THE DESIGN OF WHEELCHAIR SYSTEMS WITH RASPBERRY PI 3-BASED JOYSTICK ANALOG AND VOICE CONTROL

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Abstract. In this study, an electric wheelchair that combines two controls: joystick analog and voice control is designed. IC MCP3008 is used to navigate wheelchairs by using Joystick, where joystick analog data will be converted into digital data. The movements resulted from the joystick analog on the xAxis axis (horizontally) are the right turn and left turn, and on the yAxis axis (vertically) are forward and backward. The movements on the yAxis and xAxis axes set by the user affects the speed of the wheelchair. Meanwhile, the AMR-Voice application on Android is used to navigate wheelchairs by using sound. There are five commands in this voice control: "Forward", "backward", "left", "right", "stop". The order will be sent to Raspberry Pi 3 via the HC-06 module to then be recognized for the command. If the voice commands are received accordingly, Raspberry Pi 3 will provide an activation signal to the motor driver to move the wheelchair in the direction corresponding to the command given by the user. Voice control testing on wheelchairs is tested in quiet rooms and noisy rooms. The results of the wheelchair control testing with sound indicate that the accuracy and speed of the wheelchair response rely heavily on Internet connection and room conditions. The average response when the condition of the room is quiet is 0.16 s and when the condition of the room is noisy is 5.18 s.

Wheelchairs with joystick control and the voice made can be used for the disabled, whether for those who can move their fingers or not, at a low cost so that they can be an alternative in developing countries.

1. Introduction
Paralysis is a major issue that requires someone to use a wheelchair. The usefulness of this tool is often interpreted as accommodation for people with paralysis. Wheelchair assistance for these patients is widely approved to provide the proper running therapy for a patient who is paralyzed. The large benefits of wheelchairs can help patients in their daily activities. Unfortunately, wheelchairs generally still require the help of others to push them. But there is a time when the disabled must be able to move their wheelchair independently. Wheelchairs are needed in Indonesia because of the many disabilities in the country. Based on the data of Sakernas 2017 survey institution, the number of people with disabilities in Indonesia was 21 million. Currently wheelchairs are still widely used manually,
that is with the help of others. Psychally, a person with disabilities does not want to trouble the surrounding people. A lot of wheelchair development has been done, one of which is a wheelchair capable of being controlled with voice by using module STM32F103C6T6 (STM32) [1]. On another study, brain signal-based wheelchairs are developed with various methods of brain signal processing [2], [3], [4]. This research develops a wheelchair-control system using joystick analog and voice. Speed settings can be performed on joystick control mode. The relatively inexpensive use of components is expected to be a solution to the availability of wheelchairs with special controls for the disabled in developing countries such as Indonesia.

2. Methodology
   
   A. Raspberry Pi 3

Raspberry Pi 3 has 1GB RAM and Broadcom VideoCore IV graphics at a higher clock frequency than before that run at 250MHz. There are 40 pins or 26 pins of GPIOs on Raspberry Pi 3. In the GPIO, sensors are generally connected or used to drive the relay. GPIO is used as an alternative to Raspberry communication to a device outside, exactly like a USB port or Ethernet. The GPIO pins consist of:

1. Power supply (3.3 V dan 5 V, 2 sets each)
2. UART (Universal asynchronous receiver transmitter, 1 set)
3. SPI (Serial Peripheral Interface)
4. I2C (Inter-Integrated Circuit) –EEPROM
5. GPIO (General Purpose Input Output)
6. Raspberry Pi 3 Block Diagram

   
   ![Figure 1. Data sheet GPIO Raspberry Pi 3](image)

B. Joystick Analog

Joystick Analog is two potentiometers combined for one vertical movement (yAxis) and another for horizontal movement (xAxis). The Joystick also has a select switch. This Joystick generates 2.5 V output of X and Y when the position is not moved. Adjusting the direction of the joystick will cause the output to vary from 0V to 5V depending on the direction of the movement.
Figure 2. Analog Joystick

Configuration pin:
1. GND : Ground
2. 5V : 5V DC
3. VRx : X-axis proportional voltage
4. VRy : Y-axis proportional voltage
5. SW : Switch pushbutton

C. IC MCP3008

This IC MCP3008 is a 10-bit Analog to-Digital (A/D0 Converter) device. There are 4 pairs of false differential inputs or 8 single inputs. Differential Nonlinear (DNL) and Integral Nonlinearity (INL) are determined at ± 1 LSB. Communication with the device is performed by using a simple serial interface that is compatible with the SPI protocol. The IC MCP30008 has a conversion rate of up to 200 ksps. The MCP3004/3008 device operates at a wide voltage range (2.7 V-5.5 V).

