Motor Speed Control toward Wall Surface Angle based on HC-SR04 Ultrasonic Sensor

Peri Turnip[1], Erwin Sitompul[2], Bambang Mukti Wibawa[3], Agus Trisanto[3], and Arjon Turnip[3*]
[1]*Computer Engineering, Politeknik Pajajaran, Bandung,Indonesia*
[2]*Study Program of Electrical Engineering, Faculty of Engineering, President University, Indonesia*
[3]*Department of Electrical Engineering,Universitas Padjajaran, Bandung, Indonesia*

Keywords: Brain-Controlled Wheelchair, Control Motor DC with PWM.

Abstract: Brain-controlled wheelchair is an assisting device for patients with motor disabilities controlled by brain waves. The convenience and security of users is the focus of the development of brain-controlled wheelchairs. In this final task was designed dc motor speed control system using pulse width modulation (PWM) method on a different surface slope using ultrasonic sensors. With this method it is expected that the wheelchair can move at different speeds under certain surface conditions. This way the concept of security of the user will be fulfilled for the future. The detection distance of the obstacle object is influenced by the intensity of humidity, namely the drier the place gives more accurate results in its measurement. Research on motor speed controllers can use other control methods to ensure that motor speed is stable on flat and sloping surfaces, and to improve processing speed and object detection accuracy.

1 INTRODUCTION

Wheelchairs are usually used to help move people with partial or total paralysis. Conventional or joistic wheelchairs whose movements must be assisted by other people or hand movements have not been able to help people who are completely paralyzed to move or move independently. Thus, for people with total paralysis, a wheelchair that can be moved through the mind is needed. The majority of people with total paralysis can still think well. This brain signal activity will then be used to move the motor instead of joistic. The development of this technology is supported by the development of biosignal science which is able to identify and classify brain signals for specific functions.

The ability to move freely is the desire and need of each individual. Especially for people with disabilities who have limited space. Not all persons with disabilities can use their own wheelchair to travel, therefore with the help of technology a Smart Wheelchair or Electric Wheelchair is developed based on control using physiological brain waves. Physiological brain waves can be used to control wheelchair movement (such as forward, stop, turn right, or turn left) by recording and analyzing brain biosignals. Electroencephalogram (EEG) is used to record biosignals from the brain which can then be used to run a wheelchair. In this case, control is carried out of the user's brain signal activity supported by several instruments such as sensors.

EEG is a device that captures the activity of bioelectrical signals recorded from electrodes on the scalp. In medicine, EEG is used to diagnose diseases such as Alzheimer's and epilepsy. In this case, EEG can be used as a controller that utilizes these bioelectrical signals. The processing of data obtained from the EEG makes it possible to group one's thoughts in the form of waves. This can be used as information for controllers, by adjusting the data that has been trained to control wheelchair movement.

This wheelchair with EEG system cannot reduce and increase the motor speed. EEG based signals can only be used for certain movements such as forward, backward, turn, stop. Therefore, in developing the Brain-Controlled Wheelchair system, several additional sensors are needed to obtain certain information such as detecting obstacles, road slopes, and others. Several studies related to brain-wheelchair development have been carried out [Turnip, A et al 2015; Turnip, M et al 2015].

In a previous study on smart wheelchairs, entitled Ultrasonic Tethering to Enable Side-by-Side Following for Powered Wheelchairs, tested and built

