

Development of a Voice Controlled Electric Wheelchair to Aid the Movement of the Physically Challenged

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Abstract

Nigeria is said to have the highest number of physically challenged in Africa and second only to India in the world. Traditional Electrical Wheel Chair has some limitations. In order to assist the physically handicapped, this paper presents the development of a voice controlled wheelchair. The user can control the wheelchair by voice commands, such as “jagaba (go forward)” in Hausa. A grammar-based recognition parser was used in the system. The system comprises of a wheelchair motorize by a DC motor, works on inputs such as voice commands via an android phone and navigates according to the command and battery powered. Voice command input was taken from android mobile and converted into text which is transmitted to microcontroller via Bluetooth module to control the operation of DC motors. Also an IR detection system was used to detect the obstacle in the path of wheelchair to avoid its collision. The chair enables the handicapped person to independently move around. A running experiment with three (3) persons was carried out on speech recognition. 95.4% and 94.0% of the movement command and the verification command were obtained respectively.

Keywords: Control, Home Navigation System, Microcontroller, Physically Challenged, Voice Command, Voice Recognition and Wheelchair.

INTRODUCTION

Wheelchairs are used by people who cannot easily move themselves from place to place without external aid (Bergasa *et al.*, 2000). In this category are the elderly, the physically challenged person (example, cripple, blind etc.), can be described as somebody with a condition that makes it difficult to perform some or all of the basic tasks of daily life (Microsoft Encarta Premium Dictionary, 2009). In recent years, these have been on the increase and each of these groups all have “special needs” and often require some assistance to perform their daily routine. The requirement for an external person who is apt and available to help possess a great economic and social challenge. In Nigeria, though, there are only two types of wheelchairs that have wider usage and acceptability; the hand operated and those that are being operated by the joystick. The former type needs muscular strength for its operations while the latter type needs the skill. Therefore, it will be difficult for the old and the handicapped person to use these interfaces (Choiet *et al.*, 2006). It is as a result of these challenges that here comes the need of a voice controlled automated home navigation system, which consists of a wheelchair and can be used by the elderly and the physically challenged people without the help of an external person (Mihailidis *et al.*, 2007). Voice controlled electrical wheelchair has the potential to provide these people with effective ways to alleviate the impact of their limitations, by compensating for their specific impairments (Fioretti and Longhi, 2000).

LITERATURE REVIEW

The research and analysis of motorized wheelchairs dates back in time with several scientists and researchers evaluating the stair climbing mechanism (Franco *et al.*, 2011). Ghani *et al.*, (2011) investigate the control of a stair climbing wheelchair used for indoor purposes. This review work evaluates different stair climbing mechanisms wiz crawler type, leg type, hybrid type and wheeled type. The model of a stair climbing wheelchair based on two wheels was generated using MSC Visual Nastran 4D (VN) design software. The humanoid model was developed using requisite anthropometric data. Various forces and torques acting on the wheelchair while climbing the stairs are evaluated. Preferably, the outer support assembly comprises wheels on either side of the chair. An inner support assembly, closer to the centreline of the chair, also supports the seat assembly. Franco *et al.*, (2011) did work related to development of a stair climbing wheelchair that can move in structured and unstructured environments, climbing over obstacles and going up and down stairs. Murray (2013) has elaborated the background as well as recent developments in mobility assistive mechanisms while discussing the relative importance of stairs and wheels. These various types include mobility scooters, track based stair climbers, clustered wheel concept and caterpillar wheel based devices. A mechanism was proposed which was based on the use of four wheels. The rear wheels are autonomously driven and front wheels are freewheeling castors. Lockton (2004) discusses the retrofitting of electric power into manual wheelchairs. The existing products and configurations are reviewed in a comparative table. Various product specifications are categorized and briefly described. These include control devices, drives, steering and position. Peizer *et al.*, (2014) have investigated and summarized the evolution of wheelchairs over five years. Necessary measurements and data have been collected

