80.00
74-90	83	0.15	3.67	73.34

3.2.5. Question 5. The electronic wheelchair is easy to use.

The mean of the ratings given by the respondents is shown in Table 9. There was a little difference in the answers of the respondents belonging to the three weight ranges, but the mean computed still showed high rating for the ease of use of the electronic wheelchair.

Table 9. Data Gathered by Weight Range for Question No. 5

WEIGHT RANGE (kg)	AVERAGE TIME (s)	AVERAGE SPEED (m/s)	MEAN	PERCENTAGE %
40-56	70.41	0.15	4.38	87.50
57-73	79.29	0.13	4.67	93.34
74-90	83.00	0.15	4.67	93.34

Table 10 shows the average rating of the questions in the user evaluation for the 28 Cavite State University students. The mean was computed per question which corresponded to specific performance level. The ease of use of the Android software was rated excellent while the ease of use of the touchpad controller and the electronic wheelchair, and the reliability of the sensors and path finding system were rated satisfactory.

Table 10. Response on the Performance of the Electronic Wheelchair

QUESTION	MEAN	PERFORMANCE
1. The touchpad controller is easy to use.	4.07	Satisfactory
2. The Android software is easy to use.	4.77	Excellent
3. The sensors work properly.	4.47	Satisfactory
4. The path finding system works properly.	3.93	Satisfactory
5. The electronic wheelchair is easy to use.	4.43	Satisfactory
Total Average	4.33	Satisfactory

Overall, the performance of the developed electronic wheelchair was rated satisfactory.

Table 11 shows the average time travelled by a certain range of weight at a 25 by 25 tile map with no-obstacle-straight path. Since the respondents weighed from 40 to 90 kg, the ranges set had a 16 kg weight interval. The wheelchair travelled only 23 tiles in a 25 by 25 map since it occupied 2 tiles. A tile is equivalent to 0.3048 m, thus 23 tiles is equivalent to 7.0104 m. The average speed computed was significant with respect to weight. The effectiveness was based on the evaluation given by the respondents.

Table 12 shows the average time travelled by a certain range of weight at a 25 by 25 tile map with obstacle route. Since the respondents weighed from 40 to 90 kg, the ranges set had a 16 kg weight interval. A tile is equivalent to 0.3048 m, thus 23 tiles is equivalent to 7.0104 m. The distance set was also 23 tiles in a 25 by 25 map even with obstacle. This was made to compare the average speed in a straight line from with obstacle. The average speed computed was significant with respect to weight. The effectiveness was based on the evaluation given by the respondents.

Table 11. Speed of Electronic Wheelchair Via Auto-path Finding at 25 x 25 tile map (no obstacle)

WEIGHT (kg)	AVERAGE TIME TRAVELLED (s)	AVERAGE SPEED (m/s)	EFFECTIVENESS (%)
40-56	48.50	0.19	86.66
57-73	63.00	0.16	100.00
74-90	72.00	0.14	100.00

Table 12. Speed of Electronic Wheelchair Via Auto-path Finding at 25 x 25 tile map (with obstacle)

WEIGHT (kg)	AVERAGE TIME TRAVELLED (s)	AVERAGE SPEED (m/s)	EFFECTIVENESS (%)
40-56	58.54	0.17	86.66
57-73	69.00	0.16	100.00
74-90	77.00	0.13	100.00

Table 13 shows the rating given by the two PWDs invited by the proponents. The average ratings of the PWD were interpreted using the Likert scale. The ease of use of the touchpad controller, Android software and electronic wheelchair were rated excellent. The sensors and the path finding system was rated satisfactory.