Turnip, P., Sitompul, E., Wibawa, B., Trisanto, A. and Turnip, A.
Motor Speed Control toward Wall Surface Angle based on HC-SR04 Ultrasonic Sensor.
DOI: 10.5220/0010370900003051
In *Proceedings of the International Conference on Culture Heritage, Education, Sustainable Tourism, and Innovation Technologies (CESIT 2020)*, pages 630-637
ISBN: 978-989-758-501-2

a system using an ultrasonic sensor where a wheelchair can detect someone to be used as a guide in moving (Pingali et al., 2019)). Another study using ultrasonic sensors in wheelchairs is "Low cost sensor network for obstacle avoidance in share-controlled smart wheelchairs under daily scenarios" by (Pu et al., 2018). In this journal, four cheap ultrasonic sensors are used on the underside of the front of the wheelchair to detect obstacles in front of and below the wheelchair. A fuzzy logic navigation controller implemented in hardware for an electric wheelchair by (Rojas et al., 2018; Turnip et al, 2015; Turnip et al, 2015) uses ultrasonic sensors with the help of a fuzzy logic algorithm in determining direction decisions on wheelchair movement. Smart Navigation and Control System for Electric Wheelchair" by (Dakhilallah et al., 2019) also uses ultrasonic sensors as an aid in navigation. In the paper, it is explained that in addition to ultrasoic sensors, a controller using a joystick is also built as a navigation aid. Smart Autonomous Wheelchair Controlled by Voice Commands-Aided by Tracking System explains how to control a wheelchair using voice commands and also uses a tracking system to find out the position of the wheelchair itself (Alkhalid & Oleiwi, 2019). Autonomous Wheelchair with a Smart Driving Mode and a Wi-Fi Positioning System discusses the integration design using GPS and wifi as a navigation tool while security uses ultrasonic sensors and IR sensors (Manjunath, 2018; Turnip et al, 2015).

Controlled Wheelchair System Based on Gyroscope Sensor for Disabled Patients examines an electric wheelchair that is controlled using motion using an ultrasonic sensor as a safety device from obstacles (Al-Neami & Ahmed, 2018). In this study, it was also explained that the head movement data used were obtained from a gyroscope sensor mounted on the user's head. Voice Recognition based on Intelligent Wheelchair and GPS Tracking System explains that a wheelchair can be operated by voice command by using firebase to control the direction of the wheelchair for both forward and backward (Aktar et al., 2019). Autonomous wheelchair under a predefined environment implements an electric wheelchair operating system by using a keypad as a controller in movement and using an IR sensor and also an Ultrasonic sensor as an obstacle detection system (Roslan et al., 2017). Smart Wheelchairs: Using Robotics to Bridge the Gap between Prototypes and Cost-effective Set-ups designed a wheelchair with automatic and manual control, where manual control uses a joystick as the controller and also uses an Ultrasonic Sensor as a detecting obstacle and obstacle course (Aquilina et al. al., 2019).

From all the journals that have been mentioned above, there are many studies taking references on how best ultrasonic sensors can work properly by combining them with several other sensor devices. However, in this study the ultrasonic sensor is used in a different way, namely to measure the angle of the wall surface or other obstacle. Furthermore, the tilt information will be used to adjust the motor rotation speed. Ultrasonic sensor (HC-SR04) is used as a tool to calculate the slope angle to support the brainsignal-based wheelchair motor controller from the EEG system.

A motor speed control system with a pulse width modulation (PWM) method on a different surface slope using an ultrasonic sensor is designed. With this method, it is expected that wheelchairs can move at different speeds in certain surface conditions. However, this system still has limitations where the measurement results obtained are still less precise.

2 THEORY

2.1 Brain-controlled Wheelchair

Brain-Controlled Wheelchair is a technology that combines a wheelchair with a Brain-Computer Interface (BCI) with the aim of helping wheelchair control to make it easier for people with motor disorders. BCI can communicate directly between the computer and the brain. This allows wheelchair surgery to use commands from the brain's physiological signals while thinking. BCI is able to represent the user's thoughts into controlling wheelchair movement according to the user's wishes.

