INTELLIGENT TRACTABLE WHEELCHAIR

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ABSTRACT

A fully dedicated wheelchair to the biomedical sector with its smart features is presented. This paper describes the design of a prototype of the intelligent tractable wheelchair. This wheel chair is a boon to all those people who are suffering from various ailments which makes them disable or immovable, and make them dependent on others for their movement. Persons with different symptom combination can get benefit out of it at different level. Some wheelchair users find manual or powered wheelchairs difficult or impossible to operate. Therefore many researchers and scientists are working to develop smart wheelchairs for their ease. This multi-control smart wheelchair incorporates smart control features like touch control, voice control, gesture control, computer control along with medication reminder and stair climbing facility to assist primary needs of patient. The smart wheelchair control unit consists of integration of microcontroller ATmega16 with Bluetooth module, RF receiver unit and dual tone multiple frequency decoder incorporated with sturdy and stable wheelchair base mechanism to traverse realizable routes.

KEYWORDS: *smart phone, rehabilitation, disability, smart wheelchair.*

I. INTRODUCTION

According to the World Health Organizations report on disability, currently about 15 percent of world population lives with some type of disability of whom 2-4 percent experience significant difficulties in functioning[2]. The global disability prevalence is higher than previous WHO estimates, which date from the 1970s and suggested a figure of around 10 percent. This global estimate for disability is on the rise due to population ageing and the rapid spread of chronic diseases, as well as improvements in the methodologies used to measure disability [2]. About 80 percent of the disable people live in developing countries as declared by the United Nation Development Program (UNDP).According to study report of census 2011 of India, the majority of population by the type of disability in seeing, hearing, speech, movement, mental retardation, multiple disabilities etc lies in movement which is about 20.5 percent [1]. Psychologically, reduction in the mobility can lead to feelings of emotional loss, reduced self-esteem, isolation, stress, and fear of abandonment. Multiple sclerosis and arthritis patients have severe disabilities and cannot drive joystick operated wheelchairs.

Also cases of patients on wheelchair are just not limited to just paralysis. The patient can also be affected by following listed chronic or intermittent issues:

- Blindness
- Hands and legs fractured
- Musculoskeletal issues
- Balance or gait problems
- Neurological issues
- Genetic disorders
- Amputated legs and hands

So considering all these factors a wheelchair was developed to suffice all needs of every type of user. Here are the features of the wheelchair.

- Firstly the self propelled part of conventional wheelchair is removed and replaced by smart features which nearly require no extra force to move the chair.
- The joystick operative mode is replaced by touch mode wherein user has to slide his/her finger in the direction he/she wants.
- Besides these monotonous modes it also consists of hand gesture based movement which counters various forms of paralysis or if the patient is unable to control chair with finger.
- The third mode is voice incorporated if patient is fully physically disabled or has musculoskeletal problems.
- For patients who are blind or have neurological issues, PC controlled mode is available wherein a host PC monitors all the movement of chair. The location of chair with visuals is obtained through camera mounted on chair. Also if patient falls ill suddenly while travelling the location of patient along with his position and id is sent through GSM to emergency smart phone number and PC mode can be enabled just by pairing up with the required id and patient can be taken to a safe place.
- Unlike all wheelchair products in market, this wheelchair does not just travels on flat, rough or slopes. It has reliable mechanism to climb/de-climb stairs without any effort by user or any external human efforts.
- The wheelchair consists of three modifiable positions which includes chair position, bed position & relax position. The bed position helps the patient's burden to be reduced while being shifted from wheelchair to bed while sleeping; or in case there is bed shortage at paraplegic centre's. The chair position is the conventional position while the relax position is for user's comfort to read books, watch television, etc.
- There is medication reminder facility for the patient to have his/her medicine at the prescribed time. This feature is made available to work for the desired time of the day or night and frequency of reminder can be set as per need the patient. Additional temperature and heart rate monitoring facility is also available to monitor health of critical patients.

The paper is organized as follows, section III presents a brief description of the hardware and mechanical aspects involved and implemented, section IV explains briefly about the results obtained after practical implementation of the wheelchair along with pictorial representation, section V lists the future scope and section VI gives the conclusion of the work.