Table 13. PWDs User-Acceptance Ratings

Question No.	RATING				
	1	2	3	4	5
PWD 1	4	5	3	3	4
PWD 2	5	4	5	4	5
Average	4.5	4.5	4	3.5	4.5

3.3. Technical Evaluation Data Analysis

Table 14 shows the results of the evaluation of the Android application via Bluetooth in different distances. At 3 m, the Android app successfully transmitted the commands to the electronic wheelchair. The expected function of the wheelchair was achieved for three trials. At 6 m, the Android application successfully transmitted the commands to the electronic wheelchair. The expected function of the wheelchair was achieved for three trials. At 9 m, the Android application successfully transmitted the commands to the electronic wheelchair. The expected function of the wheelchair was achieved for three trials. At 12 m, the Android application successfully transmitted the commands to the electronic wheelchair. The wheelchair responded slowly compared to smaller distances. At 15 m, no command was transmitted to the microcontroller, the electronic wheelchair did not respond to any command. The actual range of efficiency of a Bluetooth module is about 12 m, therefore it is set that the effective distance of the wheelchair away from the Android phone was 12 m.

Table 14. Effectiveness Ratio of Android Application Via Bluetooth

DISTANCE (m)	TRIAL			EFFECTIVENESS (%)
	1	2	3	
3	5	5	5	100.00
6	5	5	5	100.00
9	5	5	5	100.00
12	3	5	3	73.33
15	1	1	1	20.00

A technical evaluation was conducted for the reliability of ultrasonic sensors. Three trials for each ultrasonic sensor were conducted. These trials have different obstacles.

Table 15 shows the effectiveness of the front ultrasonic sensor. Three trials with three different obstacles were conducted. During the trials the wheelchair was set to move forward until it stops during obstacle-detection, then the distance from the ultrasonic sensor to the obstacle was recorded. The data shows that from trial 1 to trial to 3, the distance ranges from 111 – 123 cm. The average distance that the front ultrasonic sensor could detect is 122.67 cm or 1.2 m.

Table 15. Effectiveness Ratio of Front Ultrasonic Sensor

TRIAL	OBSTACLE	DISTANCE (cm)
1	Person	123
2	Wall	134
3	Chair	111
	AVERAGE	122.67

Table 16 shows the effectiveness of the rear ultrasonic sensor. Three trials with three different obstacles were conducted. During the trials the wheelchair was set to move backward until it stops during obstacle-detection, then the distance from the ultrasonic sensor to the obstacle was recorded. Distance ranged from 52 to 76 cm. The average distance that the front ultrasonic sensor could detect is 60.33 cm or 0.6 m.

Table 16. Effectiveness Ratio of Rear Ultrasonic Sensor

TRIAL	OBSTACLE	DISTANCE (cm)
1	Person	62
2	Wall	67
3	Chair	52
	AVERAGE	60.33

Table 17 shows the effectiveness of infrared sensors for edge detection. Five trials were conducted to show its effectiveness. During the trials the wheelchair was set to move forward to the stairs. The wheelchair stopped when it detected the stairs. The wheelchair was consistent during the five trials conducted. There is 100 percent effectiveness in edge detection.

Table 17. Effectiveness Ratio of Infrared Sensor for Edge Detection

	TRIAL				
	1	2	3	4	5
Stop	Yes	Yes	Yes	Yes	Yes

A technical evaluation was also conducted for the effectiveness of the path finding system. There were five routes prepared. For each route, there was a path where there were no obstacles present, and a path where there were obstacles present.

Table 18 shows the effectiveness of the path finding system. Five routes were conducted. For each route there is a path where there is no obstacle and a path where there are obstacles present. The weight was held constant since the objective was to make sure that the wheelchair finds the set destination point from the set starting point. The wheelchair successfully completed the route in five different trials. From the data of Table 18, it shows that the time it takes for the wheelchair to reach its destination point is longer than that with no-obstacle present.

Table 18. Effectiveness of Path Finding System

ROUTE	DISTANCE (m)		WEIGHT (kg)	SPEED (m/s)	TIME (s)	
	w/o obstacle	w/ obstacle			w/o obstacle	w/ obstacle
1	4.27	5.49	60	0.23	18	24
2	4.65	5.87	60	0.23	20	28
3	3.96	5.79	60	0.23	15	26
4	4.65	5.87	60	0.23	19	27
5	4.27	6.10	60	0.23	18	30

4. CONCLUSION

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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