2.2 Ultrasonic Sensor HC-SR04

Ultrasonic sensor HC-SR04 is a sensor measuring distance based on ultrasonic waves with a working principle: the emitted ultrasonic waves are then received back by the sensor receiver itself, then detects any object in front of it in the form of a solid object or a barrier. The detection range is 2-500cm, the detection angle is 15 degrees, and can be connected directly to the Arduino microcontroller input / output (Saputra, 2013). The HC-SR04 has two main components as a constituent in the form of a transmitter emitting ultrasonic waves with a frequency of 40 KHz and the receiver capturing the results of ultrasonic wave reflections (Setyawan et al., 2018).

2.3 Arduino UNO R3

Arduino UNO R3 is a microcontroller development board based on the ATmega328P chip. Arduino UNO has 14 gigital pins input / output pins (I / O, of which 14 pins can be used as Pulse Wiidth Modulation (PWM) output, including pins 0 to 13), 6 analog input pins, using a 16 Mhz crystal, including pin A0 to A5, USB connection, power jack, ICSP header and reset button. All of these pins are required to support a microcontroller circuit. The worst possibility is just damage to the ATMega328 chip, but it can be replaced easily and relatively cheaply. Since the initial launch until now, Uno has developed into a Revised 3 version or commonly written as REV 3 or R3. Arduino IDE software, which can be installed on Windows as well as Mac and Linux, functions as a software that helps you enter (upload) programs to the ATMega328 chip easily (Hasriyani & H, 2018).

Integrated Development Environment (IDE) is a software used to develop microcontroller applications starting from writing source programs, compiling, uploading compilation results and testing in serial terminals. Arduino can be run on computers with various platforms because it is supported or based on Java. The source program for microcontroller applications is C / C ++ and can be combined with assembly.

2.4 Pulse with Modulation

One way to adjust the rotational speed of a dc motor is by means of pulse width modulation (PWM). Pulse width modulation (PWM) is a way of manipulating the pulse width in one. PWM signals generally have a fixed basic amplitude and frequency, but have varying pulse widths. The PWM Pulse Width is directly proportional to the amplitude of the original unmodulated signal. This means that the PWM signal has a fixed wave frequency but the duty cycle varies (from 0% to 100%) (Hasriyani & H, 2018). Duty cycle is the percentage of high pulse length in one signal period. When the duty cycle is 0% or the signal is fully low, the value of the voltage output is 0V. When the duty cycle is 100% or the signal high is full, the voltage output is 5V.

The PWM that can be generated by Arduino has a data allocation of 8bit, or has a variation of parameter value changes ranging from 0 - 255, a change in value that represents the duty cycle of 0 - 100% of the PWM output. To set the duty cycle value on Arduino, use the analogWrite function ([Pin number], [value]). If the duty cycle is to 0% and 100%, then set the parameter values to be 0 and 255, respectively. So the duty cycle is 50%, meaning that the parameter value that must be set is 127. PWM graph can be seen as in Figure 1.

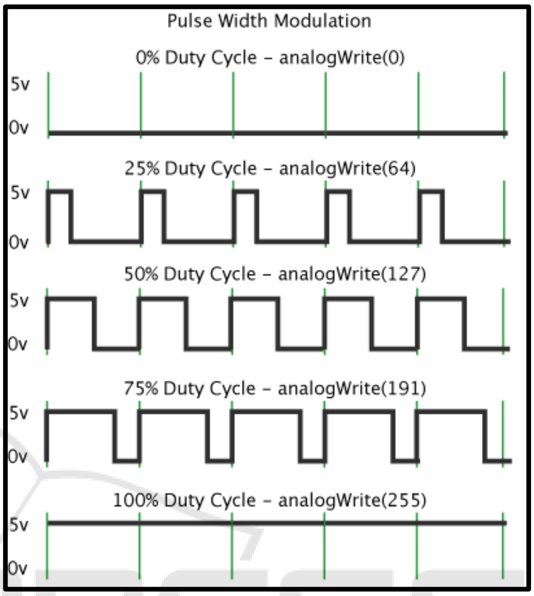

Figure 1: PWM graph.