from Indian Anthropometric Design (Chakravarty, 1987). Ambarish *et al.*, (2014) developed a home navigation system, which comprises of a wheelchair which works on the inputs such as gesture and voice commands via an android phone and navigates according to command. Their wheelchair can be used by an elderly or physically challenged person to move to different locations in a particular house just by pronouncing the direction's name or by making the movement of the android phone they are been provided with (Mihailidis *et al.*, 2007). The Americans with Disabilities Act (ADA) and a growing awareness for the rights of the disabled have greatly improved research and design efforts in the assistive technology industry. Interest has also increased in this area due to the current trend toward the "graying of America" as the average age of Americans increases (COMSIS, 1988).

METHODOLOGY AND DESIGN

The Block Diagram of the Voice Controlled Electric Wheelchair

From Table 1.0, the operator (user) gives one of the voice (vocal) commands as input in order to drive the wheelchair to his desired position, the microphone (which in this application was a headphone mouth piece) converts the voice (acoustical) signal into electrical (analogue) signal, was transmitted to the voice recognition module (kit). The voice recognition module further converts the analogue (electrical) signal into digital (electrical) signal. The digital electrical signal was thus, transmitted to the power integrated circuit (PIC) microcontroller. The PIC microcontroller then makes the decision to either switch ON or OFF, move forward or backward, turn left or right or stop the wheelchair etc., with the help of relays switching unit as shown in Figure 1.0

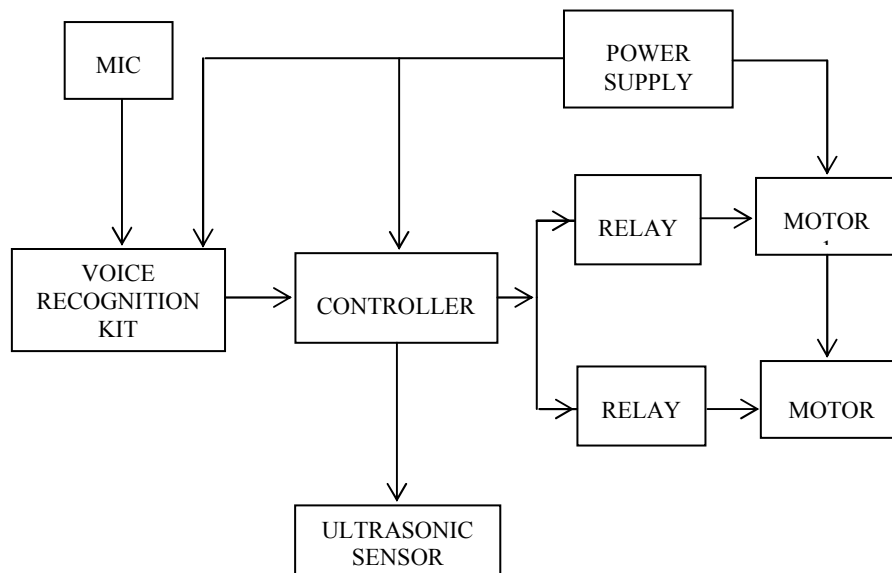


Figure 1.0:- Block Diagram of Voice Controlled Electric Wheelchair

The Voice Commands

This project will provide an alternative to the disabled people in controlling the motion of the wheelchair using their voices. The paper was therefore, the design and construction of a super-hybrid wheelchair for disabled persons which involves mechanically controlled wheelchair imposed by and electrically motorized controlled system super-imposed by an electronic vocabulary (voice) recognition and conversion board (kit). There are therefore, seven conditions for the basic motion of the wheelchair to be applied by the user such as “moving forward, moving backward, turning right, turning left, stop (or static), switch ON and switch OFF,” as shown in table 1.0 (Table of voice command conditions).

