Detachable Electric Motor Design and Data Acquisition on Smart Wheelchair System

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Abstract: Mobility for people with disabilities needs to be considered to increase their participation in activities. Hence, every action taken can be more productive. Electric vehicles are currently a major focus of development. The application of electric motors as propulsion in wheelchairs is highly beneficial for people with disabilities, as it enhances their mobility during activities. However, the use of electric motor propulsion in wheelchairs is a new and interesting development, and creating a detachable electric motor propulsion device that can be used by people who use wheelchairs is worth exploring. This study aims to examine the experience of wheelchair users using an additional electric motor drive in their wheelchairs. Android applications for sensor data acquisition are developed, and sensor data is transmitted from the wheelchair control system to the Android application using Bluetooth communication. The study collects sensor data related to the use of electric motors to assess their capabilities and responses when using this electric motor propulsion device.

1 INTRODUCTION

The Presidential Regulation of the Republic of Indonesia Number 55 of 2019, which concerns the Acceleration of the Battery Electric Vehicle Program for Road Transportation, has opened up new opportunities for mobility and accessibility for persons with disabilities who use wheelchairs. There are many efforts that can be made to address the basic needs of persons with disabilities in terms of mobility devices, such as a detachable electric drive for a wheelchair. The current advancements in battery technology have enabled the development of higher-density batteries that can achieve performance optimization. These slim, lightweight, and fast-charging batteries with sufficient storage capacity are a major step toward saving the power supply required for mobility. As the number of electric vehicles increases, battery charging stations must be able to charge batteries quickly (Tu et al., 2019). The combination of battery technology and the Internet of Things (IoT) has the potential to revolutionize the design of intelligent wheelchairs for users. The IoT provides performance optimization for electronic systems, information systems, and control systems to allow users to have complete control of their electric vehicles.

Micro-mobility, also known as "short movement," is an essential component of urban transportation and occupies an important part of a city's blueprint or urban space. The right type of vehicle with the appropriate "size and adaptation," particularly for wheelchair mobility on city roads, is critical and closely related to the area traveled, energy consumption, and the type of fuel used. Furthermore, the application of electric vehicle (EV) technology in wheelchair mobility supports the 10th Sustainable Development Goal (SDGs) program, especially with respect to providing wheelchair users with independence and empowerment to access their needs, including those outside their homes. According to data from the World Health Organization (WHO), 5% to 15% of 70 million people with disabilities must use wheelchairs to carry out their daily activities (Shabibi and Kesavan, 2021). This effort also collaborates with United Cerebral Palsy Wheels for Humanity (UCP Wheels), which, in 2018, distributed 839 wheelchairs to its partners.

Currently, not many wheelchair users with disabilities make use of electric motors to assist with their daily activities. The objective of this study is to develop a data acquisition application that will monitor the movement of electric motors used by wheelchair users. Furthermore, this data will be used for analyzing the experiences of individuals who use electric motors in conjunction with their wheelchairs.

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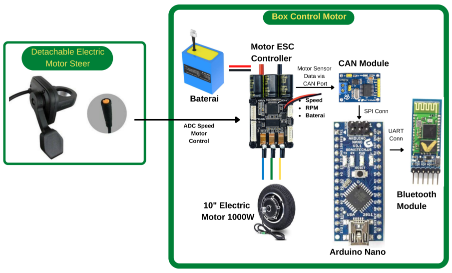

Figure 1: Wheelchair Electric Drive System Design Chart.

2 LITERATURE REVIEW

2.1 Electrice Wheelchair

Wheelchairs, traditionally viewed as a mode of transportation for individuals with physical disabilities, have undergone significant developments in the area of electrical controls, specifically those connected to the digital world or the Internet of Things (IoT). The IoT-based control concept is a new paradigm in the world of information technology, where all devices, such as sensors, actuators, and various types of indicator components, controls, and charging systems, can be interconnected through the internet network. Embedded systems and sensors are becoming easier to find, and their low cost and small size make them well-suited for developing detachable electric drive systems for wheelchairs that are IoT-based (Urooj et al., 2021; Yao et al., 2015; Desai et al., 2017; Harris et al., 2020; Parikh et al., 2007). This development is particularly beneficial for wheelchair users from different backgrounds. While manual wheelchairs can only be used by individuals with physical disabilities from the waist down, turning manual wheelchairs into smart wheelchairs with the latest technology can provide mobility for a wider range of users. The ease of control and navigation in smart wheelchairs, including touch screen management, shaking or nodding the head on a pad or joystick, voice commands, and eye commands using an eye tracker, can provide an opportunity for individuals with Alzheimer's disease, cerebral palsy, and the elderly to have the ability to move independently and safely (Matsumotot et al., 2001; Simpson et al., 2002; Montesano et al., 2010; Tomari et al., 2012; Wanluk et al., 2016).

