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Adaptive Astute Mechanized Wheelchair

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Abstract —*The application of automated systems to reduce the human effort in several areas is quite common. The recent advancements contributing to overall development of wheelchairs has led to the creation of wheelchairs which suffice the needs of patients effectively. Yet some members of the disabled community find it difficult or impossible to operate a standard power wheelchair. To accommodate this population, we have developed Adaptive Astute Mechanized Wheelchair which can accommodate every kind of patient with varying form of disability. This paper describes the design of a prototype of the Adaptive Astute Mechanized technology, which has been evaluated on wheelchair. This multi-control 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 wheelchair control system 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 navigate desired paths.*

Keywords*- Disability, touch/gesture control, voice control, computer control, smart wheelchair, smart phone.*

I. INTRODUCTION

According to the National Health Interview Survey on Disability conducted by four Federal offices (Office of the Assistant Secretary for Planning and Evaluation, Health and Human Services; Office of Supplemental Security Income, Social Security Administration (SSA); Office of Disability, SSA; and Bureau of Maternal and Child Health, Health Resources Administration) planned several national surveys about various aspects of disability in the early 1990's stating there are an estimated 35-43 million people with physical and mental disabilities in the United States. Population Census and NSS surveys (India) indicated in the year 2001, of the persons with disability (PWD) about 75% belonged to rural areas and 25% were from urban areas. About 58% of disabled were males while 42% were females. For the population of the country as a whole, 2.13% were found to have one type of disability or the other. But cases of patients on wheelchair are just not limited to just one form of disability (new category introduced at Census 2011).
The patient can also be affected by following listed chronic or intermittent issues:

- Hands and legs fractured
- Sensory Disabilities-Hearing, sight, and speech disabilities.
- Balance or gait problems
- Mental Disabilities-Also known as emotional or psychiatric disabilities.
- Mobility Disabilities
- 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.

The smart phone technology has significantly affected the lives of human and hence this technology has been implemented as an integral part of this wheelchair as smart phones are available with at least 4.77 billion members across the globe. Smart features have been included to counteract various difficulties faced by a conventional wheelchair user. Overall this wheelchair system can prove to be beneficial for all grades of people in all fields relating to military, hospitals, paraplegic centre's or even domestically or during disastrous situations like earthquake thereby making a patient totally self-reliant and self-dependent with high reliability, comfort, care, assistance & optimal low cost.

- 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 centres. 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.

II. LITERATURE REVIEW

The existing computer input devices such as keyboard, mouse, and the other input devices have been used to interact with digital instruments. These computer input devices cannot be operated by handicap persons. In this paper, a computer input device by human eyes only is proposed for handicap person and also for wearable computing. The existing computer input devices can be divided into five categories:
(1) Bio-potential based method which utilizes potential from user's body actions acquired by using special instrument. Instrument such as Electrooculography (EOG) [1], Electromyography (EMG), and Electroencephalograph (EEG) [2], Search coil can be used for measuring bio-potential. The search coil output can be used as sources of computer input for handicap person. EOG method [3] uses voltage differences between fore and aft surface of eyes.
(2) Voice Based method [4], which use user's voice as source input. Voice analysis is used to analyze user's voice and convert into digital data. The weakness of this system is vulnerable against noise. Other voices which come from surrounding user may affect the system.
(3) Motion based method [5], utilizes other normal movement organs to operate computer input. Head, foot, and etc. can be used to control computer input.
(4) Image Analysis method [10]-[15], utilizes camera to analyze user's desire and convert into digital data. Several image processing methods are used to analyze user's desire. The user's desire itself can be done by Gaze based [6], [7], [9] analyze user's desire from users gaze, Face based analyze user's desire from face expression, and the others.
(5) Search coil method [8] uses induced voltage with coil including in contact lenses attached to user's eyes.

III. PROPOSED METHODOLOGY

3.1.Hardware description

Working Description:

- The basic structure of our project consists of microcontroller, motor driver, smart phone, PC/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 paralyzed 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 paralyzed. 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.

