A BLUETOOTH TECHNOLOGY CONTROLLED WHEELCHAIR

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Abstract

This research is about the design, development and implementation of a Bluetooth Technology Controlled (BTC) wheel chair. The wheelchair was developed to solve the mobility challenges faced by disabled. Though manual wheelchairs provide some solution, they pose the challenge of high physical strain. Extensive literature review has shown that the existing powered wheelchair technologies have some limitations. These includes requirement of complex repetitive body movement and inability to control the wheelchair over a distance. In this regards, this work develops a Bluetooth Technology Controlled (BTC) wheelchair which provides the disabled a cost-effective option of controlling the wheelchair over a distance, using an input method that is dependable. The design of the electric circuit is prepared and used as a guideline for subsequent development stages. A Bluetooth module is used to receive input from an android mobile phone. The received signals are processed, and the corresponding actuating signal is sent. The completed work is a Bluetooth control system with an android phone as an input device to send signal to electric motor that actuate the wheelchair with no requirement for manual propelling by the user or another person. The BTC wheelchair is cost efficient compared to existing powered wheelchairs of the same caliber

Keywords

Bluetooth Technology Controlled, Electric Circuit, Arduino Uno, Android mobile phone, Input device

1. Introduction

Different types of wheelchairs are designed to meet the need of different users. The most popular distinction is between motorized wheelchairs and manually propelled wheelchairs. Manual wheelchairs can either be propelled by the user's hands or by a third party. It requires constant and strenuous application of upper body muscles of the users. Thus, there is constant demand for an easier method of controlling wheelchairs. According to [1], manual wheel chair has been in existence before the advent of motorized wheelchairs. However, inability to navigate through one's own house single handedly without any assistance is demoralizing [2]. A motorized wheelchair is a wheelchair that is propelled by means of an electric motor and can be controlled by the user [3]. They are automated system and involve the use of synergistic integration of various components. For instance, the Head Movement Tracking Technique(HMTT) is a common method used to control powered wheelchairs. In this method, head movements are proportionately transformed into cursor movements on the screen and the motion parameters are calculated by using accelerometer. However, disabled with cerebral palsy ailment cannot move their head comfortably. This limits the application of this method [4].

A system was proposed by [5] that uses a small camera mounted very close to the user's hand, which tracks the small movements of user fingers to understand the direction of movement of the wheelchair. A gesture recognition system which identifies the gesture is then interfaced to the wheelchair control system in order to move it to the desired location. Nevertheless, this product was limited as it required complex and continuous hand motion by already disabled. [6] presented a reliable means for human-computer interfacing based on hand gestures made in three dimensions, which could be interpreted and adequately used in controlling a remote robot's movement. The authors discussed the development of a novel architecture of an intelligent wheelchair working on wireless hand gesture control and not by the usual method of keypad for the physically handicapped people. The locomotion of the wheelchair was controlled by a microcontroller. This work's limitation was its constant requirement of a cellular network.[7] proposed a wheelchair command interface that does not require the user's hands. It includes 3 major modules; the face detection, facial expression recognition and command generation. The software contains digital image processing for face detection, principal component analysis for facial expression recognition and generating a command signal for interfacing the wheelchair. But like all existing image processing systems, this work was liable to frequent failure. Wheels Easy, targeted disabled group that were unable to drive a wheelchair with a normal joystick. Users could use switches on a panel to select between different high-level commands such as stop, left, right, forward, or drive backwards [8].

Extensive literature review has shown that the existing electric wheelchair technologies have some limitations. This includes the requirement of complex repetitive body movement by an already disabled as well as high cost of procurement. Our project aims to incorporate a number of the technologies including but not limited to Bluetooth technology, Arduino Uno, use of relay as actuator. However, the limitation of complex repetitive body movement is eliminated.

The design of the electric circuit was prepared using Proteus and used as a guideline for subsequent development stages. Button switches are used for the manual input which are connected to the Arduino Uno and are used to receive input from the user. For the Bluetooth input method, a Bluetooth module is used to receive input from an android mobile phone. The received signals are processed, and the corresponding actuating signal is sent. The completed work is a wheelchair using Bluetooth from an android phone as an input device, with no requirement for the wheelchair to propel manually by the user or another person.

