Article

IoT-Based Discomfort Monitoring and a Precise Point Positioning Technique System for Smart Wheelchairs

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Abstract: The Internet is becoming increasingly important in our daily lives, allowing people to exchange and receive a wide variety of data. It can be utilized in a variety of ways for maximum benefit. For example, the concept of the Internet of Things (IoT) suggests that objects can be linked to the Internet. Based on this concept, in this paper, we describe the creation of modern smart-wheelchair accessories. These make the wheelchair simple to use, suitable for the elderly, and foldable. A health monitoring accessory is one of the critical functions. The Internet of Things is central to the concept of an electric-powered smart wheelchair. Residential communication networks connect electrical appliances and services, enable monitoring, and provide access from which to control various devices. The controls of a smart wheelchair comprise three essential components: a smart device that connects to the wheelchair, an Internet network, and a microcontroller. The results of our tests enable remote operation of the electric-powered wheelchair; command and control are excellent. Most significantly, our method provides consumers with an extra stage of security.

Keywords: smart wheelchair; Internet of Things; smart device; modern wheelchair

1. Introduction

The healthcare sector is becoming increasingly important and challenging as the population grows. A thorough literature review revealed limited medical personnel, long recovery periods in hospitals, and communication methods as common issues related to healthcare apps. In this research, we aimed to solve these problems. There are many potential obstacles and problems relating to the Internet of Things (IoT), which involves programming to control devices through the Internet, and security on the Internet and network stability are the main priorities for developers [1]. Smart cities and the healthcare sector have been developed to facilitate and support a better quality of life. Chang et al. [2] claim that the methods and technology in respect of remote health monitoring entail a patient record application that integrates well with the proper sensing mechanisms and gathers structured and unstructured data for machine learning analysis. The concept of a healthcare apps aims to mimic expert care by setting up machines to integrate healthcare resources with smart IoT solutions. Key components of IoT-enabled smart healthcare applications are produced using various techniques, topologies, and frameworks, as shown in Figure 1 [3].

Figure 1. The component of an IoT-integrated smart wheelchair system.
There are five essential components of smart services: (1) localization-based information, (2) remote sensing, (3) healthcare service and application, (4) technology and architecture, and (5) IoT communication systems. Location-based information works best with smart wheelchair applications with integrated global positioning to locate the user. The applications must use specific models and designs for remote healthcare monitoring of the patient record to manage patient data effectively. The smart wheelchair system components include glucose level sensing, electrocardiogram monitoring, blood pressure monitoring, body temperature monitoring, oxygen saturation monitoring, rehabilitation systems, medical management, wheelchair management, and other upcoming healthcare solutions. During the COVID-19 pandemic, IoT facilitated the introduction of medical systems facilitating linked imaging, hospital operations, drug distribution, and pharmacy management [4]. In order to deliver end-to-end communication and protocols for Internet networks, technology and architecture are crucial in the shift to the IoT [5]. In this study, we use IoT and communication systems to design smart wheelchair applications. The IoT can quickly build communication systems by accessing real-time information.

The remainder of the article is structured as follows. The associated study area, autonomous smart wheelchairs, general requirements, and the Internet of Things (IoT) are described in Section 2. In Section 3, we discuss the proposed method of building smart wheelchairs, the innovative wheelchair process as applicable to the proposed method, system design and implementation, and how the Anto and Firebase platforms positively influence electric-powered wheelchairs. Section 4 provides details about the electric-powered wheelchair speed test, displacement distance test, and GPS tracking test. Section 5 sets out our conclusions.