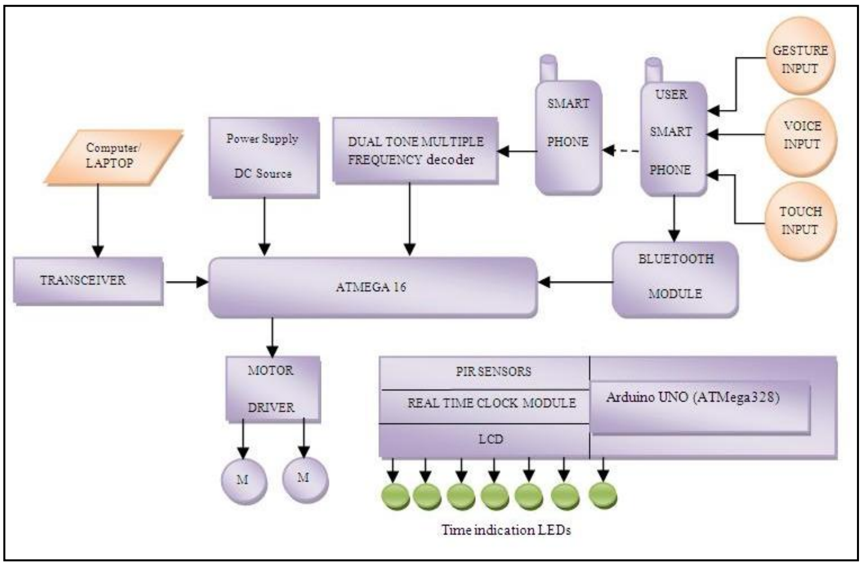


Figure 1. Main Block Diagram

The controller used is ATMEGA16. For touch/gesture control, a user smart phone is used which is wirelessly interfaced to slave Bluetooth module feeding input to controller. For voice control, a user smart phone is used as input device. The Dual tone multiple frequency decoder is used to decode the voice commands and fed to controller. For PC/laptop control, a computer is used along with a 2.48 GHz RF transmitter to send commands to a RF receiver attached to the controller. To propagate the controls to the wheels there is interfacing between controller and motors via motor driver unit (L298N).