1.1 Objectives

The objectives of this study are outlined as follows;

i. To design a Bluetooth controlled wheel chair
ii. To use an Android mobile phone to control the Bluetooth enabled wheelchair

2. Literature Review

Extensive literature review reveal that several researchers have studied extensively on easier methods of controlling wheelchairs. For an instance, Amiel et al.(2019) described the integration of hardware and software with sensor technology and computer processing to develop the next generation intelligent wheelchair. The focus was a computer cluster design to test high performance computing for smart wheelchair operation and human interaction. The LabVIEW cluster was developed for real-time autonomous path planning and sensor data processing. Four small form factor computers were connected over a Gigabit Ethernet local area network to form the computer cluster. Autonomous programs were distributed across the cluster for increased task parallelism to improve processing time performance.
Hameed et al (2021), designed and built a smart wheel chair with several control interfaces. A version of the smart wheelchair device was built based on a currently accessible traditional wheelchair on the market, with the introduction of similar electrical and mechanical developments. To improve user involvement, the system included speech and gesture-control interfaces as addition to the Mobile Application for controlling the Wheel Chair.

Also, Leela et al (2017), designed a system where the handicapped person gives their voice to the android mobile, output of the Android mobile is voice command that is converted into text. The output of the mobile is given to the microcontroller and the proposed system movement is controlled using Bluetooth module with the help of DC motors. This proposed system has battery powered wheelchair with DC motors. Also an ultrasonic sensor is used to detect the obstacle.

Furthermore, Rakhi et al (2013) designed and developed a system that allows the user to robustly interact with the wheelchair at different levels of the control and sensing. A dependent-user recognition using Head movements and infrared sensor integrated with wheelchair. A wheelchair can be driven using acceleration sensor and Head Movements with the possibility of avoiding obstacles which works on the principle of acceleration, one acceleration sensor, provides two axis, acceleration sensors whose output varies according to acceleration applied to it, by applying simple formula, the amount of tilt & output of tilt will decide to move in which direction was calculated. Total of 4 sensors were installed for detection of wall/obstacle in the forward, backward, left & right direction. However, to the best of researchers, knowledge, manual wheelchairs have failed to provide a dependable and easy to use option for disabled.

3. Methods

The development of this project began with the acquisition of manual wheel chair. A satisfactory circuit was design for the system using Proteus. The project development stages were classified into electrical design, software design, mechanical coupling or design and system interfacing.

The circuit diagram shown in Figure 1 was first designed using Proteus.