II. LITERATURE SURVEY

(a) Alex Dev, Horizon C Chacko (2011) used EOG to control the wheelchair locomotion. A pair of electrodes is placed horizontally to left and right Eye. If the eye is moved from the centre position towards one electrode, a potential change occurs between the electrodes. Due to the changes in the potential the wheelchair can be controlled [5].
(b) Sangmeshwar S. Kendre (2010) used Voice control system to control the locomotion of the wheelchair. They store the default commands in the PIC IC (micro controller) by the usage this commands the wheelchair can move. Change in the words restricts the wheelchair movement [7].
(c) Chun Sing Louis Tsui, Pei Jia (2008) used EMG control for wheelchair locomotion. They used eyebrow muscle activity to obtain required signal. By using the signal the wheelchair movement has been controlled [6].
(d) S.Tameemsultana and N. Kali Saranya (2011) [3] used head and finger movement for wheelchair locomotion. In finger movement they use flex sensor, placed on the finger. It is an analog resistor usually in the form of strip long variable resistance. Due to the bending of finger the resistance varies which controls the locomotion of the wheelchair. Bending the sensor at one point more than 90 may permanently damage the sensor which is a main drawback. The system already existing for the physically challenged person controlled by other different technologies has some defects:

- In Eye ball sensor they use infra red sensor to control the wheelchair where continuous fall of IR radiation in the eye causes irritation to the patient (Alex Dev, Horizon Chacko and Roshan Varghese, April, 2012, ISBN.) [5]
- In voice control the person must use the exact commands only to control the movement. Change in the words restricts the wheelchair movement (Manuel Mazo, 1995) [4]. All the

electronic system and also the philosophy for functioning has been sufficiently refined to attain the subsequent performances:

- To ensure easy, comfortable driving.
- To reply to the speed requirements for a system of this kind (maximum speeds of up to three m/s).
- To be simply adaptable to any kind of commercial wheelchair chassis.
- To ease learning to handle the chair and getting most potency.
- To ensure much constant speeds, to an oversized extent independently of the characteristics of the surface over that the wheel chair is moving (greater or lesser roughness of the ground and also slope of same) and the weight of the person using it.
- To form the system simply configurable, on the premise of the needs of the user: activating or de-activating of the different sensors, and choice of various speed margins, human-machine interface which allows up-to-date information on the state of the wheelchair, etc.
- To form it possible for the similar wheelchair to be utilized by various people
- To form the electronic system opens to future additions

III. PROPOSED METHODOLOGY

3.1. Hardware Description

- The basic structure of our project consists of microcontroller, motor driver, smart phone, computer/laptop, power supply and motors. The main aim of this project is construction of wheelchair having a direction control through voice commands, touches or hand gesture.
- The touchpad comprises a smart phone. When pressure is applied to the capacitive screen of smart phone, an XY co-ordinate location is produced and transmitted with Bluetooth available on smart phone to Bluetooth module (HC-05) available on wheelchair and the wheelchair will move in the desired direction.
- A change in location of the pressure will result in a corresponding change in direction .The touchpad also has a neutral or no movement point which will ensure efficient braking. This is very helpful for paralysed and physically challenged people.
- Similarly, voice commands can be used as input to a decoder which converts a particular frequency of voice into digital bits for controller to process it and take desired action. Using voice operative mode the user can operate the wheelchair using pre-decided voice commands. The voice commands will be transmitted via Bluetooth available on smart phones.
- In hand gesture mode the user will be able to manipulate the wheelchair using hand movements. This is achieved by using accelerometer sensor available on smart phone which are used for gesture gaming.
- The data, as above, will be transmitted via Bluetooth. In automatic mode, the wheelchair is controlled by a host PC to traverse the route. This is very helpful to navigate in places such as home or where user is fully paralysed. This feature can also be efficiently used if the patient feels ill and cannot regulate the wheelchair himself/herself. The patient will thereby be leaded to his/her home or paraplegic centre safely.