3 DESIGN AND DEVELOPMENT

Ultrasonic sensor signal processing aims to determine the accurate distance between a wheelchair and a wall in an inclined or non-vertical position. The signal that is obtained is data from the sensor on objects that are obstructions in front, side and back of the wheelchair. The design of a speed control system for the wall surface slope using an Ultrasonic sensor is illustrated in Figure 2. The system workflow starts from reading the distance data on the Ultrasonic sensor. The distance data from the two sensors as a reference for flat and tilted surfaces is processed by Arduino UNO R3. Furthermore, Arduino will be given a program with an if condition, if sensor *a* is the same as sensor *b* then it is assumed that the sensor detects a flat surface, otherwise if one of the sensors reads the distance is less then it will be detected as a sloping surface. PWM control provides control action on the motor based on the distance obtained where if the surface detected is flat, the motor will reduce the speed according to the predetermined speed, conversely if the surface is detected is tilt, the motor speed will be lowered according to the angular conditions obtained in the calculation by the system.

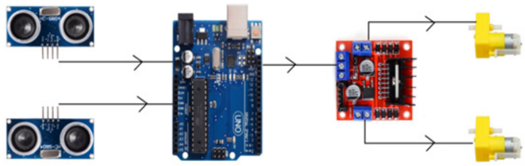

Figure 2: Sheme of velocity control system for wall surface slope using Ultrasonic sensor.

3.1 Motor Speed Control Design

The ultrasonic sensor added to the wheelchair system is a device used to read the distance of an object or object surface that will be traversed by a brain-controlled wheelchair. Furthermore, the motion controller is used to determine the precision of an instrumentation system with the characteristics due to good feedback on the system. Motion Controller is used as a speed controller by providing control action on the DC motor based on the distance value obtained. Furthermore, the DC motor will provide a speed value that is close to the desired value in the form of a Set Point value.

3.2 Obstacle Detection System Design

Motion Control usually refers to a system with accurate position, speed, torque capability that operates in open or closed loop mode. The open-loop drive sends a Movement command to the DC motor, but receives no information about the result. The closed loop system has a feedback device on the motor shaft to verify or adjust the resulting motion.

The initial stage begins with data acquisition from TrigPin by ultrasonic sensors (Figure 3). The calculation process is carried out at the recorded wavelength and the system will divide the wave according to the equation used to convert the wavelength into a measurable distance. In processing signals from ultrasonic sensors, the concept of median-filter is used as a reference so that the data obtained has less noise and good quality. The Median-Filter has a characteristic: it only uses some of the data obtained previously and is then processed to produce an accurate value by taking the middle value of some of the data collected and has sufficient accuracy because it always performs calculations when the sensor reads new data. The filter aims to minimize reading errors from the ultrasonic sensor. The process of measuring angles is obtained with several conditions that must be met in order to obtain accurate and consistent results. The calculation of angles and distances is obtained from equations (1) and (2). The calculation process is expressed in Figure 4. The wheelchair kinematic model is used as a reference in calculations to determine the wheel speed whether the wheel rotates more to the left or right.

```
class Sonar{
  //These wont change
  int TrigPin;
  int EchoPin;
  int MaxDistance;                    //
Maximum range allowed in mm
  float TrustFactor;
  int PreviousDistance;
  //These will change
  int CurrentDistance;
  public:
  Sonar(int trigpin, int echopin, int
maxdistance, float trustfactor){
    TrigPin = trigpin;
    EchoPin = echopin;
    MaxDistance = maxdistance;
    TrustFactor = trustfactor;
    pinMode(TrigPin,OUTPUT);
    pinMode(EchoPin,INPUT);
    digitalWrite(TrigPin,LOW);
    }
  int Measure(){
    digitalWrite(TrigPin,HIGH);
    delayMicroseconds(10);
    digitalWrite(TrigPin,LOW);
    int Time =
pulseIn(EchoPin,HIGH,5000);
    CurrentDistance = (Time/2)/29.1;
    if (CurrentDistance == 0){
      CurrentDistance = MaxDistance;
      }
    return CurrentDistance;
    }
  int Filtered(){
    CurrentDistance =
constrain(PreviousDistance*(1-
TrustFactor) +
Measure()*TrustFactor,0,MaxDistance);
    PreviousDistance = CurrentDistance;
    return CurrentDistance;
    }
};
```