2.2 Wheelchairair Mobility and Accessibility

Micro-mobility, or short-distance movement, is an important component of a city's urban space and transportation infrastructure. The concept of short-distance travel is not solely about moving from point A to point B but also considers the speed and travel time required to connect residential areas with other activity spaces in the city. However, this type of short-travel vehicle faces a challenge in dense cities due to the difficulty of accelerating. The issue of short-distance travel is also closely tied to accessibility rights and equality for wheelchair users.

One problem that arises in short-distance travel is how wheelchair users can access other activity spaces outside their homes, such as traditional markets, hospitals, schools, and government buildings (Tomari et al., 2012). Wheelchairs are often the only means of transportation for wheelchair users to access the outside world where they live. This situation affects not only accessibility rights but also the independence and confidence of wheelchair users, particularly in developing countries (Wanluk et al., 2016; Watson and Woods, 2005). The accessibility of these spaces is linked to the road as a hub or intermediary area. In many situations, slow-moving modes of transportation, such as wheelchairs on highways, may face pressure from faster modes of transportation. This is because they are often viewed as causing congestion or slowing down transportation flow, as is currently the case with e-bikes in China (Hopkins, 2015).

Figure 2: Brushless Motor DC.

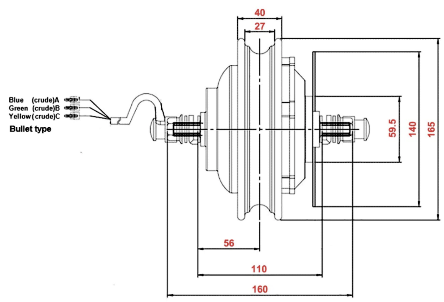

Figure 3: Brushless Motor DC Dimension Specification.

3 DESIGN SYSTEM

Electric wheelchair propulsion is divided into three major parts Fig. 1, namely (1) motor, (2) battery, and (3) controller. The electric motor, as a driving force, has a type of motor in the form of a brushless motor with a power source using DC electric power. This type of brushless motor is often used as a motor in electric bicycles and electric scooters. As a power source, this drive system uses a LiFePO4 battery. The control system has two systems: the motor power distribution control system and the wheelchair control system. An electric drive is required to support wheelchair mobility. At this design stage, the electric drive used is a brushless motor (Figure 2). Brushless motor DC dimension is shown in Figure 3 with the following specifications:

- Rated current: 48V
- Power: 1000W
- Shaft length: 160MM
- Applicable models: 10-inch scooter
- Fork size: 110MM
- Outer diameter: 168MM
- Width: 40MM
- Weight: 3.2kg
- Black
- Speed: 30-65km/hour

These specifications are considered very suitable to be implemented in wheelchairs with considerations of weight, diameter, power, and motor speed. Meanwhile, the main power source for the motor uses a LiFePO4 battery. Based on the engine's specifications and the calculation of the motor's power requirements, it depends on the battery's resistance to support the motor's performance.

$$P_{motor} = 1000W \tag{1}$$

$$V_{motor} = 48V \tag{2}$$

$$I_{motor} = \frac{P_{motor}}{V_{motor}} = \frac{1000}{48} = 20.8\ Ampere \tag{3}$$

The current obtained from the motor is 20.8 A. This current is the maximum current that the motor can receive. If the engine is given an excess current of 20.8 A, the motor will burn out. If the current supplied to the engine is 20 A constantly for 1 hour, then the calculation of the battery power that must be provided is:

$$\begin{aligned} bateraiPower &= current\ \ time(hour) \\ &= 20A\ \ 1 = 20\ A = 20,000\ mAh \end{aligned} \tag{4}$$

Assuming the current to be used is 75% of maximum current, the resulting motor speed can be calculated by comparing the motor's maximum current and maximum speed, and the motor efficiency factor is greater than 87.6%.

$$\frac{current}{current_{max}} = \frac{speed}{speed_{max}} \tag{5}$$

$$\frac{15A}{20A} = \frac{speed}{65km/h} \tag{6}$$

$$speed = \frac{65\ x\ 15}{20} \tag{7}$$

$$speed = 48.7\ km/h \tag{8}$$

By applying a minimum motor efficiency of 87.6capacity specifications will affect battery life to provide electrical power to the motor. The greater the battery capacity, the longer the engine can work. In this electric drive system, the control system components are divided into two parts, such as: (1) motor power speed control and (2) wheelchair controller.