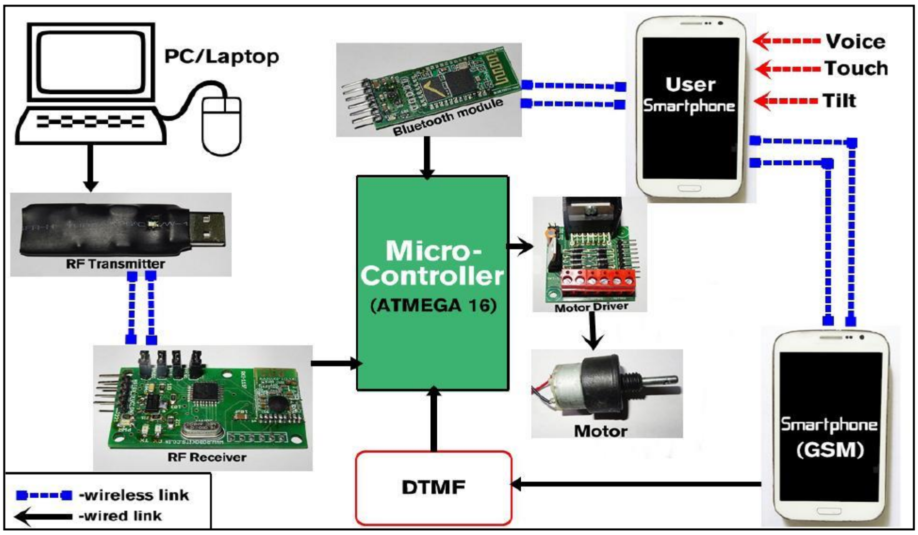


Figure 1. Main Block Diagram

BLOCK DIAGRAM DESCRIPTION

The heart of the circuitry is based on the microcontroller ATMEGA16. The microcontroller along with other peripherals attached does the actual processing of data accumulated from sensors.

- For touch/gesture mode of control, a user smart phone is used which comprises of capacitive touch screen and inbuilt Bluetooth module. It is wirelessly interfaced to another slave Bluetooth module which feeds input to the controller via wired lines.
- For voice mode of control, a user smart phone is used which comprises of sound sensor and uses GSM to wirelessly communicate with other devices(cell phones).The Dual tone multiple frequency decoder is used to decode the voice commands received and is fed to the controller.
- For computer/laptop mode of control, the universal serial bus (USB) is used along with a 2.48 GHz ISM band RF transmitter to send commands to a RF receiver unit attached as a peripheral to the controller.
- To propagate the controls to the wheels so that movement can take place there is interfacing between controller and motors via motor driver unit (L298N).

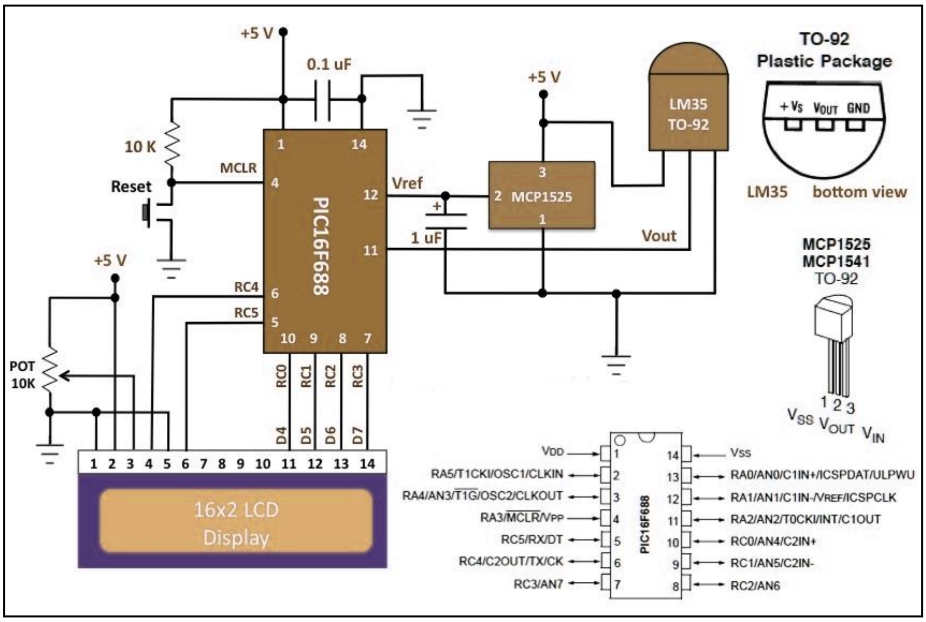


Figure 2. Temperature monitoring circuit diagram

PIC16F688 is used to process the data sensed by the LM35 sensor. A popular voltage output analog integrated circuit temperature sensor is the LM35 DZ, manufactured by National Semiconductor. This is a 3-pin analog output sensor which provides a linear output voltage of 10 mV°/ C. The temperature range is 0°C to +100 °C, with an accuracy of ±1.5 °C [11]. The reference voltage essential for temperature calculation is provided by interfacing MCP1525 IC.MCP1525 is a low power, high precision voltage reference. It provides a precise output voltage of 2.5V which is then compared to other voltages in the system [12]. The calculated temperature is displayed using liquid crystal display (LCD).