Table 1.0: Table of Voice Commands and Conditions

VOICE COMMANDS	CONDITIONS
ON (START)	Giving the supply to the wheelchair.
FORWARD	Moving the wheelchair straight Forward (to the front).
REVERSE (BACKWARD)	Moving the wheelchair straight in the Backward.
LEFT	Turning the wheelchair to the left side.
RIGHT	Turning the wheelchair to the Right side.
STOP	Bringing the wheelchair to a Standstill (no motion).
OFF	Switching off the Supply to the wheelchair.

Source:

The Design of the Voice Controlled Electric Wheelchair

This project describes the design (and construction) of the voice controlled (electric) wheelchair using embedded system. The proposed design supports voice activation system for severely disabled persons, incorporating manual operation with switch. The design was based on grouping of microprocessors with speech recognize development circuit. In this case, a power integrated circuit (PIC) 16F877A and a voice recognition processor, HM2007 are used (logically grouped together) to support the wheelchair. This is a unique system incorporating wheelchair control through voice, which provides reliability, safety and comfort.

Proposed algorithm/Flowchart for the System Design

A flowchart is used as a diagrammatic representation of the problem, and also provides a complete solution in the analysis, designing and work process or program. The main part of the design is to control the motion of the wheelchair. There are four basic conditions of motion considered; moving forward, moving backward, turning to the left and turning to the right. For the speed, the user may use SLOW or FAST command. The system starts by applying the supply voltage to the speech recognition circuit. For fast condition, the system will supply higher current to the motors. On the other hand, if the user does not want the chair to move in high speed, he can give the SLOW command, which can set the application of low current supply to the motors. Hence, the direction and speed of the wheelchair depends on the user. For the Forward command, the chair moves in the forward direction, and for the reverse direction, the opposite movement of the rotation will occur, as seen in the Figure 2.0 (Flowchart for the motion controlled Wheelchair using voice).

