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Design of Electric Wheelchair Using Pulse Width Modulation Method

Fidyatun Nisa[1]✉, Dahlan Abdullah[2], Daniel Akhyar[3]
[1,3]Department of Information Systems, Faculty of Engineering, Universitas, Aceh, Indonesia
[2]Department of Informatics, Faculty of Engineering, Universitas, Aceh, Indonesia
fidyatun.nisa@unimal.ac.id

Abstract

An electric wheelchair is an essential mobility device for individuals with physical disabilities. Unlike traditional manual wheelchairs, which can be challenging for users to operate independently, an innovative PWM (Pulse Width Modulation) based electric wheelchair has been developed and tested. This wheelchair employs an Arduino Uno microcontroller, ultrasonic sensors, joystick input, and motor drivers to control speed and direction effectively. The system utilizes PWM to adjust the motor speed in proportion to the joystick input. Testing demonstrated that the wheelchair's motor responds efficiently to changes in PWM values. Additionally, the system successfully stops the motor when obstacles are detected within 80 centimeters. The ultrasonic sensors demonstrated an impressive measurement accuracy, with an average error of only 1%. Moreover, increasing the PWM values resulted in faster wheelchair speeds, showcasing the system's ability for responsive speed control. This design provides an affordable and effective solution to improve mobility for users with disabilities.

Keywords: *Electric Wheelchair, PWM, Arduino Uno, Speed Control, Obstacle Detection.*

1. Introduction

Wheelchairs play an essential role for individuals with limited mobility due to injury, illness, or physical disabilities [1]. However, conventional manual wheelchairs require physical effort to operate, which can be burdensome [2]. With technological advancements, motorized or electric wheelchairs are increasingly being developed to enhance mobility and independence [3]. Despite their usefulness, the high cost of commercial electric wheelchairs limits accessibility for many users in developing regions.

This research addresses this gap by designing a low-cost electric wheelchair using the Pulse Width Modulation (PWM) method. PWM allows precise control of motor speed by varying the duty cycle of electrical pulses [4]. The system is based on an Arduino Uno microcontroller, which integrates inputs from a joystick and ultrasonic sensors to control a pair of DC motors via motor drivers [5]. The wheelchair is designed to move in multiple directions and adjust speed according to joystick inputs, while also ensuring user safety by halting when obstacles are detected[6]. The objectives of this study are: (1) to design and implement a PWM-based electric wheelchair system; and (2) to analyze the responsiveness of the system in relation to obstacle detection and speed control.

2. Research Methods

The research methodology consisted of several stages including problem identification, literature review, system design, hardware and software implementation, and testing. The control system utilizes an Arduino Uno as the core microcontroller. Joystick input is used to determine direction and speed, with PWM signals sent to dual DC motors via BTS7960 motor drivers. Two ultrasonic sensors are positioned at the front and rear of the wheelchair to detect obstacles. The hardware components used include: Arduino Uno, dual-axis XY joystick, ultrasonic sensors (HC-SR04), 20x4 I2C LCD, DC motors, and a 12V battery. The software component was developed in the Arduino, implementing logic to control motor direction and speed based on PWM values and joystick input. Testing was conducted to measure the accuracy of the ultrasonic sensor, the effect of PWM values on motor speed, and the overall functionality of the system under varying loads.

The stages carried out in the electric wheelchair design research using PWM control are:

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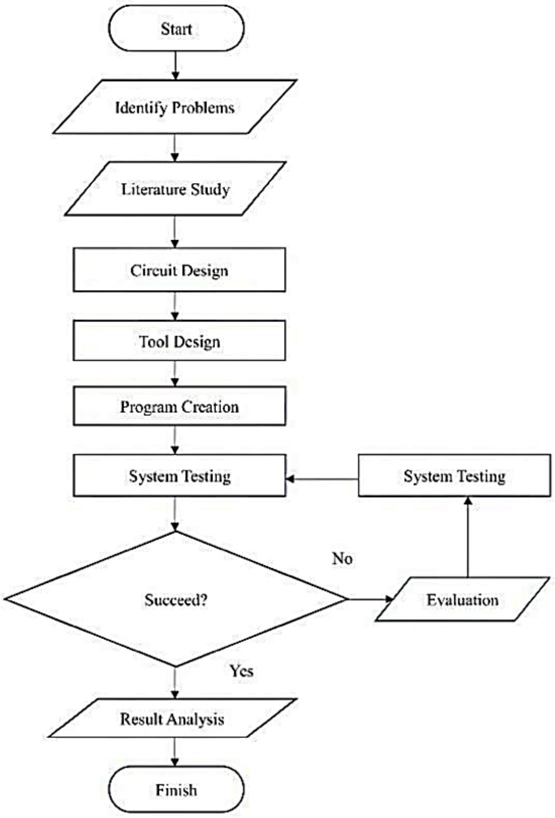

Figure 1. Research Flowchart

2.1. System Design

The design of electrical wheelchairs using Arduio Uno is shown in the Figure 2:

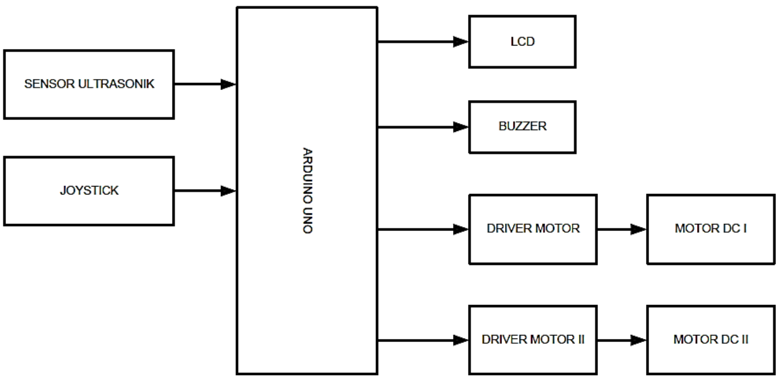

Figure 2. System Design of Electric Wheelchairs

The functions of these components are as follows:

1. Arduino Uno : functions as the controller of the entire system.
2. The joystick : as a control lever for forward, backward, right and left turns, and as a speed controller for the wheelchair.
3. The ultrasonic sensor is used to detect obstacles at a certain distance. This sensor is used to detect the distance of objects behind the wheelchair.
4. The motor driver is used to operate the DC motor.
5. The LCD is used to display data [7]
6. The buzzer is used as an audible indicator when the sensor detects an obstacle at a predetermined distance [8].

2.2. Hardware Design

The schematic of the whole system is made to connect ultrasonic sensors and joysticks as inputs to Arduino, LCD, motor drivers, DC motors, and buzzers as outputs.

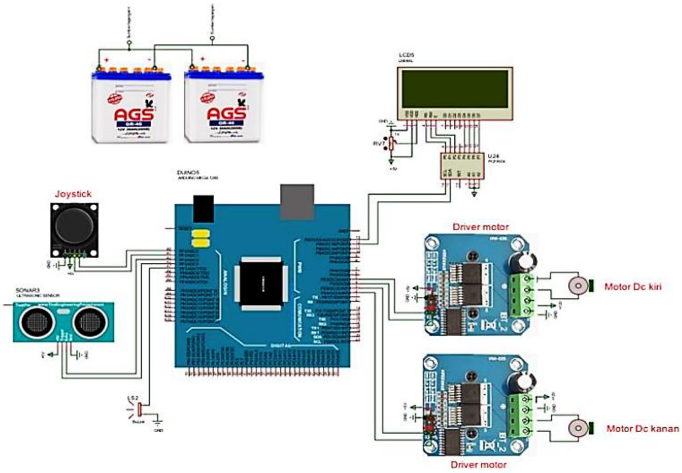

Figure 3. The Schematic of the Whole System

2.3. Electric Wheelchairs Design

The electric wheelchairs designed with spesifications :