Figure 3: Recording and division process of recorded wavelengths to get the closest wheelchair distance with the wall.

$$\theta = \tan^{-1}\left(\frac{a-b}{Lu}\right) \tag{1}$$

where, θ is the angle formed from the results of calculations that have been done, Lu is the distance between the ultrasonic sensor a and the ultrasonic sensor b, a is the distance between the ultrasonic sensor a and the wall, and b is the distance between the ultrasonic sensor b and the wall.

$$h = \left(\frac{a+b}{2}\right)\cos\theta \tag{2}$$

where θ is the angle formed from the results of the calculations that have been done, h is the actual distance between the wheelchair and the wall.

The following equation (3) is used to convert the angle value into radians so that it can be recognized by Arduino;

$$n = N\frac{\pi}{180} \quad (3)$$

where, n is the value of the angle of the degree you want to find, N is the radian value that we know beforehand, and is a value that contains 3.14.

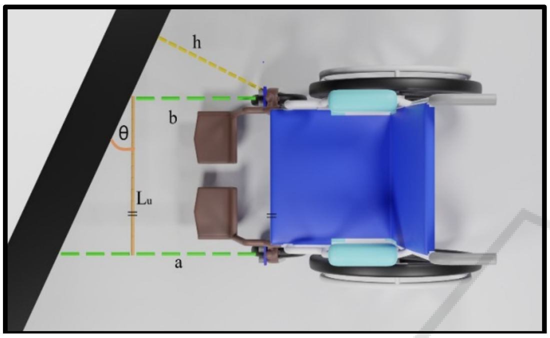

Figure 4: Calculation of the distance of a wheelchair to a sloping wall.

4 RESULTS AND DISCUSSIONS

Tool testing is carried out on hardware by obtaining data using the serial monitor from the Arduino IDE. The data obtained include: distance data read by the ultrasonic sensor by testing the distance, angle and velocity. The actual distance was measured as comparative data for the results from the system. Ultrasonic sensor test data aims to determine how much influence the distance between the object and the rotation speed of the DC motor wheel.

The waves from the ultrasonic sensor are sent by setting the pin in the input state or as output on the microcontroller. The distance was obtained by calculating the speed of propagation of the wave against the time difference between the transmitter of the wave by the transmitter and the time when the reflected wave is received by the receiver. The received distance is processed again to get the results from the calculations between several sensors installed. The data is processed to obtain accurate angles and distance calculations. The following is a snippet of program code for the change process from the distance received by the sensor to be converted into the desired distance (Figure 4). *Ba* is a variable that is made to accommodate the value of the reduction between sensors *a* and *b* then it is divided by the distance between the two sensors. Su is a variable created to accommodate the tan-1 value of Ba; Cs is a variable created to accommodate the cos value of Su; h is the ideal distance that you are looking for or you can also call it the setpoint. After fulfilling the conditions described in the program code, then the wheelchair speed is from the distance that has been obtained. Figures 5 and 6 are the program code for distance and the speed control of a dc motor.

```
double Ba,Su,h;
    double Cs,degress;
    if(sonar1.Measure()>sonar2.Measure() ||
sonar1.Measure()==sonar2.Measure()){
       Ba = (sonar1.Measure()-
sonar2.Measure())/12;
       }else{
       Ba = (sonar2.Measure()-
sonar1.Measure())/12;
       }
       Su = (atan(Ba)*180/3.14); //nila dari
Ba tadi masukkan untuk mendapatkan
perhitungan yang mutlak
       Cs = cos(Su); //Cs variabel yang di
buat untuk menampung nilai dari variabel
perhitungan dari COS Su.
       h  =
((sonar1.Measure()+sonar2.Measure())/2)*Cs;
       if (h<(-1)){
         h = h*-1;
       }
```

