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Smartphones Transforming Wheelchairs with Intelligent Assistance

Journal of Electrical Systems

Abstract: - A smart wheelchair usually consists of a standard wheelchair plus a CPU and sensors. We can use a joystick and a Smartphone with an Android application in our wheelchair input control signal. Signals and wheelchair control indications are transmitted by cell phone. This mobile telephone can be put for patient use on the wheelchair armrest or can be used by a caregiver, such as a nurse, to move the wheelchair wirelessly instead of pushing it physically. Various sensors have been added to prevent collisions with surrounding obstacles. It also contains a sensor that detects steps and prevents malfunctions due to their descent.

Keywords: Smart wheelchair, Smart phone, Bluetooth module, Infrared Range finder, Cortex M4, STM32F4 Discovery board, IC 3921A, Hall sensor based joystick, obstacle detection, staircase detection.

I. INTRODUCTION

Self-appreciation is boosted by independent movement, whereas reduced mobility is linked to social isolation, anxiety, and depression, among other things. Muscular dystrophy, attention deficit disorder, paraplegia, trauma, cerebral palsy, spinal cord injuries, and old age are all common physical limitations that prevent people from travelling for free. These persons require mobility aids in order to move freely, which can be performed with the help of wheelchairs by extending their range of motion. We devised a revolutionary technique to regulating our wheelchair mobility with the help of a smart phone installed in our wheelchair. The fundamental idea is a "Smartphone" that runs on the Android operating system and can also control a wheelchair. The smartphone is connected to the wheelchair via Bluetooth wireless technology [1]. The smart phone not only controls the wheelchair's speed and direction, but it also shows information about the battery's status and any other system issues. This smart phone can be placed on a patient's armrest or used by a caregiver, such as a nurse, to remotely manoeuvre a wheelchair using Bluetooth technology. A Hall sensor-based joystick has been mounted on the armrest to give a secondary control input. Ultrasonic sensors and a Sharp Infrared Range Finder are included to help it avoid colliding with surrounding obstructions. It also features a sensor that detects steps and prevents issues caused by the downward direction of the steps. The entire system is built around a Cortex M4 processor, which receives control signals from a joystick or a smart phone via Bluetooth, receives signals from various sensors, and transfers control systems to two motor drivers, which control the direction and speed of two geared DC engines, allowing for controlled movement [1-5].

The following sections comprise the paper: The second section of the paper is a review of the relevant literature on the topic of the system. The third section gives a high-level overview of the architecture of the system. The integration of a number of modules used in the circuit/system development process is discussed in

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Section IV. We'll look at the various procedures that go into software development in Section V. Section VI shows the final wheelchair product design as well as the wheelchair's mechanical design. Finally, Section VII puts the article to a close, while Section VIII discusses the wheelchair system's potential in the near future

II. LITERATURE SURVEY

To investigate existing user conditions, aspirations, and medical requirements, a user research study was conducted [2]. Many frequent illnesses make it difficult for patients to roam freely, including muscular dystrophy, attention deficit hyperactivity disorder, paraplegia, trauma, cerebral paralysis, spinal injuries, and old age. This population is confined to wheelchairs and is entirely dependant on others for their daily needs and mobility. Many attempts to personalise the wheelchair have been undertaken by attaching various modifications to the chair's frame. There are further alternatives available, in addition to the voice-activated wheelchair [3] the wheelchair joystick [4,] the wheelchair head-activated [5,] and the wheelchair tactile screen activated [6,]. However, reliability, human safety concerns, mechanical flaws, and expensive costs are only a few of the technology's drawbacks. In some other researches the authors proposed different AI models in order to help in different aspects that help and support human being [7]-[11]. As a result, in this article, we designed an intelligent wheelchair that allows people with disabilities to move safely and autonomously according to their own needs. In order to identify the current status of the prototype, a cost and feasibility study was also conducted.