2. Autonomous Smart Wheelchairs

Managing an aging population has become a national research strategy in Thailand. One issue that has arisen is that the elderly or at-home patients need to sit while moving their mobility scooters/wheelchairs around. Accordingly, various mobility scooters/wheelchairs are available. The most commonly available mobility scooter/wheelchair is a standard model with no additional features. Wheelchairs with a range of other features are more expensive and must be imported [6], resulting in the majority of older people not having access to them. Thus, the concept of creating smart-wheelchair accessories was conceived. These devices are cost-effective, convenient for older people, and state of the art. In this study, we discuss portable health monitoring devices. Vital indicators such as blood pressure and electrocardiogram (ECG) signals can be measured with such devices, together with breath signals when an irregularity occurs, and body temperature. For a medical professional or nurse to see the irregularity that exists, an initial diagnosis can be made by a physician, who can guide treatment methods and recommend alternative wheelchairs; for example, those who spend a lot of time in a wheelchair could potentially develop pressure ulcers. As a result, when a person sits for a long time, a built-in air protection system could be used to automatically send air into a specific cushion to help avoid pressure sores. Another feature of the smart wheelchair is that it contains a system to detect falls or unusual motion, for example, moving too quickly, which could result in a slip or accident. In addition, the smart wheelchair should deliver accurate vital sign data in real time according to international standards, enabling users, such as family members and medical professionals, to react quickly to irregularities experienced by the patient. The patient can sit comfortably without developing pressure sores. We can perform data collection through the wheelchair’s associated equipment due to the development of wheelchair accessories [7]. The advantage of the Internet of Things is that each device can connect via the Internet. Being able to send information to multiple persons instantly or issue notifications immediately allows for real-time data transmission. The Wi-Fi module ESP8266 can connect numerous sensors to the microcontroller and functions as a small computer connected to the sensors receiving different values [8]. One uses the operating system’s Visual Studio code to connect. The microcontroller can also use Wi-Fi to connect
to the Internet [9]. This satisfies the demands of the elderly by allowing them to monitor and transmit data, and it employs Wi-Fi for real-time data transmission. It also makes it possible to connect to the Internet wherever there is a mobile phone signal. A variety of vital signals can be used to manage wheelchair mobility while adjusting the cushion to prevent pressure sores, and determine the user’s location via Global Positioning System (GPS) data provided to the web application in real time in the database [10]. To connect to the platform’s database and function with desktop and mobile web browsers such as Internet Explorer, Google Chrome, and Safari, we will be developed using Node.js, HTML, CSS, and JavaScript. We will send any necessary vital signs to a doctor or appropriate person for further diagnosis and initial evaluation.

A powered wheelchair that has been specially adapted and equipped with various sensors and a control system is known as an autonomous wheelchair or smart wheelchair [11]. Users with significant physical disabilities can benefit from smart wheelchairs [12]. The wheelchair’s primary function is to reduce or completely remove the user’s responsibility for maneuvering the wheelchair. It can also be created with the user’s circumstances and impairment in mind. There are two kinds of smart wheelchair. One is a seat attached to a moving robotic base, while the other is a typical electric wheelchair with a computer and various sensors [13]. Early versions of intelligent wheelchairs were mobile robots with added seats. The smartest wheelchairs that have been developed and are available on the market are vastly improved versions of standard power and office wheelchairs, offering better maneuverability and navigational intelligence. An intelligent wheelchair was proposed by Cui et al. [14] and is based on the following three features. A PAJ7620 sensor is used for occupancy–wheelchair–environment multimode sensing, while GPS (Global Positioning System) and IMU (inertial measurement unit) sensors are employed to sense positioning, speed, and postural data. Wheelchairs can work with the Internet of Things (IoT) to enable smart technologies, according to a paper by Bhat et al. [15] that proposes an Acceptability Engineering (AE) framework to support the growth and extension of markets reliant on these settings. AE, as a common engineering approach, would help review the characteristics of IoT-wheelchair environments, analyze their market patterns, and expose the shortcomings between early and prevailing markets. This will highly impact manufacturers who offer wheelchairs specifically for IoT environments and will also enable the identification of potential customers. In the present work we determine the improvement in the foldability elements of wheelchairs regarding the wheels employed. In contrast, most research focuses on the development of mobility by reducing the diameter of the wheels. In terms of portability, this method makes wheelchair storage easier. However, the electric wheelchair should be able to carry a load of up to 150 kg. Manoj et al. examined this wheel’s durability after it was constructed using aluminum alloy 6061 [16]. To improve the rehabilitation process for patients with lower-limb problems and lessen the difficulty in transporting the wheelchairs used, this might be further expanded by creating an electronically controlled wheelchair based on a foldable design [17]. The author focuses on the wheeled robot’s anti-saturation positioning and obstacle avoidance control. To ensure that the robot speed is decreased when the orientation error is considerable, an enhanced direction error auxiliary function (DEAF) is first developed. Then, by including a smooth switching function, a novel Gaussian barrier Lyapunov function (BLF) is created. In contrast to the conventional Gaussian function, the repulsion field’s range is controllable by parameters. Finally, the innovative Gaussian BLF and the enhanced DEAF are combined to produce a control law for dodging multiple obstacles. The study’s methodology is based on a thorough literature review identifying the many problems and their remedies. The selection process produced 81 primary sources in total. After extracting and synthesizing the data, 14 distinct IoT heterogeneity concerns were identified. Among the difficulties noted are the heterogeneity of devices, heterogeneity in data formats, heterogeneity in communication, and interoperability issues owing to heterogeneity. The stated difficulties have been examined in terms of timeframe and digital libraries [18]. Moreover, to provide users with tailored safety services at an affordable price while increasing the profit of the safety
service provider (SSP) using the Safety-as-a-Service (Safe-aaS) platform, Roy et al. [19] introduced a differential pricing scheme termed Diff-Price. None of the current pricing models accounts for the dynamic variation in price when users’ requests for decision parameters and user types change. The results of a thorough mathematical study and simulation show that the proposed pricing plan, Diff-Price, enhances the service providers’ financial benefit as the number of users rises.