Figure 5: Program code snippets for distance calculation.

```
if(h>100 && h<200){
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    digitalWrite(in3,HIGH);
    digitalWrite(in4,LOW);
    analogWrite(enA, 255);
    analogWrite(enB,255);
    Serial.print(255);

    }else if (h>=50 && h<100)
{
    digitalWrite(in1, LOW);
    digitalWrite(in2, LOW);
    digitalWrite(in3,LOW);
    digitalWrite(in4,LOW);
    analogWrite(enA, 200);
    analogWrite(enB,200);
    Serial.print(200);
   }else if (h>40 && h<50){
    digitalWrite(in1, LOW);
    digitalWrite(in2, LOW);
    digitalWrite(in3,LOW);
    digitalWrite(in4,LOW);
    analogWrite(enA, 150);
    analogWrite(enB,150);
    Serial.print(150);
   }
```

Figure 6: Code for setting motor speed.

Object detection testing using two ultrasonic sensors was carried out to determine the success in the detection of angles and distances with the processing process that had been designed. The simulation calculation results to get the closest distance to the wheelchair and the change in the motor rotation speed to the change in angle can be seen as in Table 1 where θ is the change in angle, a and b are the distance of each sensor on the wall (cm), h is the calculated closest distance v is the rotational speed of the motor due to the change in distance h, and Lu is the constant distance between sensors.

Table 1: Calcualtion resuts on simulation with disferent angels.

θ	a	b	h	v	Lu
75	50	5	7.1	0	12
70	50	17	11.45	0	12
65	50	25	16.22	0	12
60	50	29	20	0	12
55	50	33	24	0	12
50	50	36	28	32	12
45	50	38	31	32	12
40	50	40	35	32	12
35	50	41.5	37	40	12
30	50	43	40	40	12
25	50	44.5	42	50	12

The results of manual calculations in Table 1 show that when the h value is less than 28 cm, the v value automatically becomes zero, which means that the wheel rotation stops. In this case the wheelchair will wait for information from other sensors such as cameras or brain signals to decide whether to stop or turn (left or right) or reverse. When the distance or h value is greater than or equal to 28 cm, the wheel rotation becomes 28 rad / s and will continue to increase as the h value is greater. If the wheelchair moves towards the wall at a certain angle, the sensor will calculate the closest distance before the wheelchair hits the wall. Because the angle θ is less than 90 degrees, the distance between the wheelchair and the wall will differ between sensors, so it is necessary to estimate it.

Figure 7 shows the test results displayed using a serial monitor in realtime where the distance and speed generated on the monitor screen work in accordance with the conditions obtained. Figure 8 is the print result of the serial plotter where it can be seen that the ultrasonic sensor distance changes quickly. These changes occur because of the disconnection of sensors in detecting objects. With the help of filters and averaging this problem can be solved. If this result is used directly to the motor rotation it will result in unstable wheelchair movement. Further development related to this problem needs to be done, namely by increasing the ability of filters and estimators. In this experiment, the results of this problem can still be resolved considering that testing is still limited. However, if applied with a wheelchair on a varied track, it is assumed that the stability will decrease.

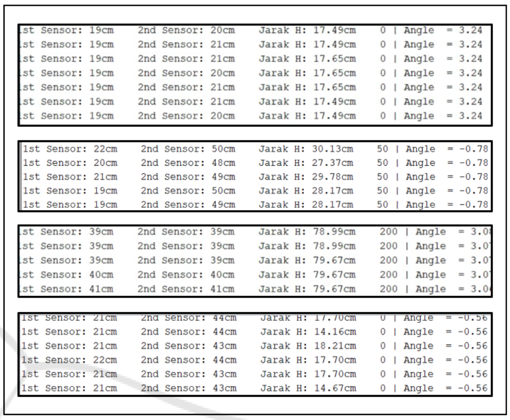

Figure 7: Realtime Test Using Serial Monitor.