III. SYSTEM ARCHITECTURE

As demonstrated in the example, Figure 1 demonstrates how a smart phone can be connected to a wheelchair system utilising a Bluetooth module. It is capable of putting a huge number of wheelchair orders, as well as displaying battery status and potential system failure. An command is sent to the Control Unit when it is received from the panel or the smartphone joystick (CU). Ultrasonic sensors and the Infrared Range Finder (IRF) receive and interpret information from the surrounding environment to detect barriers and stairwells.

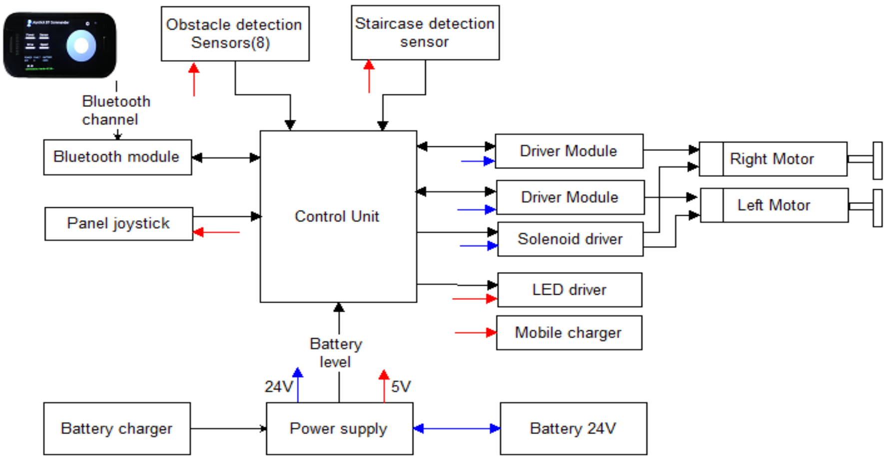

Figure 1. Functional Block Diagram

It calculates and sends a command to the driver module to control the speed and direction of two high-current permanent magnet direct current (PMDC) motors (DM). The motor's speed is controlled using PWM (Modulated Pulse Width) signals. Gradual acceleration and deceleration have been introduced to allow wheelchairs to move securely. Each geared PMDC engine has its own DM, which is different from the others. In the event of a fault, DM also interacts with the control unit. The solenoid brakes are controlled by a solenoid driver in the case of geared PMDC motors. It provides efficient brakes for the wheelchair when it is on a slanting surface. On the bracket panel of the bracket assembly, there are indicators for Bluetooth connectivity and battery charging [12-13]. Two 12V 18AH batteries were utilised in parallel as a power supply. The power supply unit is in charge of supplying the electricity required by the wheelchair's numerous components. When the battery is being charged, it has a device that protects it from harm. The computer system has been turned off. A mobile charger device is also available for charging mobile devices.

IV. ASSEMBLY OF DIFFERENT MODULES

The proposed model includes: Living magnet DC Motor, a driver of an automobile, control unit; It also includes a bluetooth interface module, joystick, detectors (Ultrasonic distance meter, IR range finder), a power source, and an android application.

A. Living magnet DC Motor

The roller chair has a high torque requirement at low speeds, which is met by increasing the torque while decreasing the speed through the use of a transmission system. Worm gears provide significant torque speed reductions as well as self-locking capabilities. The PMDC geared motor is selected because it meets all of the parameters listed above. In addition, the motors are equipped with a solenoid brake, which is typically held in the brake position and unbreaked when the motors are energised. This feature assists the user in maintaining control of the wheelchair when sitting or moving away from it. It is also beneficial to keep the wheelchair immobile as it is being rolled down the ramp [14-15]. A set of engine characteristics has been developed and is depicted in Table 1.

A driver of an automobile it accepts the input CU signal and supplies the power needed to move the PMDC motor at a set speed in a given direction [26]. It has the following objectives listed below. To advise the CU of any driver part defects, such as overheating or a short circuit. The engine needs to be protected because it utilises a lot of electricity. To avoid excessive power from the driver board to the processor [16-20].