2.1. System Requirements

The design of autonomous wheelchairs has attracted significant interest in six key areas: personalization for users, compliance with security requirements, and the function, user-machine interface, navigation, and benefits of a smart wheelchair [20]. User personalization is essential for smart wheelchairs to be accepted by potential users. In particular, when designing smart wheelchairs to assist people with disabilities, consideration must be given to how the design can adequately complement the remaining capabilities of the human operator [21]. As a result, the control system for the chair may be used to complete tasks with the aid of human operators and their expertise.

The software of a smart wheelchair works in tandem with a human operator to provide highly interactive system control. People with impairments directly interact with the functional aspects of smart wheelchairs. Therefore, the error of smart wheelchairs can seriously affect humans. For instance, the command must be accurately and reliably followed when users want to control a dangerous area. Smart wheelchairs are therefore regarded as safety-critical systems. To specify the safety requirements for their systems, manufacturers have adopted formal methodologies, including hazard analysis approaches and model testing. Wheelchair functionality varies depending on the target group. Customization and usability are the two most important factors when designing a wheelchair. A smart wheelchair must operate reliably and robustly in a user-friendly environment. Functional block design and maintenance should be as simple as possible so that the company’s specialist staff can handle issues without assistance from robotics experts. A joystick is a standard input device widely used to give instructions and commands [22]. In the smart wheelchair, a user can use an interface on a touchscreen touchpad to drive a wheelchair. The smart wheelchair autonomously navigates to its destination using an in-vehicle map. Uses for this map range from showing connections between locations without specifying distances (such as Google Maps) to providing sufficient information about the distance to a destination (such as metric maps). Many other technologies are also available, such as self-guided wheelchairs that run along the floor rails and enable automatic navigation.

People with different requirements can generally benefit in various ways when assisted by a smart wheelchair. Being able to move independently is a huge advantage for both adults and children. Overall, independent mobility improves employment and educational opportunities, reduces dependency on family and caregivers, and fosters a sense of independence. Reduced social connectedness and decreased or impaired engagement are related to decreasing functional mobility. The psychological implications of limited mobility include emotional loss, low self-esteem, loneliness, anxiety, and fear of rejection. Autonomous wheelchairs can move independently without user intervention. Thus, they help (1) cognitively impaired people who cannot remember where they are going or how to get there, or who have difficulty with analytical functions; (2) people who tire easily and find it difficult to travel long distances; (3) people who, due to visual impairment, are unable to perceive (or have difficulty perceiving) environmental prompts that may aid in navigation.

2.2. Internet of Things (IoT)

Devices that are part of the Internet of Things (IoT) are those that can connect to the Internet and exchange data. To manage physical objects with innovative interactions, these devices require advancements in machine-human interfaces, from sensory input to actuators for actively included in business operations and be seamlessly incorporated into
information networks [23]. Services can communicate with these “smart devices” over the Internet, query their state and obtain relevant information while keeping security and privacy concerns in mind.