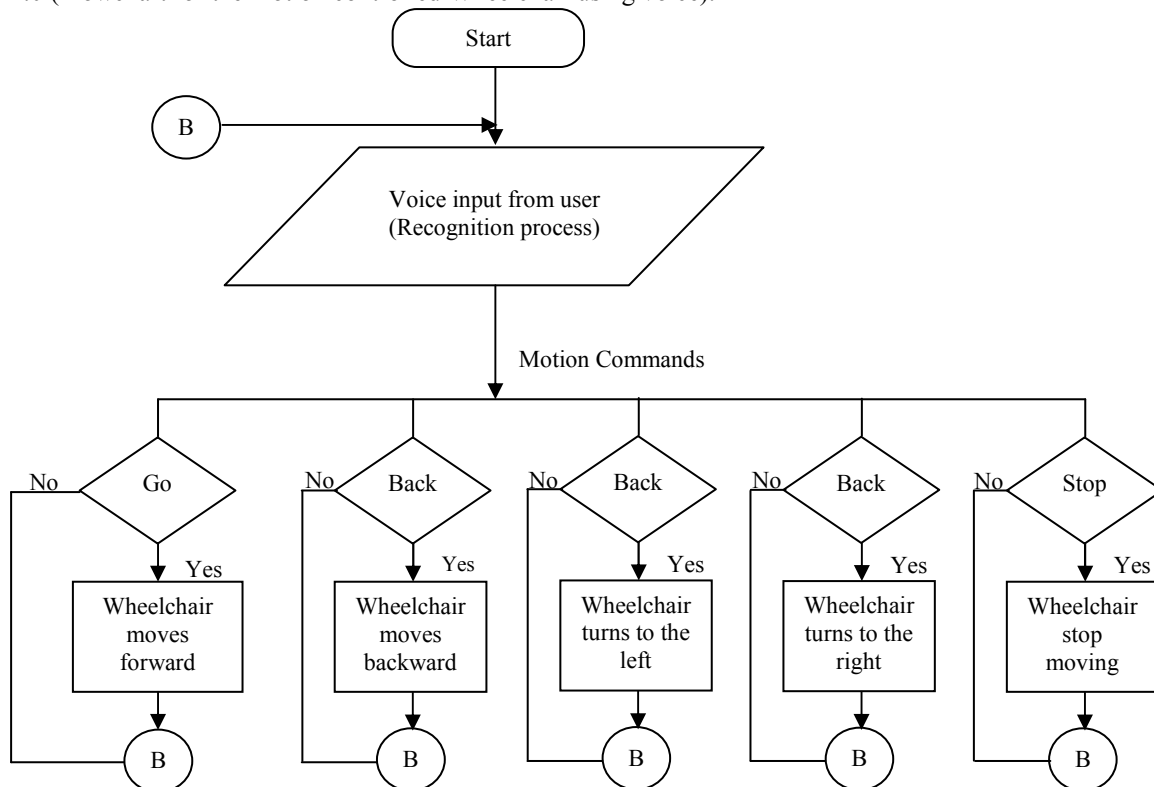


Figure 2.0: Flowchart for the Motion Controlled Wheelchair Using Voice

The Circuit Diagram of the System Design

Figure 3.0 below shows the Circuit Diagram of the System Design of the voice controlled electric wheelchair, which consist of the basic PIC 16F877A connection, which is connected through 16MH2 crystal oscillator through pin 13 and 14. The reset switch is connected through pin 1.

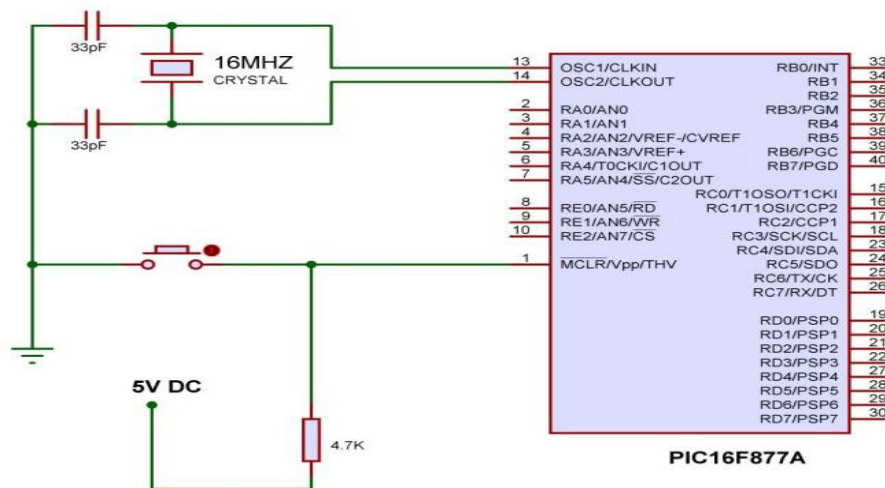


Figure 3.0:- Circuit Diagram of the Voice Controlled Electric Wheelchair

Power Supply to the System

This deals with the power requirements of the wheelchair for the D.C. motors, Microcontroller (and other sections). The ideal voltage required for the PIC 16F877A is 5V. It should however, not be higher than 5.5V, because it can blow up the power integrated circuit (PIC), and on the other hand the power supply should not be less than 2V. A D.C. Battery is used to provide the power supply to a UL2003A driver IC at 12V supply, which drives the D.C. motors, Microcontroller and IR sections operating on 5V provided with the help of LM7805 which is a 5V regulator IC by converting the 12V into 5V. The LM7805 5V regulator IC is thus, used to supply a constant 5V to the PIC, while LM7812 IC is used in the power unit to charge the battery. Pins 11, 32 and also 12, 31 are used for grounding the PIC +5V. See power supply circuit in Figure 4.0.