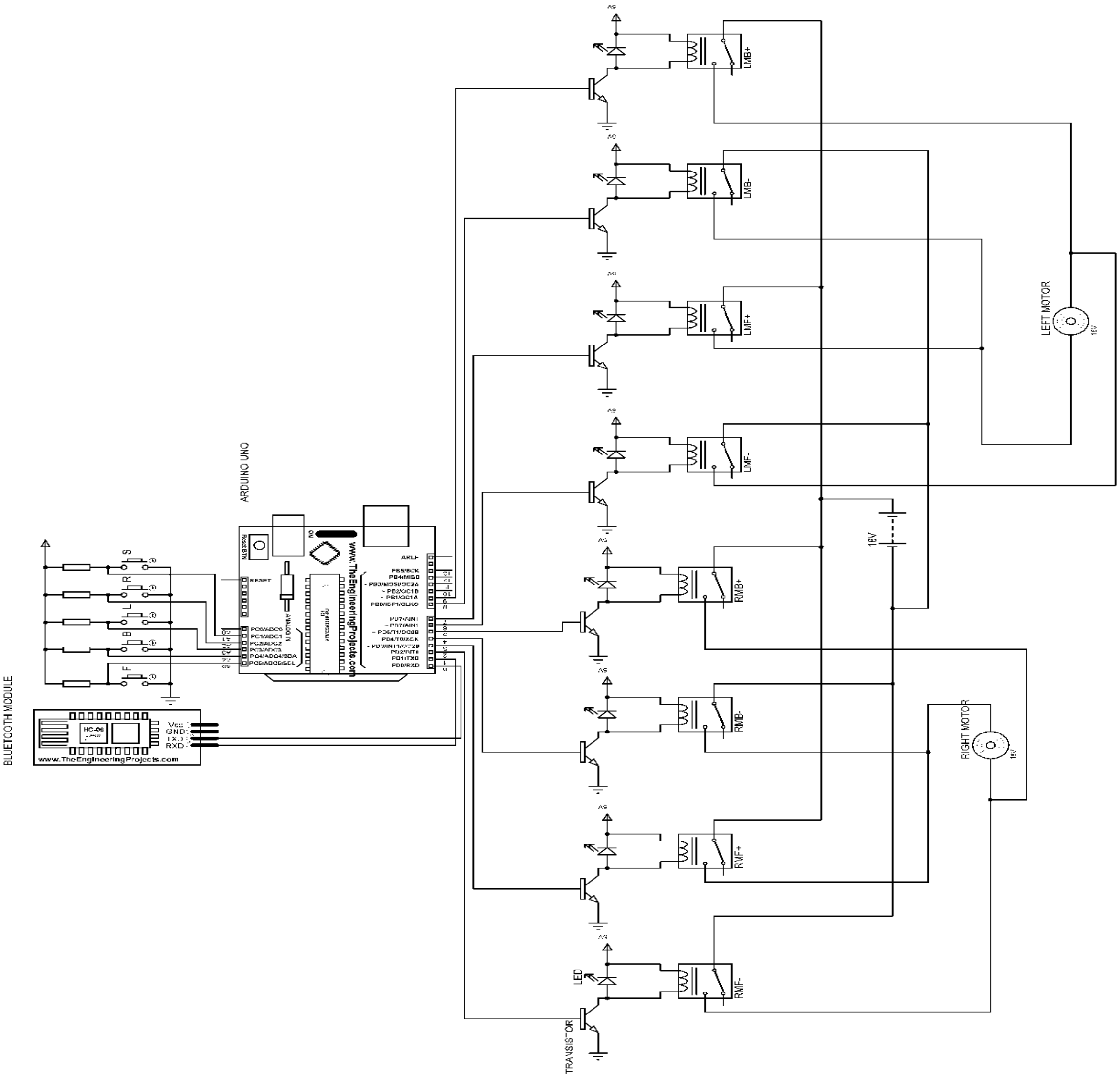

Figure 1: Circuit Design of the System

For the Bluetooth input method, a HC-06 Bluetooth modules used for receiving input from an android mobile phone. The Bluetooth application on the android device has 4 inputs, front, back, left and right. When any of the inputs are pressed, a corresponding signal carrying the specified data is sent wirelessly to the Bluetooth module. The Bluetooth module has 2 data pins, namely transmitter labelled as TX and receiver labelled as RX. Figure 2 shows the Graphical User Interface used to control the BTC wheelchair on the android device.