1. Total height : 130 cm
2. Width : 60 cm
3. Total Length : 70 cm

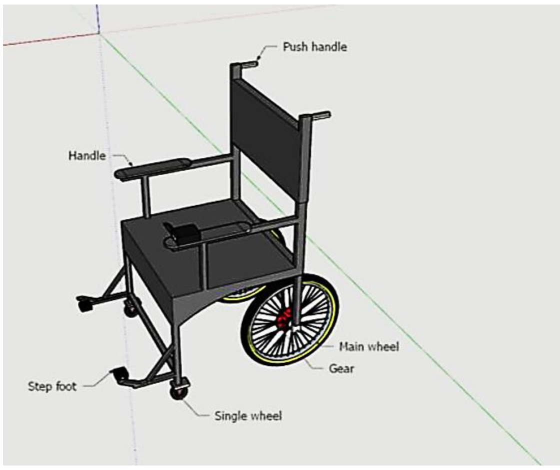

Figure 4. Electric Wheelchairs Design

2.4. Testing Design

Data errors are obtained by comparing the actual measurement distance with the measurement distance by the sensor. The percentage error formula is as follows:

Error = $\frac{(x-y)}{x} \cdot 100\%$ ……………………………………………………………………………………… (1)

With x is actual value of distance measurement results and y is distance value measured by sensor.

The wheelchair speed can be calculated using the formula :

V = $\frac{s}{t}$ with V is speed (m/s), s is distance (m), and t is travel time (s) ……………………………………….. (2)

3. Results and Discussion

3.1. Electric Wheelchairs Design Result

The mechanical system is designed using iron as the main material. Meanwhile, the seat, back seat, and armrests are made of 6 mm plywood. At the bottom of the seat, there are two motors that drive the wheelchair. To control forward/backward/right/left movements, uses a joystick located on the armrest. On the joystick, a potentiometer controls the wheelchair's speed using Pulse Width Modulation (PWM). The LCD and I2C are installed on the armrest to control the wheelchair and display the distance read by the ultrasonic sensor. The DC motor placed under the wheelchair seat is used to drive the wheelchair automatically. The DC motor functions as the automatic drive for the wheelchair. A controller box at the back of the wheelchair is where the microcontroller and battery are placed. The battery capacity used in this device is 12V 8.2 AH. The battery is used as a power supply to drive the wheelchair and control the output power of the motor.

Figure 5. Electric Wheelchairs Design Result

3.2. Testing the Sensitivity of the Ultrasonic Sensor

Ultrasonic sensor is used to detect obstacles behind the wheelchair. When the sensor detects an obstacle at a certain distance, the wheelchair will automatically stop. Sensitivity testing reads the errors generated by the sensor. Error data is obtained by comparing the measurement distance by the sensor and a ruler. The sensitivity testing of the ultrasonic sensor can be seen in Table 1.

Table 1. Sensitivity Testing by Using the Ultrasonic Sensor

No	Distance measured by Ultrasonic Sensor (cm)	Distance measured by Ruler (cm)	Error (%)
1	0	0	0
2	5	5	0
3	10	10.5	4.7
4	15	15.2	1.3
5	20	20	0
6	25	25	0

Average Error = $\frac{number\ of\ data\ errors}{total\ data}\ x\ 100\% = \frac{0+0+4.7+1.3+0+0}{6}\ x\ 100\%$ = 1%

Based on testing, this ultrasonic sensor has a low error rate. An error rate of 1% is still tolerable because the ultrasonic sensor datasheet specifies an accuracy level of +/- 2 cm.

3.3. Testing the Effect of Obstacle Distance Through Wheelchair Movement

If the sensor detects an obstacle, the motor will automatically stop. Test data on the effect of obstacle distance on wheelchair movement can be found in Table 2.

Table 2. Sensitivity Testing by Using the Ultrasonic Sensor

No	Barrier Distance (cm)	DC Motor Condition	Buzzer Condition
1	160	On	Off
2	140	On	Off
3	120	On	Off
4	100	On	Off
5	80	Off	On
6	60	Off	On
7	40	Off	On
8	20	Off	On

DC motors will be active when the distance between the wheelchair and an obstacle is <80 cm. However, when the distance between the wheelchair and an obstacle is >80 cm, the DC motor will turn off.