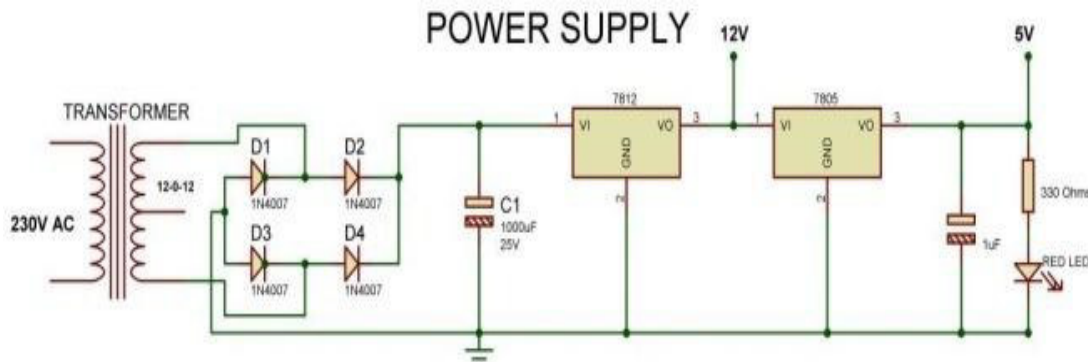


Figure 4.0:- Power Supply to the Voice Controlled Electric Wheelchair

The Voice Recognition Kit (Hm2007) of the Design System

The voice recognition module (VRM) consists mainly of integrated circuit (IC), regulators, capacitors and diodes. The voice recognition kit (HM2007) is a single (micro) chip CMOS voice recognition LSI circuit which consists of the on-chip analogue front end, voice analysis, recognition process and system control functions. This is a forty (40) isolated-word voice recognition system which can consist of external microphone (head phone), keyboard, and 64K SRAM memory combined with microprocessor, as shown in Figure 3.5.

The speech recognition system is a complete assembly, and easy to use programmable speech recognition circuit. It is programmable in the sense that the words (or vocal utterances) which you want the circuit to recognize are trained (programmed). The board allows you to experiment with many facets of speech recognition technology. It consists of 8 bit data output which can be interfaced with the PIC microcontroller for the control of the motor direction.

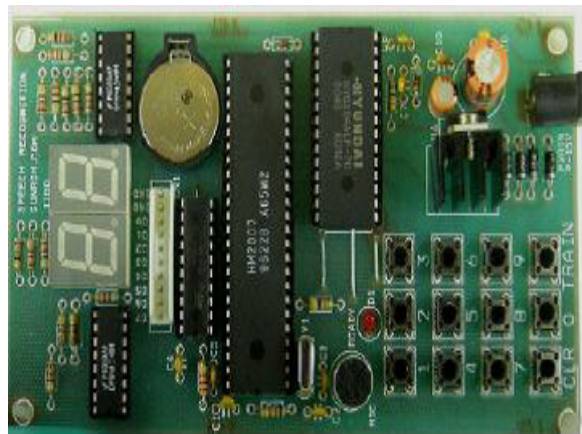


Figure 5.0: Voice Recognition Circuit (kit) of the Design System

Circuit for Motor Interfaced with PIC using Relay driver UL2003A

The motors are controlled through the relays which are connected through UL2003A IC. To operate the motors, output current from the microcontroller is not sufficient to actuate the relays, so the IC UL2003A IC is used to amplify the output current of the microcontroller. Thus, the relay can be actuated to control the motors. Refer to Figure 7.0 (for Circuit for Motor Interfaced with PIC).

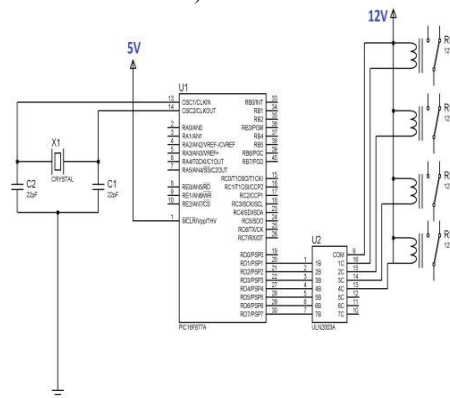


Figure 6.0:- Circuit for Motor Interfaced with PIC.