3. Design Concept for a Smart Wheelchair

Many people with various capacities typically rely on others daily to move from one point to another. For wheelchair users to propel their chairs, they need regular support. Their lives grow more difficult because wheelchairs do not have an intuitive control structure that allows for autonomous movement. Our objective was to create an intelligent wheelchair designed to make life simpler for disabled persons and is controlled by a LattePanda touchpad. As a result, the device has been updated with current IoT-based technology. An embedded device with a Wi-Fi module and a motor driver form the basis of the hardware architecture of the smart wheelchair. The chair can be controlled and moved using a LattePanda touchpad. The user can communicate via the Wi-Fi module and a LattePanda touchpad.

A smart wheelchair is created in five steps: (1) problem identification and motivation, (2) setting the solution’s objectives, (3) design and development, (4) demonstration, and (5) evaluation. Table 1 displays the condensed information about creating an inventive wheelchair process related to the suggested technique.

Table 1. The summarized details of designing an innovative wheelchair process, are as applicable to the proposed method.

| Stage Name                          | Designing an Innovative Wheelchair Process                                                                 |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------|
| Problem identification and motivation | Through a thorough analysis of the approaches and objects to be identified, a search of the many positioning systems enabled us to examine the accuracy of various applications in both internal and external contexts, leading to the problem’s identification. The positioning error of the wheelchair results in a complete loss of information when driven in areas with weak internet or no Global Positioning System (GPS) signal. |
| Defining the goals of the solution   | According to problem identification and motivation, it is possible to determine which policies to develop and research to minimize errors as much as possible, bearing in mind the external environment and autonomous movement. |
| Design and development               | This resulted in the system’s architecture and aided in creating diagrams that could detail the many operations the system would carry out. The system’s implementation consisted of three components: a location system, an autonomous wheelchair system, and particular procedures that could optimize the entire program. |
| Demonstration                       | The smart antenna detects the path the smart wheelchair can take, compares it to the initial path chosen by the user, and displays the result on the graphical user interface. This demonstrates how the unique approach reduced the positioning error. |
| Evaluation                          | Three detection nodes are utilized in various positions to test the application quality and then consider whether the internal or external environment affects the accuracy of the system’s performance. |
We design electric smart wheelchairs for the benefit of patients, the elderly, and the disabled person, and are both lightweight and electric. For an electric wheelchair that folds, users can choose an electric wheelchair that best suits their needs from various alternatives, including regular electric wheelchairs and adjustable electric wheelchairs. The study was conducted with an electric wheelchair weighing 122 kg and a maximum speed of 6 km/h (kilometers per hour). We can also convert it from an electric wheelchair to a straightforward manual wheelchair. It has a continuous operating range of 16 to 20 km and can move left, right, or in any other direction. An electric-powered smart wheelchair is shown in Figure 2. In the example presented, the skeleton components can be folded, and there are options for front-wheel off-road drive, rear-wheel drive, all-wheel drive, and stair climbing.

![Figure 2. Realization of a smart wheelchair prototype in practice.](image)

In general, the power used for mobility is used to categorize wheelchairs. The two main categories of wheelchairs are manual and motorized. Powered wheelchairs that are operated manually can be further divided into types based on how the commodes are built and how easily they can collapse. Electric-powered wheelchairs, as the name suggests, are propelled by electricity. However, manual involvement is required to operate the wheelchair’s user interface, which is commonly a joystick. To make the wheelchair easier to operate, more components may be applied. The critical elements of the electric-powered smart wheelchair in this study are as follows:

1. The display and control systems require an eDP+ touch-screen panel and a computer board running Windows 10 (a minicomputer), respectively.
2. Two 10-inch-diameter castor wheels with front-wheel drive.
3. Three sets of levers control the six-inch-diameter rear-wheel drive castors.
4. The chair can recline to 60 degrees and move in four directions (forward, back, left, and right).
5. Three different levels of movement speed adjustment.
6. Developing control systems for various devices through the sensor system displayed on the touch screen.
7. C Sharp (C#) programming languages were used to write the control unit programs.
8. The sensor system measures the car’s distance from the obstacles in front of it; if it is less than one meter, it will cause the wheelchair to stop automatically.
9. While the automobile travels, eight sets of lights are visible, along with a liquid crystal display (LCD) panel that displays the battery’s status.
10. Battery charging outlets and a charger with a minimum voltage and current of 24 volts and 10 amps, respectively.
11. A four-ball, 250-watt, 24-volt direct current (DC) motor with an integrated reduction gear.
12. The DC motor driving unit of the metal-oxide-semiconductor field-effect transistor (MOSFET) hybrid type is at least 80 amps in size.