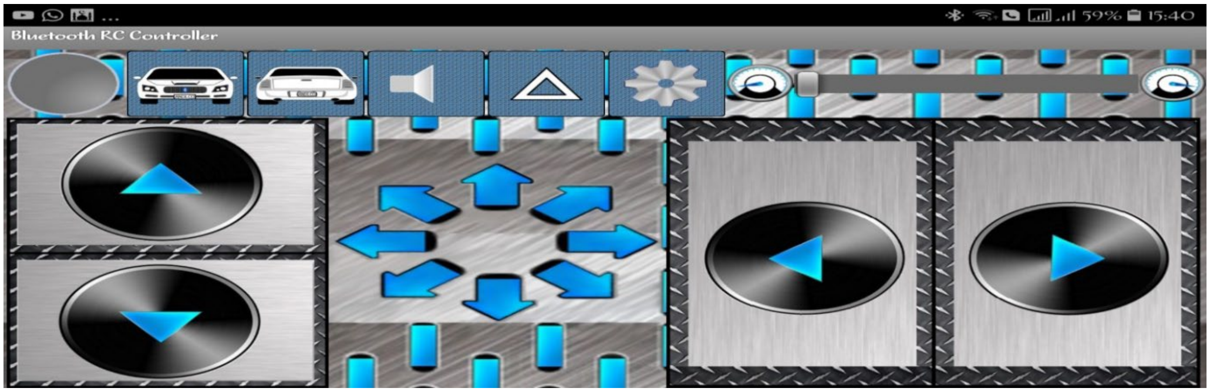

Figure 2: Application for Bluetooth Control on Android Device

The relays used are Single Pole Double Throw (SPDT) switches. Each of the relays is connected to a digital pin on the Arduino Uno that has been configured as an output. The relays are named based on the polarity of connection meant for switching.

The code was written on Arduino 1.8.5 software which is an Integrated Development Environment (IDE). The flowchart in Figure 3 illustrates the operations of the code.