3.2. Mechanical description

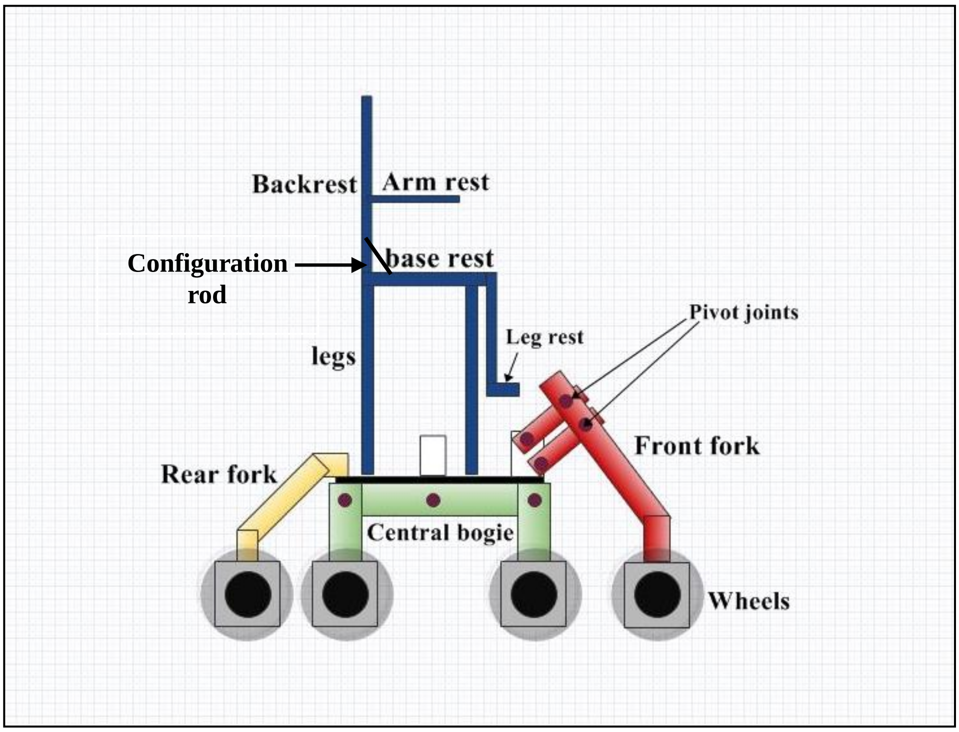


Figure 2. Mechanical structure

The original design detail of mechanical section of the wheelchair is shown in Figure 2. Blue part is the chair design showing details about back rest, legs of the chair, arm rests, leg rest and base rest along with rigid position rod (black) to configure the chair to desired position. Installation of these individual sections on a common platform proves to be the base of the chair. The motorized wheels are attached to the circular slots in these sections.

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 or half-thread screw.

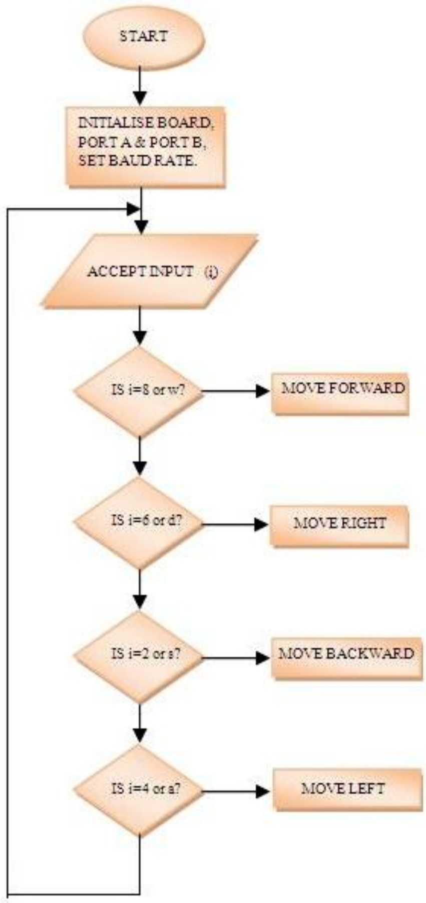
3.2.3. Front and rear forks

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. These fork sections are made using aluminium hollow pipes for improved rigidity purpose.

Figure 3. Implemented design of front fork

Figure 4. Implemented design of base structure composing of front fork, rear fork and central bogie

3.3. Software design



The software is written in 'C' language and compiled using CodeVision AVR 'C' compiler and QuickC compiler. The source program is converted into hex code by the compiler and downloaded to the ATmega16 AVR microcontroller. Ports A and B are set as the outputs. The program will run forever by using 'while' loop. This 'while' loop makes it possible to monitor the inputs given on a regular basis. The baud rate of UART is set as per requirement. Here it is set to 9600 baud/second.