The proposed wheelchair system’s primary controller is a cheap minicomputer. Due to its inexpensive cost, compatibility with various electronic devices, versatility, and performance in numerical computing, a LattePanda system was chosen in this case. Two DC motors with speed reducers power the wheelchair’s left and right movements. The joystick module helps the wheelchair user issue movement control commands. The specific application is utilized to activate all the components, which include webcams, a joystick, a microphone, a helmet, electronics for data collection, and DC motors with reducers. The system can move the wheelchair in all four directions and regulate its movement. The wheelchair can be started and stopped using the control system via a touchscreen. In addition, it can warn of any detected obstructions, enabling the chair to move smoothly and safely.

3.1. System Design and Implementation

During implementation, large positioning errors can occur due to the localization of static and dynamic objects. However, the need to know the location of people and things at all times has led to using previously available approaches for developing and implementing applications. A Wi-Fi tracking system aims to use sensors or modules with specific characteristics. Furthermore, particular procedures and practices enable real-time reception and distribution of data at central nodes. To complete this work, the current method is split into two parts. The first section explains how the modularity of hardware and software enables the creation of sensor nodes with Wi-Fi components and receivers, as well as the procedures that ensure the positions of objects in both their internal dynamic and static states are implemented and that settings are correct. The circuit diagram for the electric wheelchair is seen in Figure 3 and includes a display, DC motor, microcontroller, Wi-Fi receiver, and DC motor driver [24].

![Figure 3. The overall architecture of the microcontroller-based system and sensor connections for the system.](image)

According to Figure 3, the microcontroller can receive data from sensors, smartphones, and assistance buttons via RX (receive data) and TX (transmit data) ports. Through the output, the microcontroller will manage the procedure. We have created a revolutionary design that uses a Bluetooth-connected smartphone to operate a motor and lighting over the internet and generate an automated design utilizing the data analysis findings. The core project, which consists of hardware and software, includes the tracking system. Hardware for the prototype includes the Wi-Fi module, antenna, and battery, while the software offers a graphical user interface that demonstrates the project in operation. In order to predict the position, the software also uses data from the wheelchair system. The wheelchair positioning system consists of a LattePanda and multiple ESP8266 modules, as shown in Figure 4.
This is a functioning joystick that can give the user input. Any accessories that practically all of the devices that the average user is familiar with, including printers, joysticks, and cameras. The joystick is the most commonly used method of controlling the wheelchair. This is a functioning joystick that can give the user input. Any accessories that function on a PC will also function on a LattePanda. Wheelchair system implementation was carried out as follows.

Various materials were subjected to preliminary testing, including servo motors, relay modules, batteries, power banks, and ultrasonic sensors. The LattePanda was set up. This included kernel upgrades and updates. In order to configure the ESP8266 modules, serial communication was used. We tested video recordings and the driving relays with the camera, and then connected the ESP8266 modules to a network and created communication between them. Finally, the triangulation technique was used to calculate distances using the ESP8266 modules. The control area includes two distinct control features. Smartphones are included in the lighting control, and the lighting control component is shown in Figures 5 and 6.

A LattePanda is a fully functional single-board Windows 10 computer. It can perform any task that a typical personal computer (PC) can and has all of its features. It works with practically all of the devices that the average user is familiar with, including printers, joysticks, and cameras. The joystick is the most commonly used method of controlling the wheelchair. This is a functioning joystick that can give the user input. Any accessories that function on a PC will also function on a LattePanda. Wheelchair system implementation was carried out as follows.

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The smart wheelchair application is installed Windows 10 and has an Intel Cherry Trail Z8350 quad-core processor running at 1.44 GHz, with 4 GB of DDR3L RAM and 64 GB of Flash memory. The display is connected using a high-definition multimedia interface (HDMI) port or a dedicated MIPI display serial interface (MIPI-DSI) port for 7-inch displays, a LattePanda touchpad, USB 3.0 × 1 and USB 2.0 × 2 ports, Wi-Fi and Bluetooth 4.0, a 100 Mbps ethernet local area network (E-LAN) port, a Micro SD card slot, and an audio jack. A Raspberry Pi and several ESP8266 modules, including motors that power directional antennae, make up the wheelchair positioning system. Wi-Fi antennae support the triangulation method to help acquire coordinates (longitude and latitude). Intel HD Graphics 200 MHz and a GPU support resolutions of up to 1920 × 1080.