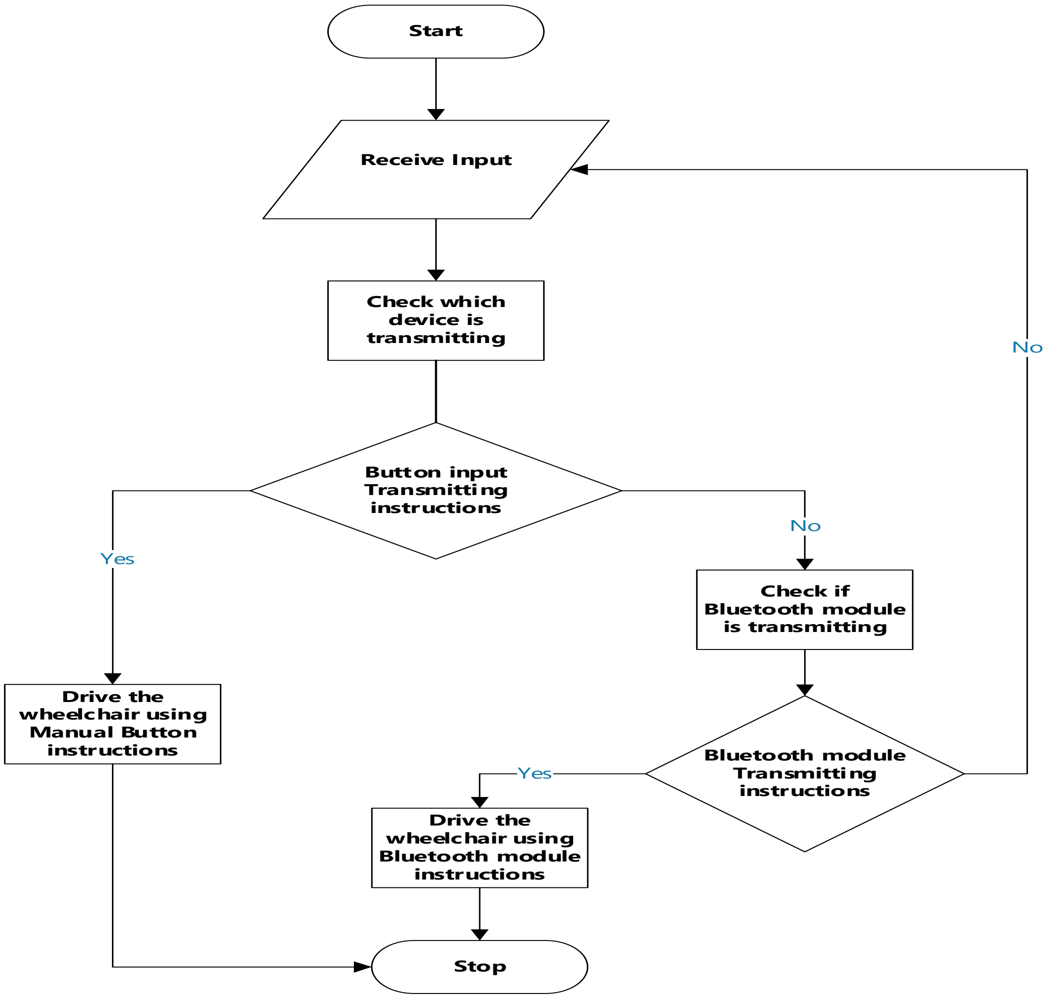

Figure 3: Flowchart of the Arduino Code

The following procedures were carried out to couple the mechanical components

i. The exiting shaft on the wheelchair was removed to detach the wheel.

ii. Turning operation was carried out on the lathe to produce an 8mm stainless-steel shaft

iii. The shaft was mounted on the wheel and the electric motor mounted on the shaft. An 8mm diameter shaft was adopted because, the diameter of the shaft slot on the wheel is 8mm. Figure 4 shows the Computer Aided Design (CAD) of the coupling.

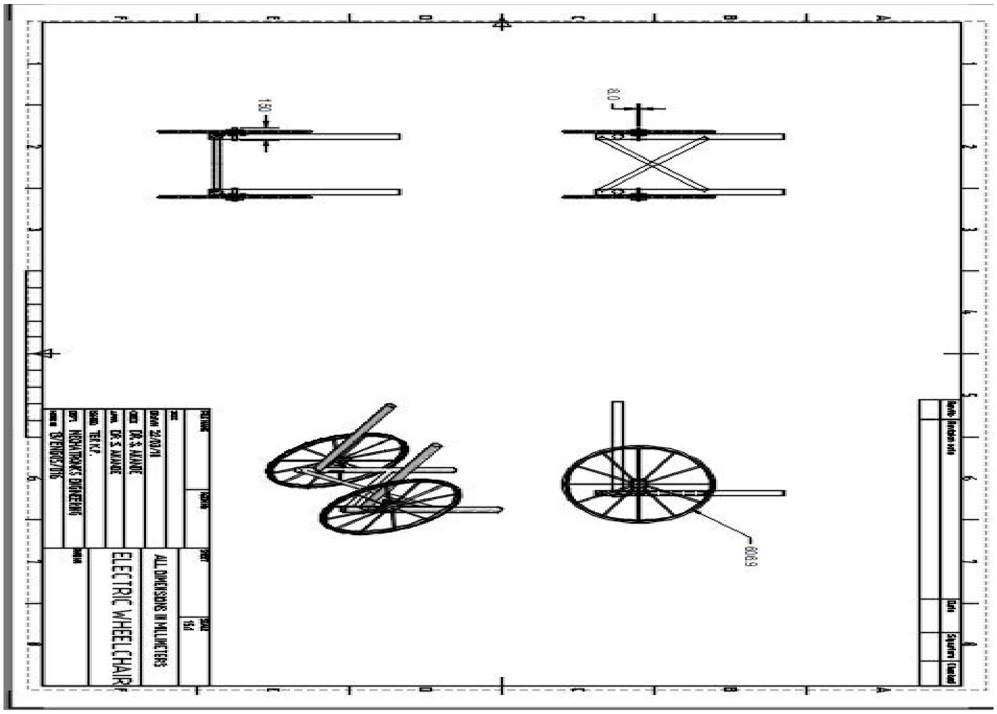

Figure 4: CAD Design of the Shaft Attached to the Wheel

The interface between two (or more) systems describes how the systems “communicate.” In the development of BTC system, different components are interfaced, both hardware and software to produce the required output. The code written is embedded in the Arduino Uno which serves as Programmable Logic Device (PLD). The code was written using C language on the Arduino IDE and was uploaded to the Arduino board, using a type A USB connection. When the Arduino has been connected, the port through which the Arduino was connected was picked in the Arduino IDE. With the above listed steps completed, the code was uploaded to the Arduino Uno board.