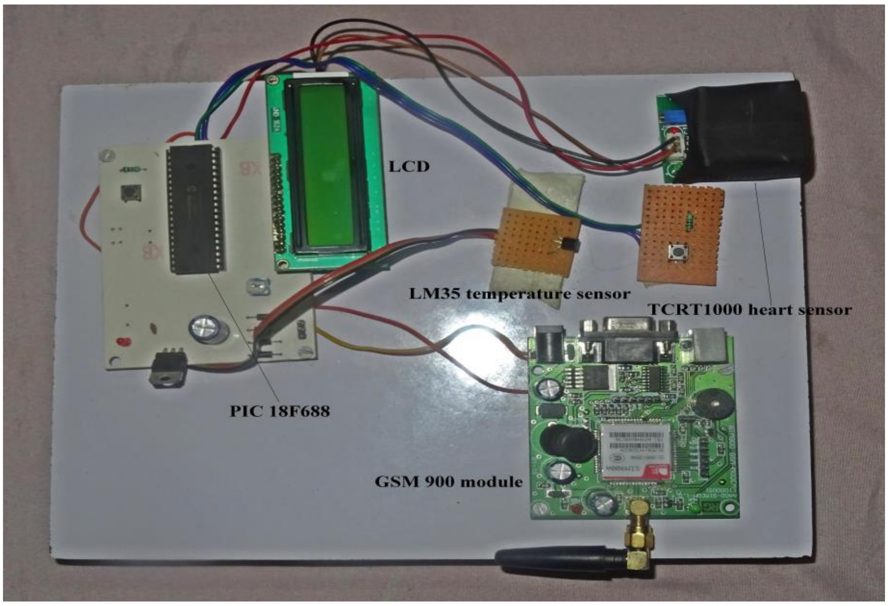


Figure 3. Implemented setup of temperature and heart rate monitoring

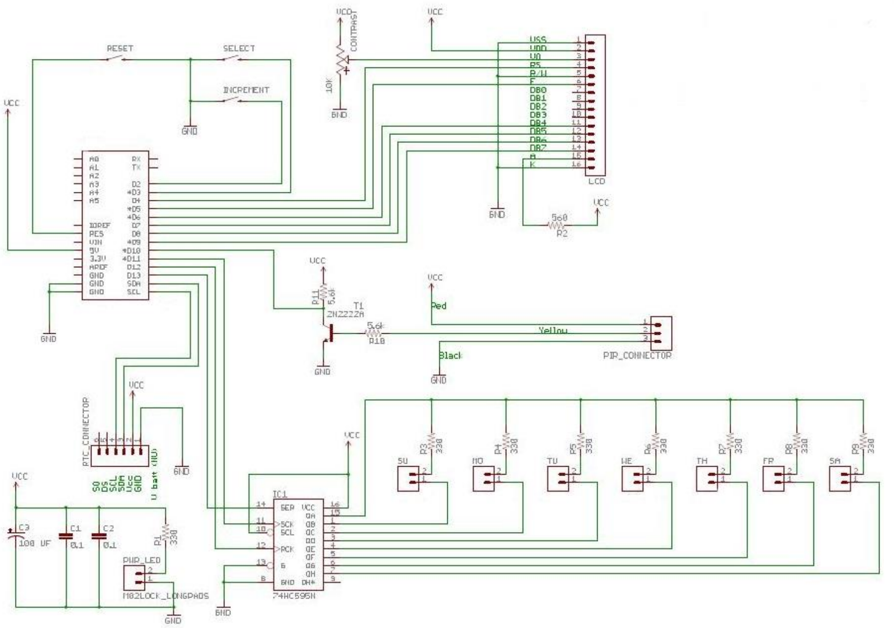


Figure 4. Hardware schematic of medication reminder

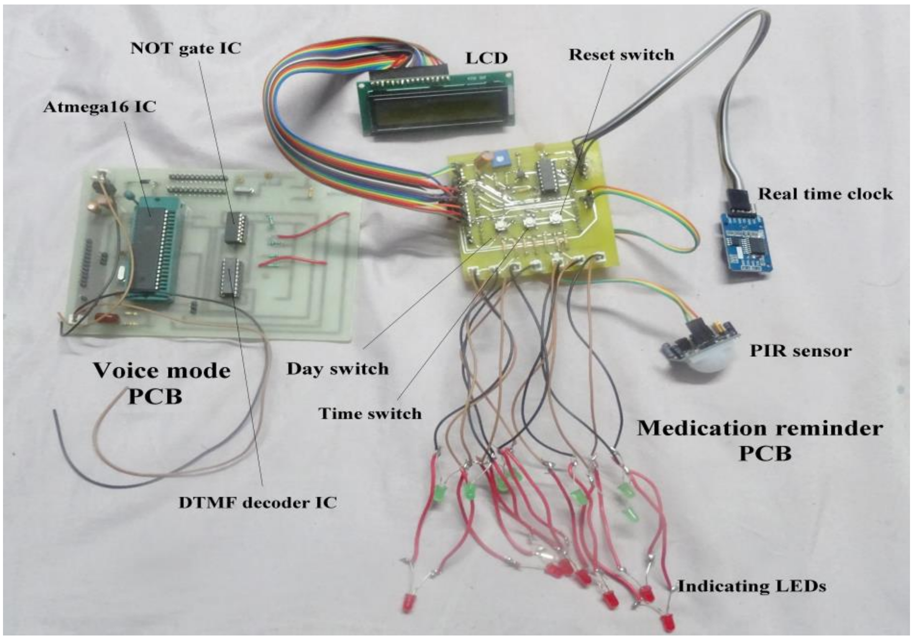


Figure 5. Voice mode control circuit diagram

ATMEGA 16 is used to process the frequency data received (voice data). The frequency data cannot be fed directly to the controller due to its digital characteristics, hence a decoder is used prior to the controller. This decoder is a dual tone multiple frequency decoder (DTMF) which decodes the frequencies received and converts into digital output using NOT gate IC (74LS04). This output can now be fed to the controller and appropriate movement of wheels can be achieved for desired locomotion.

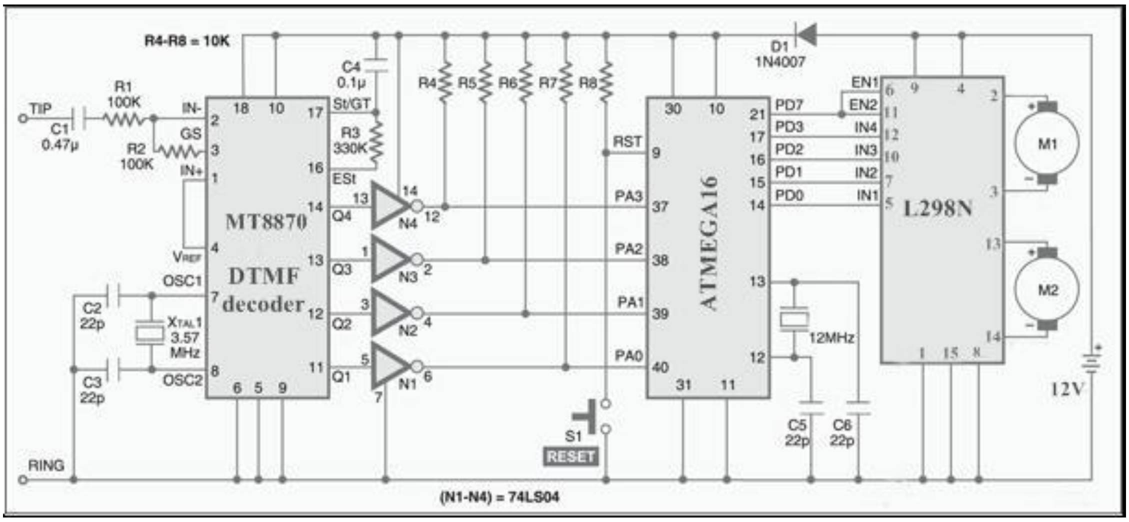


Figure 6. Implemented setup of voice mode control and medication reminder

3.2. MECHANICAL DESCRIPTION

The rover named Shrimp has a steering wheel in the front and the rear, and two wheels arranged on a bogie on each side. The front wheel has a spring suspension to guarantee optimal ground contact of all wheels at any time. The steering of the rover is realized by synchronizing the steering of the front and rear wheels and the speed difference of the bogie wheels. This allows for precision maneuvers and even turning on the spot with minimum slippage. The use of parallel articulations for the front wheel and the bogies enables to set a virtual center of rotation at the level of or below the wheel axis. This insures maximum stability and climbing abilities even for very low friction coefficients between the wheel and the ground [8].