3.4. Electric Wheelchairs Motion Testing Through Joystick Control

The joystick used is a dual-axis xy joystick module. The movement of the joystick, either vertically (axis x) or horizontally (axis y), will produce an analog value ranging from 0 to 1023. This analog value will be converted into a PWM value. Then the PWM value is converted into a voltage value by the driver to move the motor. The PWM value set in the system is 0-255. The PWM value will affects wheel speed. The higher the PWM value supplied, the higher the voltage produced, which causes the DC motor driving the wheelchair wheels to move faster.

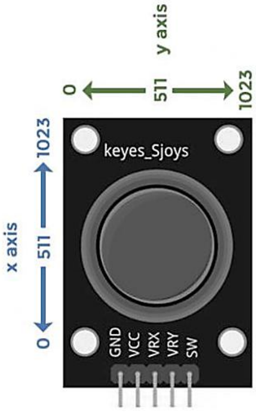

Figure 6. Dual Axis xy Joystick Module

3.5. The Effect of PWM Value Changes on Voltage Conditions on the X-axis and Y-axis of a Joystick

To move the wheelchair forward or backward, the user only needs to move the control lever on the joystick vertically (Axis x). This movement will change the analog value displayed on the serial monitor. This analog value will be converted into a PWM value, then converted into a voltage value by the driver. The effect of changes in PWM values through the voltage condition on axis x can be seen in Table 3.

Table 3. Changes in PWM Value to X-axis Voltage Conditions

No	Analog x	PWM Value	Voltage (V)	Wheelchair Condition
1	0	255	10.5	Reverse
2	45	188	7.5	Reverse
3	112	161	6.0	Reverse
4	132	144	5.0	Reverse
5	309	65	1.5	Reverse
6	511	30	0.0	Stop
7	563	53	0.7	Forward
8	754	118	5.0	Forward
9	808	140	6.3	Forward
10	999	246	10.5	Forward
11	1023	255	10.6	Forward

When the joystick is not moved, the control lever will be in the center position. At this position, the analog value of the joystick is 511. When the joystick control lever is moved, the analog value will change according to the condition of the lever. If the joystick lever is moved on the x-axis upward (↑), the analog value when the lever is moved to the maximum position is 1023. When the analog value reaches its maximum value, the PWM value will also be at the maximum value of 255. Similarly, when the joystick lever is moved downward on the x-axis (↓), the analog value when the lever is moved to its maximum position is 0. When the analog value reaches its maximum value, the PWM value will also be at the maximum value of 255. Based on the data, the higher the PWM value, the higher the voltage produced. The voltage is used to drive the motor wheels. The wheelchair's position will move according to the joystick lever's movement. If the joystick lever is moved upward (on the x-axis), the wheelchair will move forward. Similarly, when the joystick lever is moved downward (on the x-axis), the wheelchair will move backward. The position of the joystick lever on the x-axis can be seen in Figure 7.

Figure 7. Joystick Lever Position on the X-axis

To move the wheelchair to the left and right, user only needs to move the joystick control lever horizontally (Axis y). The effect of changes in PWM values through voltage conditions on the y-axis can be seen in Table 4.

Table 4. Changes in PWM Value to Y-axis Voltage Conditions

No	Analog y	PWM Value	Voltage (V)	Wheelchair Condition
1	0	255	11.5	Left
2	57	197	7.5	Left
3	101	158	6.0	Left
4	172	125	5.0	Left
5	498	65	1.5	Left
6	511	30	0.0	Stop
7	578	68	4.0	Right
8	698	118	5.0	Right
9	776	140	6.3	Right
10	974	246	10.5	Right
11	1023	255	10.8	Right