3.2. Anto and Firebase Platform

The IoT requires the coordination of software and hardware. The IoT’s complex hardware connects the electric wheelchair, while the software is used for programming. To send commands from a smartphone requires a device to be connected to the Internet in order to be able to control devices via the Anto and Firebase Platform. The ANTO platform includes many functionalities that reveal program code and can be connected to a database in real time. Therefore, developers do not need to design and configure server settings because Anto and Firebase platforms connect all devices. In addition, the Firebase platform is able to save data in real time and does not depend on a specific language format for APIs. REST APIs or HTTP protocols can send or request data in languages without built-in libraries (PUT).

4. Experimental Results

The capacity to constantly communicate with the network is necessary for testing electric wheelchair functioning including Internet of Things control. Performance testing to ensure control system accuracy, safety, and reliability consists of the following methods.

4.1. Electric-Powered Wheelchair Speed Test

The results of evaluating the electric wheelchair’s ability to travel quickly in a horizontal direction, using a test weight that ranged from 50 to 90 kg, and the data at a distance of 10 to 50 m are shown in Table 2, which displays the findings for each test period. The speed comparison chart is illustrated in Figure 7.
### Table 2. Electric-powered wheelchair speed test.

| Distance (m) | Weight 50 kg | Weight 60 kg | Weight 70 kg | Weight 80 kg | Weight 90 kg |
|--------------|--------------|--------------|--------------|--------------|--------------|
| 10           | 86.20        | 75.10        | 66.85        | 56.80        | 45.90        |
| 20           | 58.80        | 60.30        | 53.40        | 45.10        | 36.80        |
| 30           | 51.60        | 45.32        | 40.10        | 34.10        | 27.60        |
| 40           | 34.40        | 30.10        | 26.90        | 22.60        | 18.50        |
| 50           | 17.20        | 15.10        | 13.40        | 11.30        | 9.20         |

![Electric-powered wheelchair speed comparison chart.](image)

**Figure 7.** Electric-powered wheelchair speed comparison chart.

#### 4.2. Electric Powered Wheelchair in an Incline Test

The results of the experiment for determining the speed of upward motion on a slope of 10 degrees with different distances can be seen in Table 3. These were compared with the test outcomes for the rate of upward movement on an incline, as depicted in Figure 8.

### Table 3. Electric-powered wheelchair in an incline test.

| Distance (m) | Weight 50 kg | Weight 60 kg | Weight 70 kg | Weight 80 kg | Weight 90 kg |
|--------------|--------------|--------------|--------------|--------------|--------------|
| 10           | 127.60       | 100.50       | 86.60        | 72.50        | 62.90        |
| 20           | 102.90       | 80.80        | 69.40        | 58.60        | 50.90        |
| 30           | 77.50        | 60.30        | 51.90        | 48.80        | 38.40        |
| 40           | 51.10        | 40.60        | 34.60        | 29.40        | 25.60        |
| 50           | 25.90        | 20.40        | 17.40        | 14.50        | 12.80        |

![Incline comparison chart.](image)

**Figure 8.** Incline comparison chart.

#### 4.3. Displacement Distance Test

Smart wheelchairs were performance measured in mobility tests with a load of up to 100 kg for support no more than 100 kg with a distance of up to 3250 m. The test results for the distance of the wheelchair with two 12V/5 A dry batteries are shown in Figure 9.
4.4. GPS Tracking Test