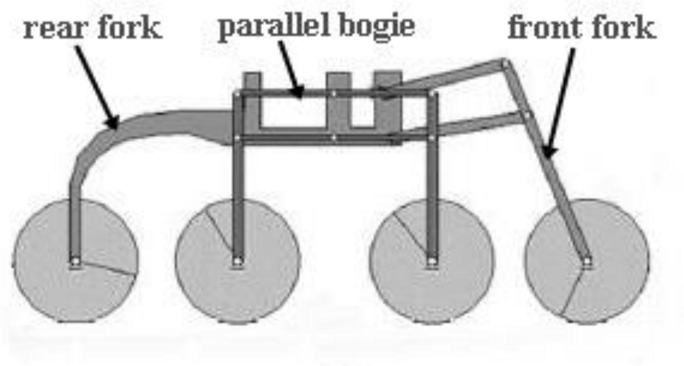


Figure 7. Simplified Shrimp structure

3.2.1. MAIN BODY

We began the construction with a fairly accurate (up to 1 mm accuracy) cut-out of 2mm thick aluminium sheet, which forms the top cover and the base plate of the wheelchair. The shape of these twin plates is a rectangle with a triangle appended on one of its sides. Thus, it's a pentagon, forming the rear of the wheelchair base. Fixed between the two plates, on either side, is an aluminium support, which has a pair of pivot screw set into it. This support joins the two plates, serves as a column for load bearing and provides mounting points for the parallel bogies. The screws on this support prove to be a revolute joint between the bogie and the main body. There are 2 other such support for mounting the front fork, while a plain, screw-less support for supporting the rear fork.

3.2.2. PARALLEL BOGIE

It consists of a set of links, which form a couple of two wheels, mounted on a support that can freely rotate around a central pivot. We created C-section links to build the frame of the bogies. The C-section allows for the frame to be sufficiently light without compromising on its strength and rigidity. We used two different cross-section sizes for the C-section links such that amongst the two, the smaller one could be perfectly inserted inside the bigger one. The frame was so formed that no adjacent links were of the same cross-section, thus, permitting us to create a freely rotating revolute joint by merely using a rivet. It is advised to exercise caution during the manufacture of the two bogies, because they need to be greatly identical. Any mismatch between the twins will give rise to non-uniform travel of rover.

3.2.3. FRONT AND REAR FORKS

The front fork consists of a 4 bar mechanism robustly mounted on 2 aluminium supports. In all, 4 pivot screws are used to move the fork. The rear fork is a fixed link, at the end of which a wheel is mounted.

3.3. CURVED SURFACE ADAPTABILITY

It is very important for the rover to adapt passively to concave and convex surfaces as the actual surfaces are not going to be flat in nature. For testing this ability, the rover was made to fall from a certain height on concave and convex surfaces. It can be deduced that the parallel architecture of the bogies and the spring suspended fork provides a non-hyperstatic configuration allowing the bogie to adapt passively to any terrain profile.

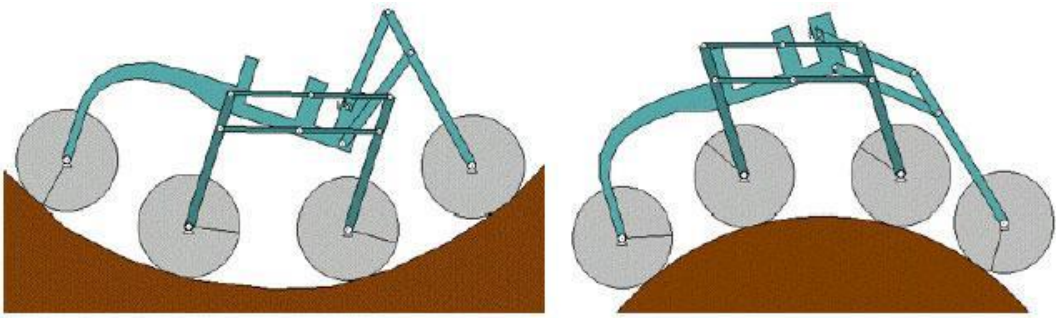


Figure 8. Concave terrain adaptability test

Shrimp can climb the terrains involving lateral or frontal inclination of up to 40° [8]. An environment involving a frontal inclination of 40 degrees was designed using RecurDyn software. Using RecurDyn's plot tool, we were able to obtain the driving torque versus time graphs. These, obviously, had some inherent noises affecting the actual data. Hence, a Fast Fourier Transform (FFT) was applied on all individual driving torque v/s time plots.