For the hardware connection, the Arduino was connected to two input devices, the push buttons and the android mobile device through Bluetooth.

Five (5) push buttons are used, each connected to one analogue pin on the Arduino Uno (Figure 5), these buttons are momentary switches and provide manual input to the system.

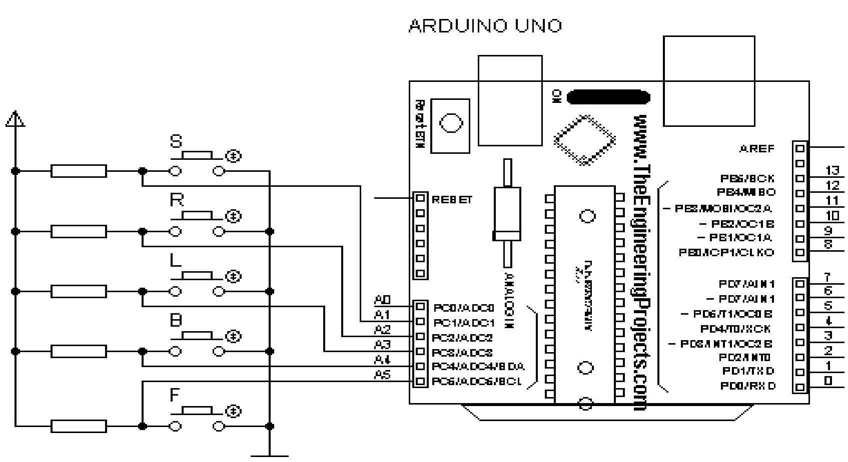

Figure 5: Circuit Connection of the Buttons and the Arduino

The second input method is the Bluetooth module which is connected wirelessly to an android device. It receives input signals from the android device and relays them to the Arduino for processing through the RX and TX pins of the Arduino. This is illustrated by Figure 6.

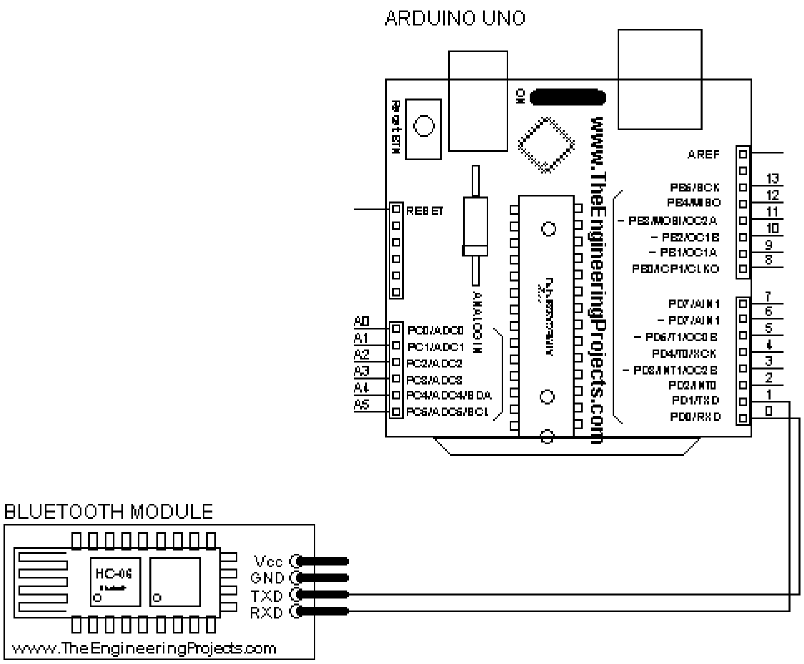

Figure 6: Bluetooth Module Interfaced with Arduino

The 8-channel relay system serves as an actuator for the system. The input for the relay comes from the Arduino digital pins. The relay has 8 pins, 1 for each relay. Each of these is connected to an Arduino pin (Figure 3), namely pin 3,4,5,6,7,8 and 9. This is illustrated in figure 7