3.4. Theoretical details

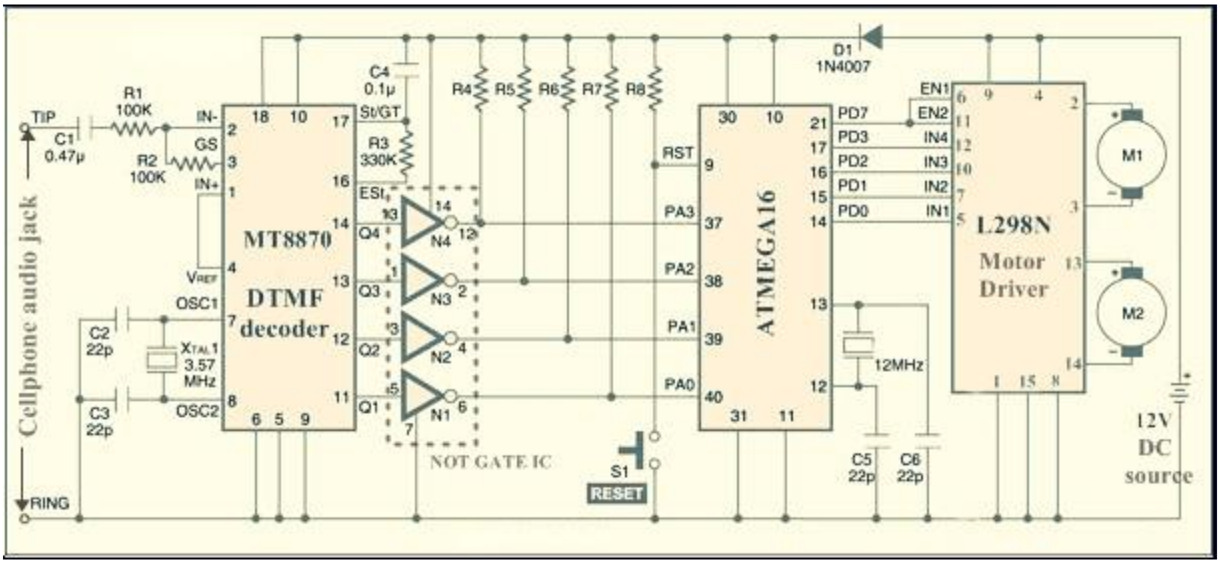
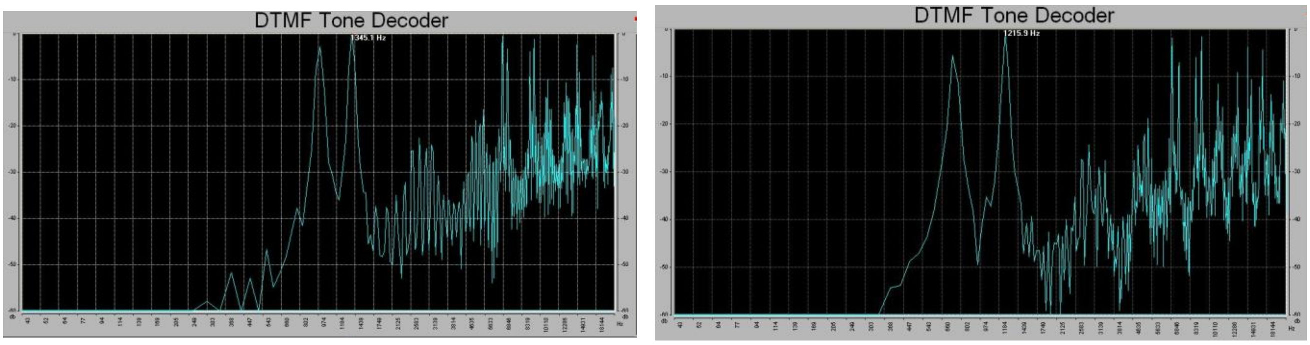


Figure 5. Circuit diagram of voice mode implementation

ATMEGA16 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.



(a) *(b)*

Figure 6. Simulated outputs of DTMF tones. (a) DTMF tone of '0' (b) DTMF tone of '1'

When we press the buttons on the keypad, a connection is made that generates two tones at the same time. A "Row" tone and a "Column" tone. These two tones identify the key we pressed to any equipment we are controlling. If the keypad is on our phone, the telephone company's "Central Office" equipment knows what numbers we are dialing by these tones, and will switch our call accordingly. If we are using a DTMF keypad to remotely control equipment, the tones can identify what unit we want to control, as well as which unique function we want it to perform.