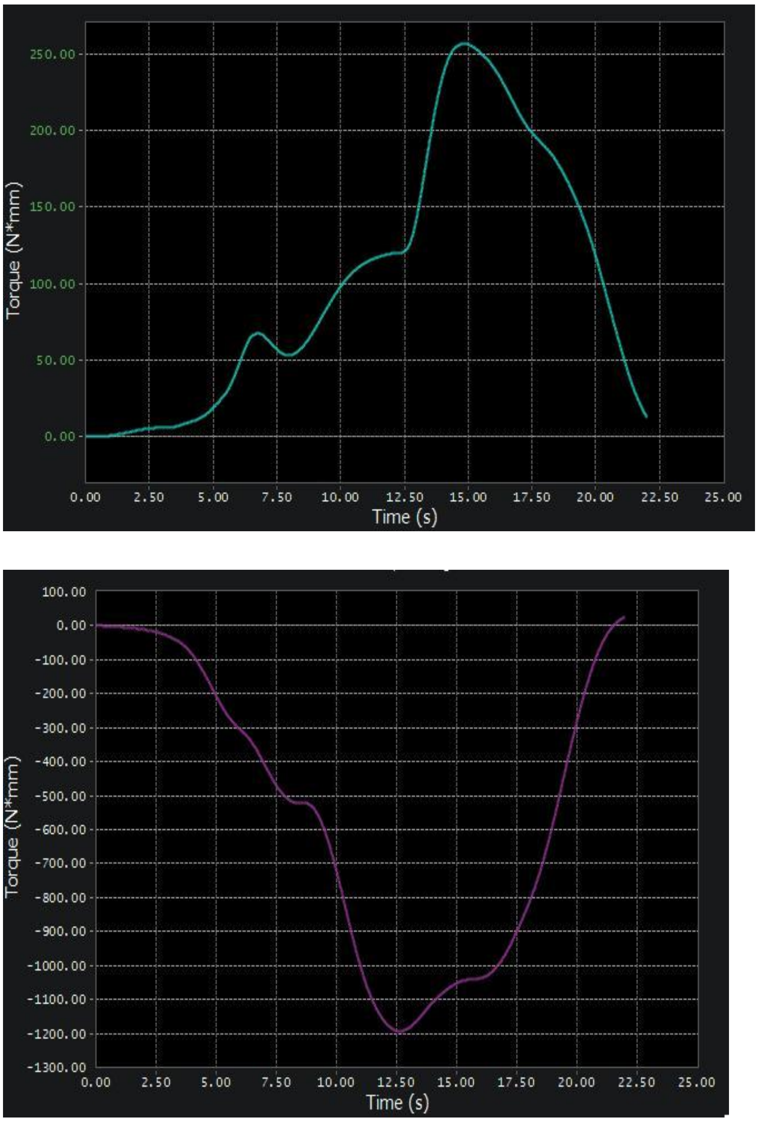
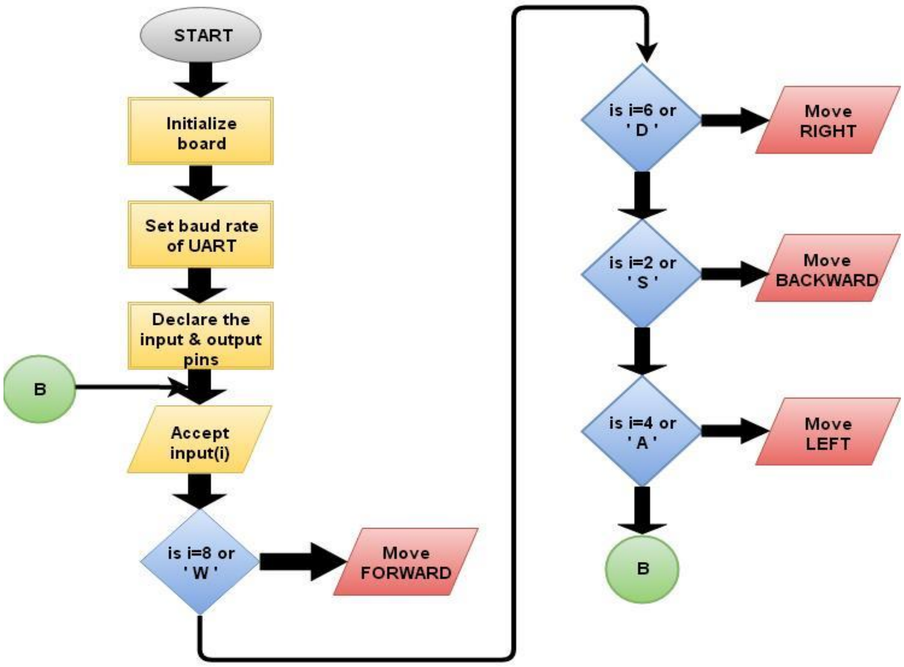