Figure 3. IC MCP 3008

D. AMR-Voice Control

AMR-Voice is an Android application available in the Google Play store. When it is impossible for the user to type with the touch keyboard on Android, it can be replaced by saying a sentence, then Google Voice will analyze the sound it takes. Therefore, this developed voice control requires an Internet connection when used.
E. **HC-06 Bluetooth Module**

Bluetooth is one form of data communication wirelessly, based on radio frequencies. This Bluetooth module is replacing serial communication using cables. Bluetooth consists of two types of devices, namely Master (data sender) and Slave (receiver).

Communication can be done immediately after both Bluetooth modules pair the connection. Connection via Bluetooth is serial communication, namely the presence of TXD communication pins and RXD communication pins.

F. **System Block Diagram**

From the two controls used will be integrated into a system capable of navigating the direction of the wheelchair. Figure 6 is a block diagram of wheelchair control using joystick and voice control. And Figure 7 shows a control system flowchart using a joystick.

Analog Joystick produces analog data which will be converted into ADC digital data. Figure 7 shows that to move the wheelchair forward, the user must move the yAxis axis on the joystick analog until the value is larger than 600. Users can increase the speed on the wheelchair by
moving the yAxis axis on a joystick analog up to a maximum value of 1024. As for the backward movement, the user must move the yAxis axis on the joystick analog until the value is smaller than 470. The backward speed can also be adjusted by moving the yAxis axis on the joystick analog up to a maximum value of 0. As with the forward and backward movements, for the right turn the user must move the xAxis axis on the joystick analog until the value is larger than 600. Users can increase the speed on the wheelchair by moving the xAxis axis on an analog joystick up to a maximum value of 10-24. As for the left Turn movement, the user must move the xAxis axis on the joystick analog until the value is smaller than 470. The left turn speed can also be set up by moving the xAxis axis on the joystick analog up to a maximum value of 0.

![Flowchart of joystick analog control](image_url)

**Figure 7.** Flowchart of joystick analog control
In this system, the speed of the wheelchair movement is divided into two: 'normal' speed mode and 'fast' speed mode. Normal speed mode has been determined with PWM 49 and the values on xAxis and yAxis are > 600 and ≤ 800 or xAxis and yAxis are < 400 and > 200, while fast speed mode uses PWM 100 and the values on xAxis and yAxis are > 800 and ≤ 1024 or < 200 and > 0. As shown in Figure 8. These two speed modes can be used to all directions from joystick control.

While controlling the wheelchair with voice control uses an Android application: AMR-Voice. This application makes use of Google Voice feature, the data read from Google Voice will be sent via Bluetooth Android and will be received by HC-06 module. The commands that can be executed by raspberry are only five commands; namely, forward, backward, right, left, and stop. When the user gives a command other than the five predefined commands, Raspberry PI will not execute the command and the wheelchair will not respond to anything. Figure 9 is a wheelchair-controlled flowchart using voice control.

Figure 8. Flowchart of Speed Control
3. Result and Discussion

A. Wheelchair Control Testing Using Joystick Analog

Table 1. Motor Movement

| No. | Joystick Output ADC Value | Movement xAxis yAxis | Motor 1 Motor 2 | Movement Direction |
|-----|---------------------------|----------------------|----------------|-------------------|
| 1   | < 470 >= 0               | -                    | Stop CW        | Left              |
| 2   | > 600 and <= 1024        | -                    | CW Stop        | Right             |
| 3   | -                        | < 470 >= 0          | CCW CCW        | Backward          |
| 4   | -                        | > 600 and <= 1024   | CW CW          | Forward           |