3.1 Motor Power Speed Control

The given element manages the allocation of electric power from the battery to the motor. It serves a dual function as a power inverter, converting battery-generated electricity to be used by a brushless motor that employs three motor poles. Acting as a bridge between the motor and the user's engine control system, this component facilitates adjustments in the motor's speed and rotational direction. It also has the capability to integrate remote controls through wireless technology. The VESC Speed Controller type components depicted in Fig.4will be employed in the motor power distribution control system.

3.2 Wheelchair Controller

The mentioned part serves as an intermediary control between components and the user, specifically accepting inputs transmitted via thumb throttle. Through this control system, the user is able to operate their wheelchair with the assistance of wireless communication technologies like Bluetooth. An Arduino Nano controller, displayed in Figure 5, is employed by this component to provide communication between the motor controller and the Android application via Bluetooth. CAN module is used as a communication module between Arduino Nano and the motor controller.

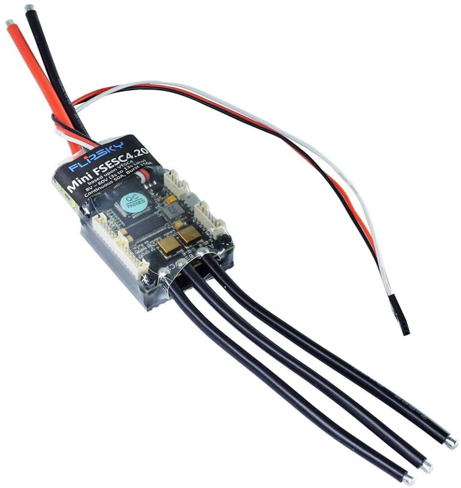

Figure 4: Motor speed controller.

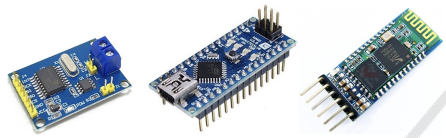

Figure 5: Communication and Control System.

4 RESULT

The development of control system applications and sensor data acquisition in this study aims to obtain data related to wheelchair movement. The data obtained from the sensor is to show the movement of the detachable electric motor, namely data on motor speed, motor rpm, battery, wheelchair detachable coordinates (latitude and longitude), wheelchair position direction, wheelchair usage time, and wheelchair ID. The connectivity design between the motor controller module and the android smartphone is shown in Figure 6.

Android smartphone applications are used to add sensor data to describe the activity and movement of wheelchairs. Data originating from the electric motor is sent to the Android application via a Bluetooth connection in the motor control box. The rotational speed of the engine is controlled via the Tumb Throttle, which is connected to the Motor ESC via the ADC connection.

4.1 Electric Motor Rotation Control System

The motor rotation control is carried out through a Thum Throttle, which will be mounted on a detachable electric motorbike handlebar. The Thum Throttle opening value is read by the Motor ESC (Electronic Speed Control), which is in charge of converting the Thum Throttle opening and then passing on the amount of electric power in A to the motor that the motor can rotate at a certain speed. The results of the electric power distribution control process so that the engine can rotate are shown in Figure 7.

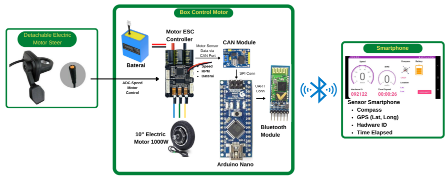

Figure 6: Design of component interconnection and communication on the motor controller and display.

Figure 7: Motor Control Test with Thumb Throttle.

4.2 Control Box Design and Battery Placement

Design and implementation of the placement of the control box and battery placed on the handlebar pole of the detachable electric motor. This is done so that the center of gravity can be more evenly distributed in the center of the complete structure between the detachable electric motor and the attached wheelchair. This helps the electric motor to have good traction to pull the wheelchair. The stage that still needs to be finalized is the design of the placement of the electric control box, which takes into account the aesthetics of the detachable electric motor. The control box position and battery placement are presented in Figure 8.