The Transmitter and Receiver Circuit

The **HT12E** encoder IC will receive and convert the 4-bit parallel data supplied to the pins D0-D3 into serial data and then make it available at the output. This output serial data is further transmitted as input to the Radio Frequency (RF) Transmitter. Address inputs A0-A7 is used to provide data security, and is connected to GND (Logic ZERO) or left opened (Logic ONE). The status of these Address pins must match with the status of the Address pins in the receiver for proper transmission of the data. The data can only be transmitted when the Transmit Enable (TE) pin is LOW. A 1.1kilo ohm resistor is used to provide the external resistance necessary for the operation of the internal oscillator of the **HT12E**. The RF Transmitter receives the transmitted data and supplies it to **HT12D** decoder which converts the received serial data from 4-bit parallel data D0-D3. Again, the status of these Address pins A0-A7 must match with the status of the Address pin in the HT12E at the transmitter, for the proper transmission of the data. In this case, a 47 kilo ohm resistor provides the necessary resistance required for the internal oscillator of the **HT12D** to operate.

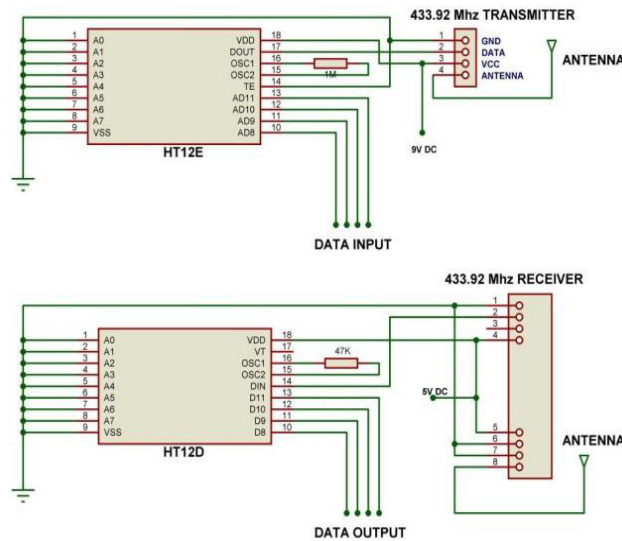


Figure 7.0: The Transmitter and Receiver Circuit of the Design System

The Encoder

The encoder used in this project is HT12E. To transmit the signals efficiently, the encoder is used. There are a number of sensors in the unit, and hence the signals from all the sensors must be transmitted and this task is accomplished by the encoder section. Basically, the encoder is a parallel to serial converter. It receives a number of data at the same time, and it converts these data signal and gives a serial output. The parallel to serial converter rate depends on the oscillation frequency (or clock frequency). To reduce the complexity a device with an internal oscillator is used and the frequency can be controlled by changing the resistance value. An encoder is nothing but a series of flip-flop which stores data in a parallel manner and give the output in a serial manner. In every encoder, there is one terminal enable pin. Whenever this terminal enable pin is active then the encoder performs the encoding operation, otherwise it does nothing about any input.

The Transmitter

To transmit the encoded signal, a transmitter is necessary. The selection of the transmitter depends on the type of input, that is, whether the input is analogue signal or digital signal. If the signal is analogue then either amplitude modulation (AM) or frequency modulation (FM) can be used. And if the encoded signal is digital in nature the amplitude shift keying (ASK), frequency shift keying (FSK), Quadrature phase shift keying (QPSK), phase shift keying (PSK), etc; can be used. Since in our system the encoded data is in digital form, the amplitude shift keying (ASK) is used. The transmitter used in the system fulfils all the requirements such as range data transfer rate etc. various ASK modules available in the market operates in VHF/UHF and ISM bands.