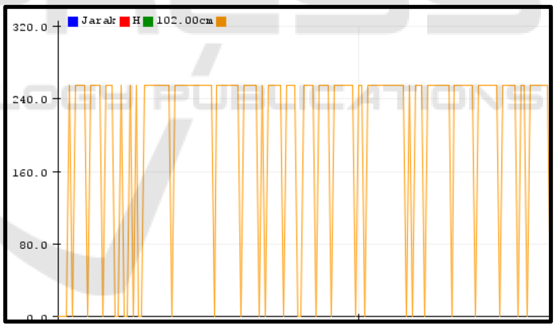

Figure 8: Serial plotter display.

5 CONCLUSIONS

The object detection system based on the ultrasonic sensor with a direction at a certain slope is able to recognize obstacles in the form of walls in realtime. A filtering system to minimize unwanted values due to sensor limitations as well as changes in wheelchair direction has been developed with accurate results. The detection distance of the obstacle object is influenced by the intensity of humidity, namely the drier the place gives more accurate results. Research on motor speed controllers can use other control methods to ensure that motor speed is stable on flat and sloping surfaces, and to improve processing speed and object detection accuracy. The offline and realtime test results show fairly accurate results where a wheelchair is able to detect objects in the form of walls at an angle of less than 90 degrees.

Incorporation of additional sensors such as an ultrasonic sensor to detect paths before the IMU sensor detects surface slope is necessary. The motor used must be equipped with a speed reading so that the accuracy of the speed reading can be better.

ACKNOWLEDGEMENTS

This research was supported by Technical Implementation Unit for Instrumentation Development, Indonesian Institute of Sciences, Department of Electrical Engineering, Universitas Padjadjaran, and Toba Research Center, Indonesia.

REFERENCES

Aktar, N., Jaharr, I., & Lala, B., 2019. Voice Recognition based intelligent Wheelchair and GPS Tracking System. 2nd International Conference on Electrical, Computer and Communication Engineering, ECCE 2019, February. https://doi.org/10.1109/ECACE.2019.8679163.

Al-Neami, A. Q. H., & Ahmed, S. M., 2018. Controlled Wheelchair System Based on Gyroscope Sensor for Disabled Patients. Biosciences Biotechnology Research Asia, 15(4), 921–927. https://doi.org/10.13005/bbra/2703.

Alkhalid, F. F., & Oleiwi, B. K., 2019. Smart Autonomous Wheelchair Controlled by Voice Commands-Aided by Tracking System. Iraqi Journal of Computer, Communication, Control and System Engineering, 82–87. https://doi.org/10.33103/uot.ijccce.19.1.10

Aquilina, M., Bugeja, M. K., & Fabri, S. G., 2019. Smart wheelchairs: Using robotics to bridge the gap between prototypes and cost-effective set-ups. ICINCO 2019 - Proceedings of the 16th International Conference on Informatics in Control, Automation and Robotics, 2(Icinco), 181–189. https://doi.org/10.5220/0007796801810189.

Dakhilallah, B., Alrashdi, S., Rao, K. P., & Alotaibi, N. D., 2019. Smart Navigation and Control System for Electric Wheelchair American Journal of Engineering Research (AJER). 4, 90–94.

Hasriyani, & H., 2018. Bab II tinjauan pustaka BBLR. 5, 1–40. http://eprints.undip.ac.id/62287/4/BAB_II.pdf

Ii, B. A. B., 2001. Universitas Sumatera Utara 6. 1(2), 6–38.