This testing is done to determine the accuracy of the joystick output value to the movement of the two wheelchair motors, which represents the direction of the wheelchair movement. At the time of testing, the wheelchair uses joystick analog to turn left, then the user must shift the analog lever left so that the angle on the xAxis axis becomes < 470 and >= 0. Then, Motor 2 (M2) is moving clockwise (CW), while Motor1 (M1) is in the state of Stop. On the other hand, if the wheelchair moves right then the user must shift the analog lever right so that the angle on the xAxis axis becomes > 600 and <= 1024 then Motor1 (M1) rotates clockwise (CW) while the Motor2 (M2) is in the state of stop. For the backward movement, the user must move the analog lever backwards, so that the angle on the yAxis axis becomes < 470 and >= 0. Then both motors move counterclockwise (CCW), while for forward the movement, the user must drive Analog
lever forward so that the angle on the yAxis axis becomes > 600 and <= 1024, then the motor will move clockwise (CW).

### Table 2. Movement Direction And Speed

| Joystick ADC Output XAxis | ADC yAxis | Movement Direction based on XY axis input | Wheelchair Movement PWM Direction | Duty Cycle (%) | Speed Mode | Accurate (%) |
|---------------------------|-----------|------------------------------------------|-----------------------------------|----------------|------------|--------------|
| 498                       | 690       | Forward                                  | Forward                           | 49             | 50%        | Normal 100   |
| 495                       | 887       | Forward                                  | Forward                           | 100            | 100%       | Fast 100     |
| 497                       | 388       | Backward                                 | Backward                          | 49             | 50%        | Normal 100   |
| 700                       | 510       | Right Turn                               | Right Turn                        | 49             | 50%        | Normal 100   |
| 910                       | 509       | Right Turn                               | Right Turn                        | 100            | 100%       | Fast 100     |
| 382                       | 510       | Left Turn                                | Left Turn                         | 49             | 50%        | Normal 100   |
| 99                        | 512       | Left Turn                                | Left Turn                         | 100            | 100%       | Fast 100     |

The test in Table 2 was done to see the suitability of the joystick output data to the direction and speed of the wheelchair motor movements. The test results show that each joystick analog output data has precise accuracy of the movement direction and of the wheelchair motor speed.

### B. Wheelchair Control Testing Using Voice Control

![Figure 10. AMR-Voice Display Receiving Command from User](image)

User-spoken voice commands are accepted by AMR-Voice so that the command is sent to Raspberry Pi 3 via the HC-06 module, after which the command will be executed. If appropriate, the wheelchair will move according to the given command. If not appropriate, the wheelchair will not respond to the command. Table III is a response time of AMR Voice that is performed in two conditions; namely, 'quiet' condition and 'noisy' atmosphere condition.

From table 3, it is seen that the time response of the AMRVoice application is different in quiet and noisy conditions, where the respond time when the condition is 'quiet' will be better than the 'noisy' condition. It will also affect the response of the wheelchair movement.
Table 3. Data Of Wheelchair’s Movement Comparasion Result Againts ‘Noisy’ And ‘Quiet’ Condition

| No | User Input | Raspberry Data | ‘Noisy’ Respond Time (s) | ‘Quiet’ Respond Time (s) | Wheelchair Movement |
|----|------------|----------------|--------------------------|--------------------------|---------------------|
| 1  | Forward    | *Forward#      | 4.12                     | 0.12                     | Forward             |
| 2  | Backward   | *Backward#     | 6.03                     | 0.20                     | Backward            |
| 3  | Right      | *Right#        | 4.60                     | 0.19                     | Right               |
| 4  | Left       | *Left#         | 5.02                     | 0.15                     | Left                |
| 5  | Stop       | *Stop#         | 6.15                     | 0.18                     | Stop                |

4. Conclusion
The purpose of this research is to make a wheelchair control system that is cheap and easy to use for people with disabilities who have limited limbs or cannot use their fingers. This wheelchair control using a joystick and voice successfully moves the wheelchair in the desired direction. Joystick controls are for users who can still use their hands to move the joystick, while voice controls are for users who are unable to use their fingers to push or direct the joystick. Voice control has a very good response time in quiet noise situations with a good internet connection.

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