Figure 9. Driving torque versus time characteristics

IV. EXPERIMENTAL RESULTS



- According to the structural design and mechanism the wheelchair is able to climb stairs and trespass small obstacles like stone, pot holes etc. easily. As per the height adjustment mechanism, user should be able to adjust height manually whenever it is required.
- In touch mode when an input is given from an smart phone, the Bluetooth module available on wheelchair will receive the input and the wheelchair will move in the desired direction. A change in location of the pressure will result in a corresponding change in direction .The touchpad also has a neutral or no movement point which will ensure efficient braking. This is very helpful for paralysed and physically challenged people.
- In personal computer/laptop mode, inputs are given from PC through an application installed on a computer. The receiver attached to the wheelchair will receive the inputs and the chair will move in the desired direction. If 'w' or 8 on keyboard is pressed then wheelchair will move forward, if '6' or 'd' is pressed then wheelchair will move right, if '4' or 'a' is pressed then wheelchair will move left, if '2' or 's' is pressed then wheelchair will move backwards, if 's' or '5' is pressed then wheelchair will stop. Also it can be controlled with the help of mouse movement in the desired direction. This feature will help efficiently if the patient feels ill and cannot regulate the wheelchair himself/herself. The patient will thereby be leaded to his/her home or paraplegic centre safely by monitoring in-charge.
- In gesture mode when an input is given from a smart phone, the Bluetooth module available on wheelchair will receive the input and the wheelchair will move in the desired direction. When phone is tilted forward the wheelchair will move forward, if left tilt is given the wheelchair will move left and so on.
- Similarly, voice commands will be used as input to a decoder (DTMF) which converts a particular frequency of voice into digital bits for controller to process it and take desired action. Using voice operative mode the user will be able to operate the wheelchair using pre-decided voice commands. The voice commands will be transmitted via Bluetooth available on smart phones.
- Height and tilt adjustment can be achieved via two way movable switches provided at the arm rest. The medication reminder can be modified as per the patients' medicine timings by the use of three push buttons (Day, time and reset).

Table 1. Logic level table of L298N and corresponding movement

LOGIC	ACTION
00	Stop
10	Clockwise
01	Anticlockwise
11	Force stop

Table 2. Logic levels recorded during simulation of corresponding wheel motor of the wheelchair

ACTION	MOTOR1	MOTOR2	MOTOR3	MOTOR4	MOTOR5	MOTOR6
FORWARD	10	01	10	01	10	01
REVERSE	01	10	01	10	01	10
RIGHT	10	10	10	10	10	10
LEFT	01	01	01	01	01	01

Figure 10. Implemented Prototype (a) Chair configured to rest position (b) Base of intelligent wheelchair (c) Side view of wheelchair (d) Front view of wheelchair

V. FUTURE SCOPE

5.1 GSM INTERFACE: **-** The wheelchair can be GSM based, where the patient sitting on the wheelchair can have access to additional features. If the patient on the wheelchair feels uncomfortable or will have some issue regarding health, he/she can send message to his/her relatives or friends indicating the need for help. Thereby creating a much more stable and reliable platform for the patient.

5.2 SOLAR POWERED SOURCE: **-** The wheelchair can be source powered by solar power which is free of cost and is renewable source. Presently, this wheelchair operates on DC battery source but in future it can be operated by solar power which can be stored for day-night usage. Only the initial cost for such implementation has to be taken into consideration, but will be relatively affordable in the longer run.

5.3 AUTO NAVIGATION: **-** The wheelchair can be mapped with a particular route for access to known or important localities. Such implementation will have a smart platform of sensors to assist the mapping process along with use of image processing. A definite route maybe programmed to the controller so that the wheelchair can move in specified path.

VI. CONCLUSION

Our proposed wheelchair system thus provides an easily controllable and multiple functionality environments. The design structured for this wheelchair is a comfortable one where the patient will have no issues with comfort. Overall this wheelchair has the ability to travel anywhere with no human efforts except giving it direction controls. Thus this innovative project will come in handy for various people around the globe affected from any form of disability and make them independent and self-reliant. The interface and software can be modified and re-developed according to the need in future. Further advancement in the wheelchair are possible by decreasing the power requirements of the wheel chair or finding a way to automatically charge the battery with the help of motion of the wheel chair or solar panel.

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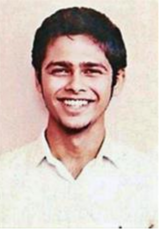

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