Table 1. Specifications of PMDC Motor

MODEL NO.	**EC82M244632MLGBL**
SUPPLY VOLTAGE	24 V
RATED CURRENT	13 A
RPM	4600±100
GEAR RATIO	1:32
BRAKE	DC24V, 0.5 A, 20N-cm

The majority of the driver board employs the H-bridge based on MOSFET, or IGBT (Insulated Gate Bipolar Transistor) that allows the motor to rotate at the desired speed (clockwise and clockwise) to respond to an input PWM signal. In order to drive the current high-powered MOSFET-based H-bridge, we use Allegro Microsystems LCC's MOSFET-gate drive IC 3921A. The Figure 2 represents the driver module board.

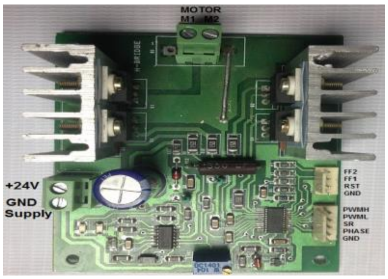

Figure 2: Driver Module Board

B. Controller Unit (CU)

After receiving input from a joystick or another user interface, as well as data from numerous sensors, an informative judgement is produced. The output control signals are sent to the wheelchair's driver component, which allows it to move around. It comes with both a CPU and an interface circuit. The STM32F407 discovery board, the Bluetooth module, five-voltage regulators, and IC interface drivers are among the components on this board as shown in Figure 3. The STM32F407 discovery board, which may be found here, houses the Cortex M4 processor. To prevent EMI effects from the transformer to the sensors, all signals are routed through line driver ICs 74HC245, and every incoming signal is routed through the Schmitt trigger IC 74 HC244 to prevent EMI effects from the sensors to the transformer. The controller board also has a joystick interface circuit as well as an ADC input circuit for measuring the battery level. To measure the voltage of the battery, the resistor divider divides the 24V input voltage by 10. On the control panel, there are several 5V regulators, one for each sensor, as well as one for the processing panel, joystick, and mobile loading source. The STM32F407 discovery board, which supplies a 3.3V supply, powers the Bluetooth module [20-27].

C. Bluetooth Module

HC -05 Bluetooth module is an easy to use Bluetooth SPP (Serial Port Protocol) module with following featured: such as complete 2.4GHz radio transceiver, UART interface with programmable baud rate with integrated antenna Permit pairing device to connect as default.

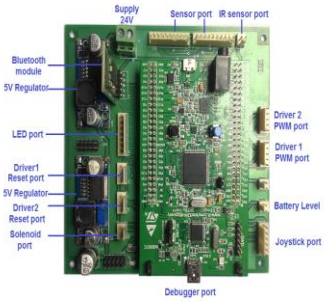

Figure 3: Controller Unit Board

D. JOYSTICK

It is the component of the wheelchair's user interface that receives user control signals and employs connected or wireless mechanisms to control the wheelchair's movement in terms of direction and speed. The intended rotational speed is represented by the x-axis of the joystick, while the desired speed is represented by the y-axis. Algorithm for mapping the joysticks: The distance between the lever and the centre () of the joystick determines the speed of the wheel, whilst the angle () of the joystick determines how the speed is shared between the wheels (see illustration). If the value is more than one, it is lowered to the smallest possible value or to an equal value. If x and y are standardised and vary between -1 and 1, then these requirements are satisfied. [16]. Hall Sensor Based Joystick: Contact less Hall sensor based joystick has less wear and tear in comparison of resistive joystick and hence are more reliable and better life. It provides analog outputs. Here we are using Contactless Hall sensor based joystick “HLS 2 L01 S12 K1 0505”.