The Receiver

The receiver receives the signal transmitted by the transmitter. The receiver thus, performs the demodulation operation of the received signal. The transmitter and receiver frequency must be tuned to be the same. At the receiving antenna, a number of waves are present but due to tuning the desired frequency signal are selected and all other signals are rejected. Various RF modules which can give good performance are available in the market.

The Decoder

The decoder used in this project is HT12D. It is possible for more than one transmitter to come in the range of the receiver. Therefore, with the intention to avoid the confusion at the receiver side addressing technique is employed. This encoder and decoder have 8-bit address, that is, 256 combination of address can be generated. The receiver will receive the data from the transmitter with which its address matches. As the number of data converted or encoded in serial form and transmitted by the transmitter. At the receiver side it is necessary to convert the data back into the original form which was before encoding. To do so a decoder is used. A decoder is nothing but series of flip flop which receives data in serial form and stores it. When all the flip flops are loaded then the data is made available at the output in parallel manner. To ensure proper decoding, encoding rate and decoding rate must be same.

GUI INTERFACE PANELS OF THE DESIGN SYSTEM

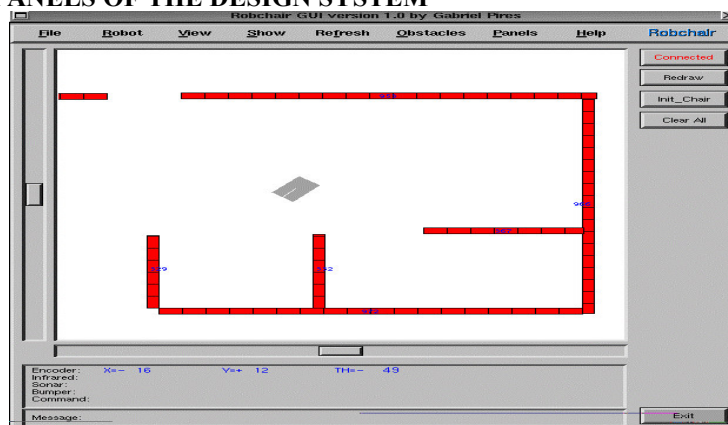


Figure 8.0a: Main Panels of the Design System.

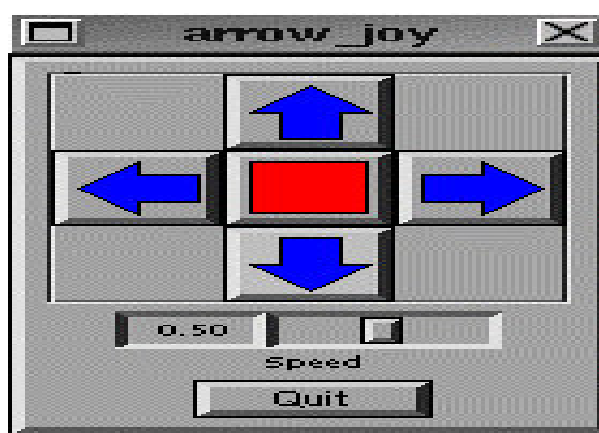


Figure 8.0b: Main Panels of the Design System.

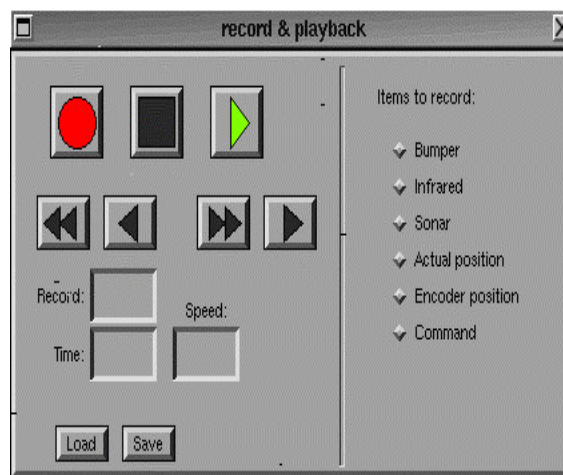


Figure 9.0: Record and Playback of the Design System.