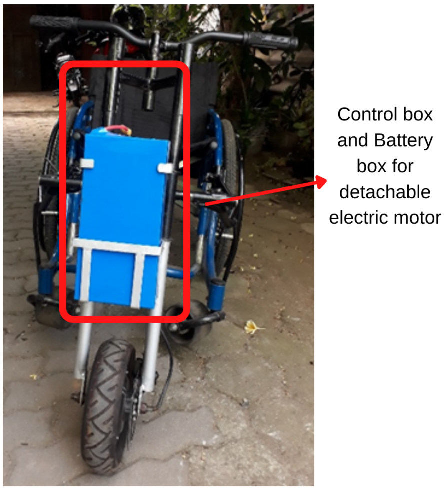

Figure 8: Realization of the box and battery position design on a detachable electric motor.

4.3 Development of Communication Media for Sending Sensor Data

The sensor data used in this system comes from 2 devices. The first device is the ESC motor. The ESC motor can provide a data sensor, such as motor speed, motor rpm, and battery capacity. The ESC motor has several ports for communication, such as a UART port, I2C port, and CAN port. In this research, the implementation process to get data through one of the provided communication ports is still being developed. The communication port using the UART port connected to the Arduino Nano until now cannot be used to get ESC motor sensor data. This is because there is no suitable library to access data from the ESC motor. Another step that has been done is to try to get data using the CAN Port. Trials using the CAN Port are still being carried out so that the Arduino Nano can access the data from the ESC motor. Furthermore, data from the ESC motor that the Arduino Nano can access is sent to the Android application via Bluetooth communication.

The android application that has been designed at this time is able to get sensor data originating from internal smartphones, such as GPS data in the form of latitude and longitude points, compass, and direction data. Android applications can also be connected to the Arduino Nano via Bluetooth connectivity, and the Arduino Nano can send data to the Android application. The android application developed to display a collection of sensor data is shown in Figure 9. Furthermore, finding the appropriate communication to send data from the ESC motor to the Arduino Nano still needs to be done.

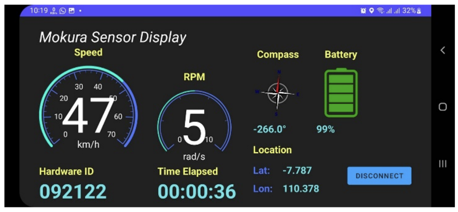

Figure 9: Android application that displays all sensor data sensors.

4.4 Development of Sensor Data Communication API

The data format between the Arduino Nano and the Android application shows is:

$$[\#]\,[Speed]\,[;]\,[RPM]\,[;]\,[BatteryVoltage]\\ [;]\,[DutyCycleThrottle]\,[\#]$$

This process is carried out to determine a good data format that can be used in the communication process between the Arduino Nano and the Android application. In addition to displaying data from the motor sensor, the Android application also saves the data in a CSV file for the purpose of analyzing the usage of the detachable electric motor, Figure 10.

A	B	C	D	E	F	G	H
timeStamp	speed	rpm	battery	compa	dutyCy	lat	lon
2022-11-14T03:03:51.985Z	0	0	52.09.00	-223	00.11	-7.697	110.417
2022-11-14T03:03:52.185Z	0	0	52.09.00	-223	00.11	-7.697	110.417
2022-11-14T03:03:52.368Z	0	0	52.09.00	-222	00.11	-7.697	110.417
2022-11-14T03:03:52.584Z	0	0	52.09.00	-222	00.11	-7.697	110.417
2022-11-14T03:03:52.784Z	0	0	52.09.00	-211	00.11	-7.697	110.417
2022-11-14T03:03:52.982Z	0	0	52.09.00	-195	00.11	-7.697	110.417
2022-11-14T03:03:53.181Z	0	0	52.09.00	-184	00.11	-7.697	110.417
2022-11-14T03:03:53.383Z	0	0	52.09.00	-183	00.11	-7.697	110.417
2022-11-14T03:03:53.583Z	0	0	52.09.00	-181	00.11	-7.697	110.417
2022-11-14T03:03:53.801Z	0	0	52.09.00	-180	00.11	-7.697	110.417

Figure 10: Data in File CSV.

5 CONCLUSIONS

The system has been built, and the Android application is now able to communicate with the motor controller and retrieve motor sensor data. This enables wheelchair users to view the speed of their wheelchairs and monitor the battery condition while in use. In the future, We will examine the data that was collected to ascertain the reaction of individuals who use wheelchairs when operating an electric motor-powered wheelchair.

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