Manjunath, G., 2018. Autonomous Wheelchair with a Smart Driving Mode and a Wi-Fi Positioning System. April.

Pingali, T. R., Lemaire, E. D., & Baddour, N., 2019. Ultrasonic tethering to enable side-by-side following for powered wheelchairs. Sensors (Switzerland), 19(1). https://doi.org/10.3390/s19010109

Pu, J., Jiang, Y., Xie, X., Chen, X., Liu, M., & Xu, S., 2018. Low cost sensor network for obstacle avoidance in share-controlled smart wheelchairs under daily scenarios. Microelectronics Reliability, 83(March), 180–186. https://doi.org/10.1016/j.microrel.2018.03.003

Rojas, M., Ponce, P., & Molina, A., 2018. A fuzzy logic navigation controller implemented in hardware for an electric wheelchair. International Journal of Advanced Robotic Systems, 15(1), 1–12. https://doi.org/10.1177/1729881418755768

Roslan, M., Yahya, M., Ahmad, Z., Hani, A., & Mokhtar, I., 2017. International Journal of Advanced and Applied Sciences. Order, 14(4), 18.

Saputra, D. A., 2013. Simulasi Pemrograman Sistem Pengendali Kecepatan Pada Rancang Bangun Mobil Remote Kontrol Menggunakan PWM Berbasis Sensor Ultrasonik HC-SR04 dan Mikrokontroler Arduino. Universitas Muhammadiyah Surakarta. https://doi.org/10.1017/CBO9781107415324.004

Setyawan, B., Andryana, S., & Winarsih, W., 2018. Sistem Deteksi Menggunakan Sensor Ultrasonik berbasis Arduino mega 2560 dan Processing untuk Sistem Keamanan Rumah. J I M P - Jurnal Informatika Merdeka Pasuruan, 3(3), 15–20. https://doi.org/10.37438/jimp.v3i3.183

Subroto, T., & Sholihah, W., 2018. Analisis Hambatan Belajar Pada Materi Trigonometri Dalam Kemampuan Pemahaman Matematis Siswa. IndoMath: Indonesia Mathematics Education, 1(2), 109.

A. Turnip, M. A. Suhendra and Mada Sanjaya W. S., 2015. Brain-controlled wheelchair based EEG-SSVEP signals classified by nonlinear adaptive filter. IEEE International Conference on Rehabilitation Robotics (ICORR), Singapore, 2015, pp. 905-908, doi: 10.1109/ICORR.2015.7281318.

M. Turnip et al., "An application of online ANFIS classifier for wheelchair based brain computer interface," 2015 International Conference on Automation, Cognitive Science, Optics, Micro Electro-Mechanical System, and Information Technology (ICACOMIT), Bandung, 2015, pp. 134-137, doi: 10.1109/ICACOMIT.2015.7440192.

A. Turnip, A. I. Simbolon, M. F. Amri and M. A. Suhendra, "Utilization of EEG-SSVEP method and ANFIS classifier for controlling electronic wheelchair," 2015 International Conference on Technology, Informatics, Management, Engineering & Environment (TIME-E), Samosir, 2015, pp. 143-146, doi: 10.1109/TIME-E.2015.7389763.

A. Turnip, T. Hidayat and D. E. Kusumandari, "Development of brain-controlled wheelchair supported by raspicam image processing based

Raspberry pi," 2017 2nd International Conference on Automation, Cognitive Science, Optics, Micro Electro--Mechanical System, and Information Technology (ICACOMIT), Jakarta, 2017, pp. 7-11, doi: 10.1109/ICACOMIT.2017.8253377.

A. Turnip, D. Soetraprawata and T. A. Tamba, "EEG-SSVEP signals extraction with nonlinear adaptive filter for brain-controlled wheelchair," 2015 15th International Conference on Control, Automation and Systems (ICCAS), Busan, 2015, pp. 1870-1873, doi: 10.1109/ICCAS.2015.7364667.