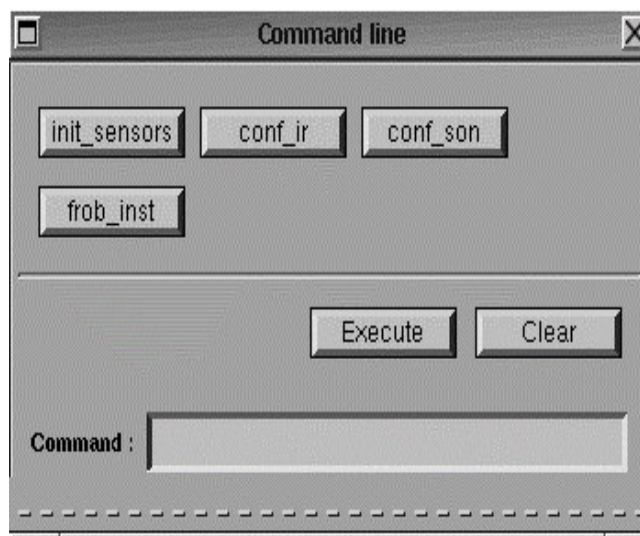


Figure 10.0: Command-Line Panel

Other Circuits in the Design

Other circuits built into the design system of the wheelchair include the following:

Obstacle Detection Circuit

The obstacle detection circuit (ODC) involves two infra-red (IR) signal emitters which emits infra-red (IR) signals continuously when some obstacles appear in front or on the path of the wheelchair. These IR signals are obstructed, and reflected back. The reflected (IR) signals are then detected by the IR sensor which is located (present) just by the side of the emitters. As the IR signals are detected, a circuit is connected to a buzzer, and the buzzer beeps, and the signal is simultaneously transmitted back to the voice recognition system, so as to stop the wheelchair, in order to avoid its collision (or crashing) with the obstacle.

TEST AND RESULTS

The electric wheelchair with the interfacing circuits is specially designed for the purpose to move the wheelchair with a load. The wheelchair motors have high torque and high revolution per minutes (RPM). Figure 3.00a&b show the final Hardware design sample of the Voice controlled electric wheelchair. Based on the tests carried out, the results were impressive. The wheelchair obeyed the input commands from the voice of the user, and operated effectively, hence, achieving the goals and objectives of the project.



Figure 11.0a: The Hardware design of the wheelchair with required interfacing circuits



Figure 11.0b: The picture of the final assembly of the wheelchair.

CONCLUSION

To achieve independence in mobility for people with physical disabilities, the right mobility equipment have to be designed based on the severity and type of disability. This is not a trivial job just because the nature and type of disabilities varies from person to person. The voice recognition circuit (module) and the motor driver control the overall operation. The proposed ARM microcontroller based voice operated and incorporated on the wheelchair with local dialect (languages) is an advantage that would bring more convenience for disabled people. By its very special designed features, the voice operated wheelchair becomes an advanced means of mobility aid for patients suffering from multiple sclerosis and quadriplegics, this wheelchair is thus, a ray of hope to the freedom of mobility for many disabled people. The technology also enhance safety for users who use ordinary joystick-controlled powered wheelchairs, by preventing collisions with walls, fixed objects, furniture and other people. That the design and development of a voice controlled electric wheelchair to aid the movement of the physically challenged had been carry out in this work – the design system will go a long way to aid the physically challenged particularly in developing country like Nigeria where the technology is still low and the economy is still developing. The social burden that goes along with the assistant often to the physically challenged will be greatly reduced because the system is affordable.

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