E. Sensors

Ultrasonic sensors and Infra-red range finder are used to help the controller unit in taking decision like to avoid obstacles. For staircase detection Infra-red range finder are used [17]. The HC-SR-04 Ultrasonic sensor uses sonar to determine distance to an object. It can detect objects from 2 cm to 400 cm. Its operation is not affected by sunlight or black material (although acoustically soft materials like cloth can be difficult to detect). On receiving a trigger pulse of 10µS It provides output a pulse whose width is proportional to the distance of the obstacle.

$$\text{Time}=\text{Width of Echo Pulse,in microsec} \quad (5)$$

$$\text{Distance in c.m.}=1/58(\text{Time}) \quad (6)$$

The user interface component receives control signals from the wheelchair user via linked or wireless mechanisms and regulates the wheelchair's direction and speed accordingly. The x-axis represents the intended rotating velocity, while the y-axis represents the desired rotating velocity.

1) Algorithm for joystick mapping: The distance between a player's heel and the centre of the joystick () defines his speed, and the angle at which he holds the joystick () affects how the speed is distributed among the wheels. When a high number of values are present, they are reduced to a minimum or an equal number of values.

F. Power Supply

It guarantees that all subsystems, including the driver, controller, sensors, joystick, and interface circuit, receive the proper regulated power they require. We connected two 12 Volt 18Ah lead acid batteries in series to achieve a total voltage of 24 Volts. As long as the battery voltage is not below 10V (which it is monitored continually by the controller), the system is shut down by the control unit and the controller. It also prevents the wheelchair from operating while the battery is being recharged.

G. Android Application (App)

The Joystick BT Commander Android software has been updated to offer additional wheelchair directions and signalling and has been acquired from the Google Play store. Bluetooth is used to connect an Android phone to a wheelchair using this application.

V. 5. SOFTWARE DESIGN

Before judging and directing wheelchair mobility, the CU received an analogue joystick, a mobile AP via Bluetooth, an ultrasonic sensor, an IR Sensor (front and escalator detector) and an H-bridge driver (fault scenarios). The CU scans the input via the joystick. If the joystick input is non-zero, the CU also analyses the input of obstacle detectors to learn about the obstacles surrounding them. If there are no obstacles, the joystick input is sent to the drivers of the H-bridge, which regulate the movement of the wheelchair. Whenever an impediment or step enters the range around the wheelchair an interrupt is carried out and the CU shall take suitable measures to prevent a collision. Figures 4, 5 and 6 show the software design flow charts.

When the wheelchair power switch is enabled, the processor initialises all the essential Bluetooth, Timers and ADC (PWM, UART) GPIOs (universal asynchronous receiver and transmitter). To connect the joystick to the panel and read the battery level, ADCs are utilised. Motors run in response to applied PWM when the power switch of the mobile app is activated. In order to read the battery level, driver fault and command signal from the mobile app, the control unit employs ADC to decide if the engine is starting or not. The ON/OFF status, fault and battery level are also transmitted to the mobile application. If there is a DM problem, or the battery level is low, the control device stops the wheelchair. Various Timers used in programming are as follows:

Table 2.Various Timers Used

Timer	Application	Period
Timer2	Sensor	50ms
Timer3	Read ADC and calculate PWM	50ms
Timer4	Re-enable Sensor.	10s
Timer5	PWM	0.1ms
Timer7	Send Bluetooth data	65ms

Eight Ultrasonic sensor modules (HC SR-04) are utilised to identify obstacles. Pulse width output is provided by the HC SR-04. As a result, nine timers (one for trigger and eight for pulse width measurement) are required to detect an impediment or measure distance with eight ultrasonic sensors.

The use of more timers degrades the wheelchair's performance, and the STM32F4 exploration board has a limited amount of timers. Figure 5 shows an alternative way that employs a single timer to collect data from eight sensors. A single timer, "Timer 2," generates a 10 microsecond trigger pulse and reads the status of all sensors after a predetermined time interval determined by the CCR registers. There are two distinct time periods. For side sensor reading, one is designated by the CCR2 register at approximately 580 micro seconds. For front and rear sensor readings, the second instant is defined by the CCR3 register at about 5.8 milliseconds.

Figure 6 shows algorithm of joystick interfacing. It read steering input from panel joystick through ADC or mobile app joystick through Bluetooth. Than calculate PWM for left and right motor. It also taking into consideration the status of all sensors and takes decision accordingly to control movement and speed of the wheelchair.