In this study, the term location refers to the data collection process used to determine the wheelchair position in a particular setting. For this, different localization methods, algorithms, and approaches are needed. By synchronizing these parameters, we can use ubiquitous computing applications to calculate the position and build a positioning system [25]. A collection of localization techniques and algorithms enables accurate position estimation of objects in both internal and exterior settings. The Global Positioning System (GPS) is a technology that can be used outside. A device will detect a GPS signal and use that signal to find the wheelchair. After processing, the data is transmitted over the cellular network in a General Packet Radio Service (GPRS) format to the operator and is then sent to the user’s device to display a map of the location and the data detected as an image and a symbol showing the location and status of the wheelchair. The longitude and latitude (states 1 to 3) are shown in Table 4. Some application interfaces for wheelchair users are shown in Figures 10–13. This application enables the wheelchair user to determine the expected GPS setting, GPS moving (tracking 1), GPS moving (tracking 2), and GPS moving (tracking 3). A supervisor can also manage the user’s account, contact the wheelchair user, and determine the latest location of the wheelchair and the shortest way to get there using Google Maps. They can also receive notifications via e-mail, Line, Facebook, and short message service (SMS) if the user is in danger. In addition, they can see how much power is left in the wheelchair batteries and whether there is enough to return home.
5. Discussion

The satellite tracking system, called GPS tracking or Global Positioning System, is used to determine the position on the Earth, which we will install on the smart wheelchair or person who needs it to be tracked for high-precision positioning. Depending on the caliber of the receiving equipment, it is possible to track a product or person precisely and with minor deviations of up to 100 meters. It is incredibly helpful for locating things. It helps with searching, dictating, and route planning to save time, fuel, and cost, and keep job efficiency under control. It involves ensuring safety in all circumstances.

6. Conclusions

As shown in Table 2, the results of the speed test of a smart wheelchair with a weight of 50 kg running at a distance of 10 meters show that it can reach full speed in just 86.20
Table 4. Longitude and latitude (GPS tracking 1 to 3).

| GPS Tracking | Item | Longitude 1 | Latitude 1 | Longitude 2 | Latitude 2 | Longitude 3 | Latitude 3 |
|--------------|------|-------------|------------|-------------|------------|-------------|------------|
|              | assign | 100.61239   | 14.13312   | 100.61165   | 14.13311   | 100.61135   | 14.13311   |
|              | round1 | 100.613284  | 14.13312   | 100.611705  | 14.13311   | 100.611128  | 14.13311   |
|              | round2 | 100.612386  | 14.13312   | 100.611709  | 14.13311   | 100.61170   | 14.13311   |
|              | assign | 100.612343  | 14.13318   | 100.611196  | 14.13322   | 100.61165   | 14.13469   |
|              | round1 | 100.612316  | 14.13322   | 100.611120  | 14.13307   | 100.611158  | 14.13384   |
|              | round2 | 100.612309  | 14.133126  | 100.611180  | 14.133159  | 100.611150  | 14.133155  |
|              | assign | 100.611378  | 14.13434   | 100.612405  | 14.13432   | 100.612384  | 14.13312   |
|              | round1 | 100.613728  | 14.13432   | 100.612397  | 14.13367   | 100.61323   | 14.13314   |
|              | round2 | 100.613808  | 14.13426   | 100.612414  | 14.133164  | 100.612380  | 14.132457  |

5. Discussion
The satellite tracking system, called GPS tracking or Global Positioning System, is used to determine the position on the Earth, which we will install on the smart wheelchair or person who needs it to be tracked for high-precision positioning. Depending on the caliber of the receiving equipment, it is possible to track a product or person precisely and with minor deviations of up to 100 m. It is incredibly helpful for locating things. It helps with searching, dictating, and route planning to save time, fuel, and cost, and keep job efficiency under control. It involves ensuring safety in all circumstances.

6. Conclusions
As shown in Table 2, the results of the speed test of a smart wheelchair with a weight of 50 kg running at a distance of 10 m show that it can reach full speed in just 86.20 s, and if a weight of 90 kilograms travels a distance of 10 m, this takes 45.90 s longer. Table 3 shows the results of the control of the tilt angle of the smart wheelchair with a weight of 50 kg running at a distance of 10 m, it can move as fast as 127.60 s, and if a weight of 90 kg travels a distance of 10 m, this can take an extra 62.90 s. Figure 9 shows the performance of the smart wheelchair in mobility tests with a load of up to support no more than 100 kg with a distance of up to 3250 m with one battery charge. In addition, the results of the three GPS tracking displacement tests with varying longitude and latitude values, the mobility of the electric wheelchair in position 1 had an accuracy of 97.66 percent of the assigned route, position 2 had an accuracy of 98.58 percent of the designated route, and position 3 had an accuracy of 96.45 percent of the given route (see Table 4).
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