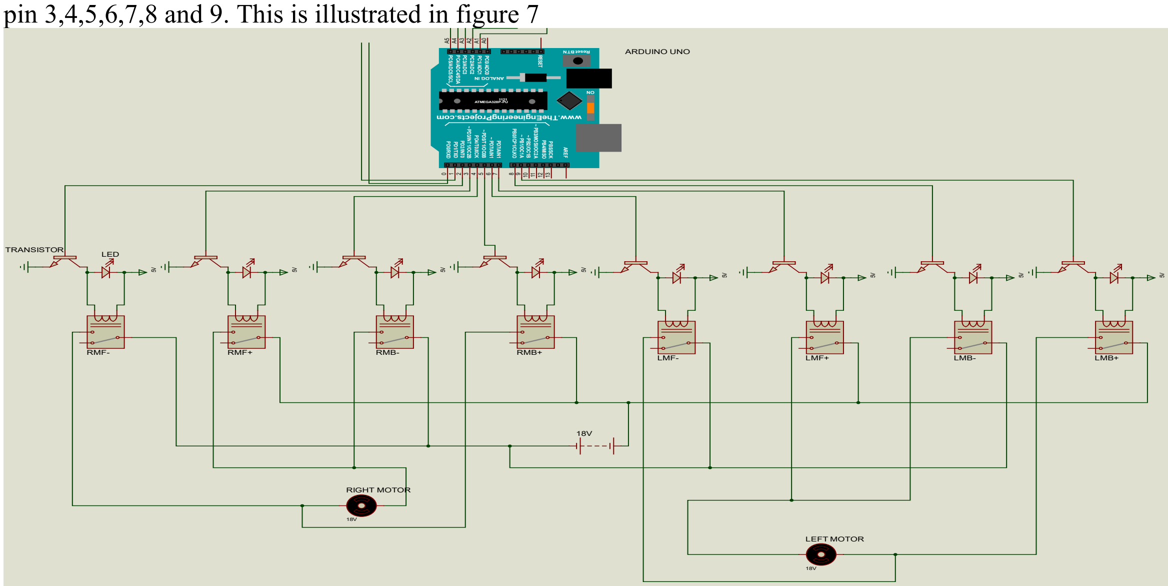

Figure 7: Integration of Relays to Arduino

The output from the relay is the switching mechanism that turns the left and/or right motor at the required time and in the required direction of rotation (which is either forward or backward).

4. Data Collection

The following analysis were required to select the motor that effectively drive the wheelchair

The Expected Weight range of User: 90 kg. [9]

Weight of Wheelchair only = 18 Kg
Using an intuition method, the power requirement to drive the wheel chair is within 8-10KW. Such a motor weight varies between 1.2-1.5 Kg. For an instance, a TP Power TP 100XL Brushless DC motor capable of delivering 8.4 KW weight 1.48 kg [10]
Also a battery of 1.55V and 1.5AH, will power the motor. The average weight of light battery of such specification is around = 0.0025kg (This is negligible)
A tolerance of 2kg is added to the total weight
Total weight expected $= 90\text{ kg} + 18\text{kg} + 2\text{kg} = 110\text{kg}$
Calculating Rolling Force
To help quantify rolling resistance in wheelchair, the "coefficient of rolling friction." Should be considered. This is a number that has been empirically determined for different materials, and can vary by the speed of the wheel, the load on the wheel, and the material the wheel is contacting. Given the coefficient of dynamic friction = 0.8 (most commonly used for wheel and cemented floor)

$$\text{F} = \mu R \qquad (1)$$

Where
F = the force required to overcome the rolling friction
μ = the coefficient of rolling friction
R is the normal reaction

$$\text{R} = \text{mg} + \text{ma} \qquad (2)$$

If the wheel is to be accelerated at 1m/s^2
R = (110× 9.8) + (110× 1) = 1188N
F = 0.8 × 1485 =950N
Since the wheelchair has 2 wheels with a separate motor on each wheel, the force required at each wheel:

$$\text{F}_{\text{wheel}} = \frac{950\text{N}}{2} = 475\text{N} \qquad (3.3)$$

Torque is the rotating force supplied from a motor to a load. In order to move a stationary load torque must be applied, likewise a rotating load may be accelerated or decelerated by applying torque in the suitable rotational direction.
Generally, torque may be viewed as a measure of turning force on an object rotating about an axis and as such may be defined as force multiplied by the distance from the axis of rotation
Wheel radius, R= 0.28 m
Wheel torque is given by:

$$\tau = \text{F} \times 2 \times \pi \times \text{R} \qquad (3)$$

Where

τ is the torque (Nm)