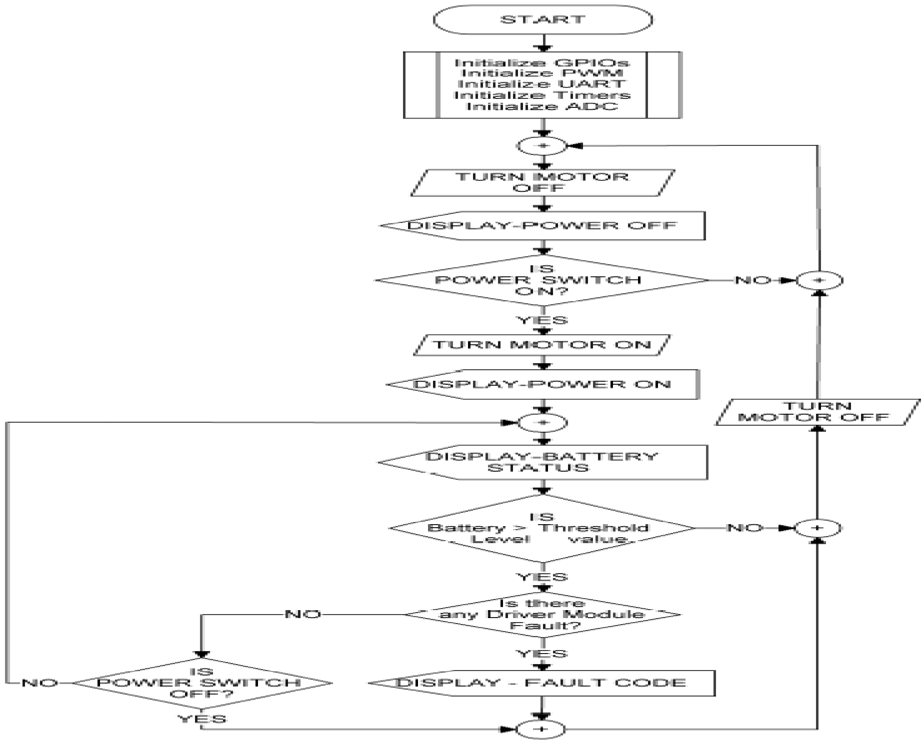

Figure 4: Flowchart for base loop

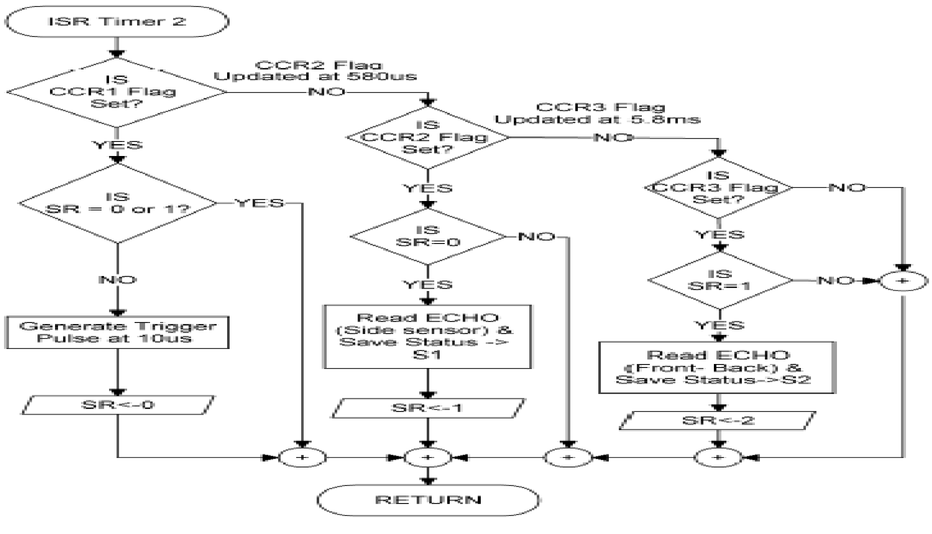

Figure 5. Flowchart for reading sensors

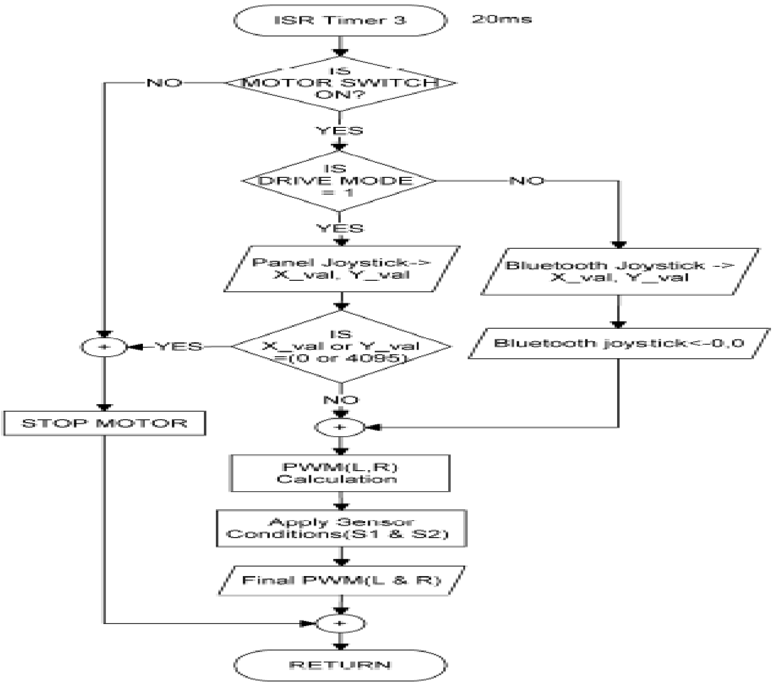

Figure 6. Flowchart for joystick interface and PWM calculation

VI. 6. Product Structure

For the prototype a wheelchair platform (Chassis) has been purchased from Callidai Motor works and all the electronic systems has been assembled on it. Figure 7 shows the exterior view of the final product "Smart wheelchair". It consists of following parts:

Figure 7. Final structure of Smart wheelchair

- Two motors with gearbox and solenoid brake are attached to the rear wheels of the wheelchair.
- Two motor drivers, main controller board, solenoid drive board, switch board and Bluetooth modules are enclosed in a box resides at the back base of the wheelchair.
- Battery 24V (12Vx2) 18AH resides at the front base of the wheelchair.
- Control panel with joystick, two indication LEDs, Smart phone with app and mobile charging port.
- Two front sensors (Ultrasonic sensor and IR range finder in enclosure box) for obstacle detection.
- Two side sensor (Ultrasonic sensor in enclosure box) for obstacle detection in each side.
- Two back sensor (Ultrasonic sensor in enclosure box) for obstacle detection.
- One sensor (IR range finder in enclosure box) in front, for staircase detection.
- Battery charging port.

VII. 7. Conclusion

This wheelchair prioritizes smooth and safe user experience through features like jerk-free motion control via both a physical panel joystick and a smartphone app connected by Bluetooth. The wheelchair achieves a maximum speed of 7.5 Km/h and incorporates obstacle and staircase detection for safe stopping. Additional functionalities through the mobile app include temporary sensor deactivation for navigating narrow spaces, speed mode selection for indoor and outdoor environments, and real-time monitoring of motor driver status and battery level. This "Smart Wheelchair" demonstrates the potential for improved user control, safety, and convenience in powered wheelchair technology. At low battery status (below 10V) it turned OFF the wheelchair to save the life of the battery.

Acknowledgments: The authors extend their appreciation to the Deanship of Scientific Research at Northern Border University, Arar, KSA for funding this research work through
the project number “NBU-FFR-2024-1578-01”

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