When the analog value is 511, the voltage is 0.0V which the control lever is in the undrawn position,. At this position, the control lever is at the center. When the joystick control lever is moved, the analog value changes according to the lever's position. If the joystick lever is moved along the Y-axis to the right (→), the analog value when the lever is moved to the maximum position is 1023. When the analog value reaches its maximum, the PWM value will also be at the maximum value of 255. Similarly, when the joystick lever is moved on the y-axis to the left (←), the analog value when the lever is moved to its maximum is 0. When the analog value reaches its maximum, the PWM value will also be at the maximum value of 255. The wheelchair's position will move according to the joystick's position. If the joystick is moved on the y-axis to the right (→), the wheelchair will move to the right. When the joystick is moved on the y-axis to the lower left (←), the wheelchair's position will also move to the left. The joystick's position on the y-axis can be seen in Figure 8.

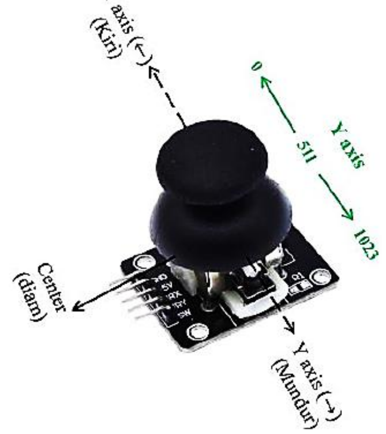

Figure 8. Joystick Lever Position on the Y-axis

3.6. The Effect of PWM Values on DC Motor Speed in Wheelchairs

To observe the effect of PWM value changes on DC motor speed, testing is required. Testing was conducted while the wheelchair was moving forward, with the same distance and road conditions but different loads. Data on the effect of PWM value on DC motor speed can be seen in Table 5.

Table 5. The Effect Of Changes In PWM Value On Travel Time

Load (kg)	Distance (m)	Travel Time (s)				
		15% D	23% D	31% D	39% D	47% D
40	10	38.2	26.2	18.9	14.7	11.9
50	10	40.3	27.1	19.4	15.2	14.1
60	10	43.0	28.6	20.3	16.1	15.2
70	10	45.4	30.4	22.1	17.9	16.0
80	10	50.5	32.8	24.0	18.2	17.3

D (Duty cycle) is the time ratio when signal from a device is in the active (ON) divided by the total cycle time (period of time). divided by the total cycle time (period of time). The wheelchair speed can be calculated using the formula on Equation 2. From the Table 6, the greater the load, the smaller the travel time produced.

Table 6. Speed Calculation Results Based on Changes in PWM Value

Load (kg)	Distance (m)	Speed (m/s)				
		40 PWM	60 PWM	80 PWM	100 PWM	120 PWM
40	10	0.26	0.38	0.53	0.68	0.84
50	10	0.24	0.36	0.51	0.66	0.70
60	10	0.23	0.35	0.50	0.62	0.65
70	10	0.22	0.33	0.49	0.58	0.62
80	10	0.20	0.30	0.41	0.55	0.57

Table 6 shows that the higher the PWM value and the lower the load, the faster the wheelchair will move. Otherwise, the lower the PWM value and the higher the load, the slower the wheelchair will move. From the data, when the PWM value given is 40 with a load of 40 kg, the wheelchair speed is 0.26 m/s. However, at the same PWM value, as the load increases, the speed of the wheelchair decreases.

When the wheelchairs are loaded with the same value (40 kg), but with different PWM values, the wheelchair speed also changes. It can be concluded that the higher the PWM value, the faster the wheelchair moves.

4. Conclusion

This research successfully designed and implemented an electric wheelchair controlled through Pulse Width Modulation (PWM) with Arduino Uno. The system effectively translated joystick input into direction and speed control and incorporated ultrasonic sensors for obstacle detection. Testing confirmed that the system has high sensor accuracy with only 1% average error, the motors stop when obstacles are detected within 80 cm, and the wheelchair speed increases with higher PWM values and decreases with heavier loads. Future work could include integrating GPS for theft protection and adding automatic charging functionality

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