F is the force (N)

$$\tau = 475 \times 2 \times 3.142 \times 0.28 = 836.12\text{Nm}$$

This is equivalent to the running or operating torque.
There are three main torque measures which must be considered; breakaway torque, running torque and high inertia loads.
Breakaway torque is the torque required to start moving a stationary load. It is typically much higher than the torque required once a load is rotating, but is however, only required for a short initial period to get the load moving with motors often being able to operate at this elevated torque requirements during start up. Depending on the nature of the machinery and the types of bearings used the breakaway torque can be anywhere from 120% to 600% and above of running torque. For a typical ball or roller bearings or wheel, the Breakaway torque is 120% to 130% above running torque.
The minimum Breakaway torque = (1.2 × 836) + 836 = 1839KNm
The maximum Breakaway Torque = (1.3 × 836) + 836 = 1922.8KNm
The breakaway torque is considered in the selection of motor.
Running torque is the torque that is required to sustain the machine at the normal operating rotational speeds. Running torque may be calculated if the power requirement and the motor speed are known.

$$\tau = \frac{30P}{\pi N} \qquad (4)$$

Where N is in RPM, P is in kW and τ is in kN.m.
In addition to the breakaway and running torque, the inertia of the load must also be considered when selecting a motor or drive. Unlike breakaway torque, if a load has a high moment of inertia it may take a significant period of time to accelerate or decelerate. This will lead to an extended period of time for which the motor must run at an elevated torque.

Revolution per Minute, (RPM)= $\frac{60\times V}{2\times\pi\times R}$ (5)

Assuming a velocity of 1m/s

$$\text{RPM} = \frac{60\times 1}{2\times\pi\times 0.28} = 34.1\ \text{Rev/min}$$

Motor Specifications:

Using the breakaway torque

Minimum Power require= $\frac{\tau\ \min\times\pi\times \text{RPM}}{30} = \frac{1839\times 3.142\times 34}{30} = 6548.56W$

Maximum Power require= $\frac{\tau\ \max\times\pi\times \text{RPM}}{30} = \frac{1923\times 3.142\times 34}{30}$ = 6847.67W

An electric motor with power rating between 6.5KW-6.8KW is required.

Therefore, a battery supplying a Voltage of 1.2 Volts with at least 1.6 Ampere Hour (AH) ratings will supply the required power to the motor.

5. Results and Discussion

5.1 Proposed Improvement

To improve mobility, safety and accessibility, the latest digital technology can be applied for improvements. Using the concept of digital twinning which is stored on a cloud computing platform, a detailed map can be accessed on the wheelchair, allowing it to navigate its way round its environment safely.

5.2 Validation

To validate the accuracy of the system developed in this work, a manual wheelchair and the wheelchair developed in this work were given to 2 individuals with difficulties in walking. The individual with the wheelchair developed in this system experienced ease in navigating rather than using a manual wheelchair. It was seen to be less tiring and durable over a period of time.

6. Conclusion

Manual wheelchairs have failed to provide a dependable and easy to use option for disabled. This problem brought about the development of the motorized wheelchair with various methods of input mechanisms. The BTC wheelchair is developed with the knowledge that a large percentage of the population makes use of android devices, any of which would function properly at no additional costs to the user. The BTC wheelchair provides a cheaper and reliable alternative to existing in accordance with the aims and objectives that were earlier stated. The BTC wheel chair is therefore recommended over the existing motorized wheel chair.

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