IV. EXPERIMENTAL RESULTS

The touch mode basically consists of Bluetooth module interfaced to the control unit on the wheelchair for sensing the transmitted signals by the smart phone comprising Bluetooth via application. This data which is conveyed to the control unit is responsible for the movement of the wheelchair. A change in location of the pressure results in a corresponding change in direction of movement. Remote operation is achieved by any smart phone with Android operating system, upon a GUI based touch screen operation. At the receiving end the movement is propagated to six DC motors accordingly. The gesture mode includes transmitter section and receiver section. At the transmitting end, a smart phone is used to transmit data based upon the accelerometer readings recorded. An Android based GUI is used to sense the tilt through accelerometer. These readings are then transmitted through a smart phone. This data is received wirelessly by the receiver Bluetooth module interfaced with the microcontroller. When the forward tilt is produced the wheelchair moves in the forward direction. Similarly movement in different directions is achieved. 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. 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.

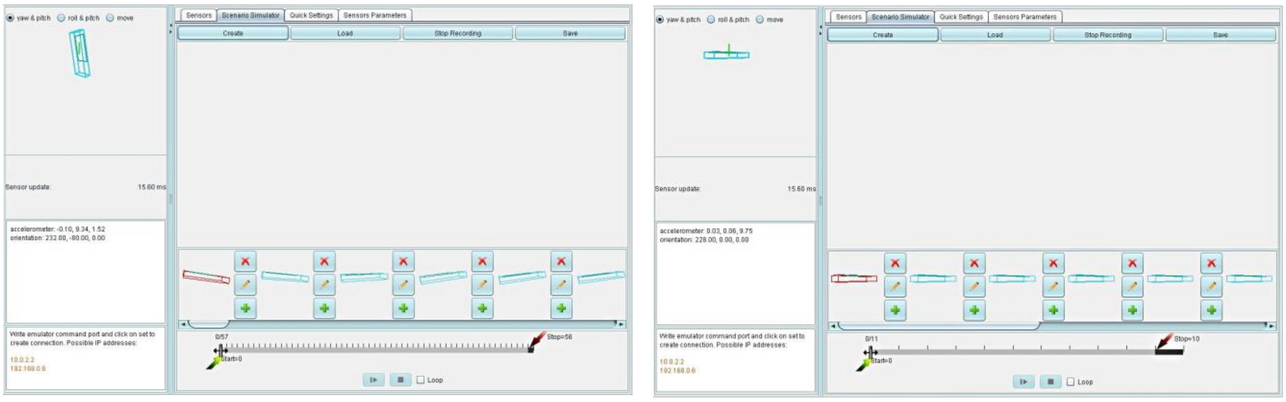
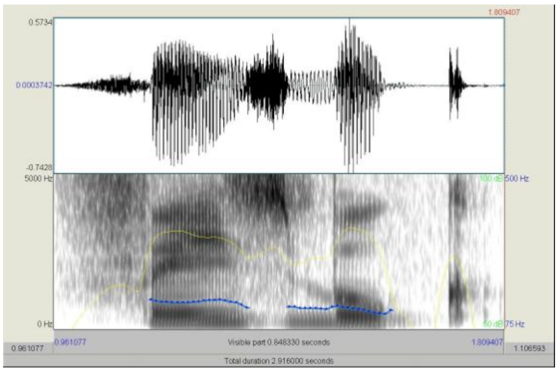


Figure 7. Simulated results of accelerometer readings using smart phone.



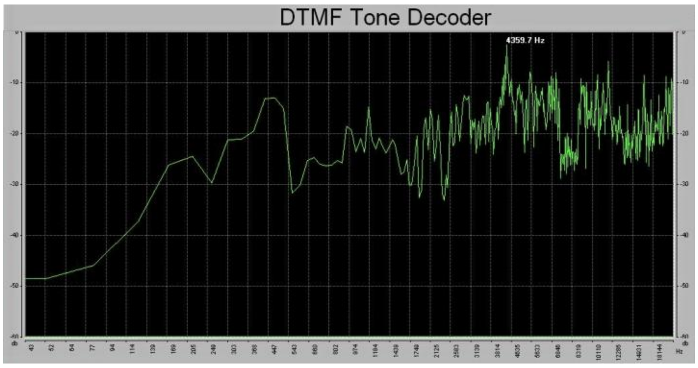


Figure 7. Simulated results of voice commands and corresponding DTMF tones.

V. 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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