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Voice Recognition for the Control of Wheelchair with Obstacle Detection

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1. Abstract:

A voice activated wheelchair is one which receives the user's voice command as input and gives an output by moving in a specified direction corresponding to the input command. The implementation process is based on building a voice activated wheelchair that can be controlled using microcontroller and voice recognition module so as to facilitate the movement of the handicapped as well as elderly people who are unable to move well. The wheelchair was designed and constructed using ELECHOUSE VR3 module interfaced with Arduino Uno AVR ATMega328p microcontroller circuit and Direct Current (D.C) motors to actuate its movement. The programming was achieved using C programming language in Arduino platform. Also, ultrasonic sensors are used for obstacle detection thereby making the wheelchair more reliable and safer while in use by avoiding collision with obstacle along its path. A standard adult size wheelchair with voice and keypad control has been designed and developed. The percentage accuracy of the voice recognition unit is 91.43% under real condition and 99% under ideal condition, according to the data sheet of the module. The wheelchair can be used in homes or hospitals by the physically challenged people that can talk audibly but have no legs and upper limbs to drive a motorized wheelchair or by the aged people who do not have the strength to drive a manually operated wheelchair.

Keywords: Wheelchair, ELECHOUSE VR3 module, ATMega328p microcontroller, C programming language.

2. Introduction

Speech is the primary means of communication between people. For reasons ranging from technological curiosity about the mechanisms for mechanical realization of human speech capabilities, to the desire to automate simple tasks inherently requiring human-machine interactions, research in automatic speech recognition and speech synthesis by machine has attracted a great deal of attention over the past five decades [1].

The desire for automation of simple tasks is not a modern phenomenon, but one that goes back more than one hundred years in history. In 1881, for example, Alexander Graham Bell, his cousin Chichester Bell and Charles Sumner Tainter invented a recording device that used a rotating cylinder with a wax coating on which up and down grooves could be cut by a stylus, which responded to incoming sound pressure. This invention however has the same principle as a microphone that Bell invented earlier for use with the telephone. Based on that, Bell and Tainter formed the Volta Graphophone Company in 1888 so as to manufacture machines for the recording and reproduction of sound in office environments. The American Graphophone Company, which later became the Columbia Graphophone Company., acquired the patent in 1907 and trademarked the term "Dictaphone". Almost the same period, Thomas Edison invented the phonograph using a tinfoil based cylinder, which was subsequently adapted to wax, and developed the Ediphone to compete directly with Columbia Graphophone Company. The purpose of these products was to record the dictation of notes and letters for a Secretary, who would later type them out, thereby circumventing the need for costly stenographers. However, this concept of office mechanization passed through a range of Electrical and Electronic implementations and improvements, including the electric typewriter, which changed the face of office automation in the middle of the twentieth century. Shortly after that, obvious interest was developed and led to the invention of automatic typewriter that could directly respond to and transcribe a human's voice without having to deal with the annoyance of recording and handling the speech on wax cylinders or other recording media [1].

The field of automatic speech recognition has witnessed a number of significant advancement in the past five to ten years, spurred on by advances in signal processing, algorithms, computational architectures and hardware. These advances include the widespread adoption of a statistical pattern recognition paradigm, a data driven approach which makes use of a rich set of speech utterances from a large population of speakers, the use of stochastic acoustic and language modeling, and the use of dynamic programming based search methods [2].

3. Block Diagram

The block diagram of the system is shown in Figure 1. It is a diagram that shows the main parts of the system and their functions.

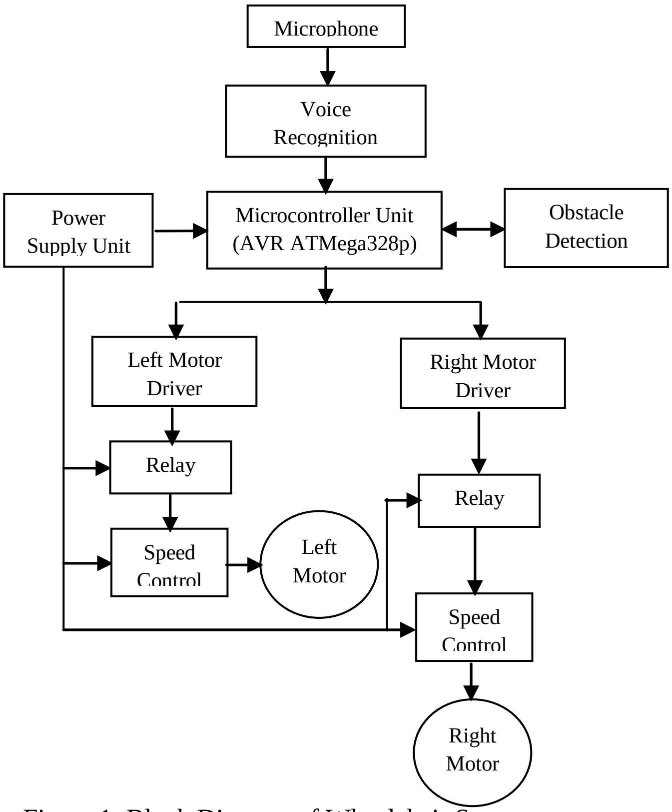

Figure 1: Block Diagram of Wheelchair System.

4. Literature Review

In their research, [3] worked on recognition of voice commands for robot using Melfrequency Cepstral Coefficients (MFCC) and Dynamic Time Warping (DTW). The approach is based on the recognition of English words corresponding to control robot in an isolated way by different speakers (male and female). The work focused on recognizing voice using MFCC and DTW. MFCCs are the coefficients that collectively represent the short-term power spectrum of a sound, deploy on a linear cosine transform of a log power spectrum on a nonlinear mel scale of frequency. Computation of Short Time Energy (STE), Zero Crossing Rate (ZCR), start point and endpoint detection. The MFCC and DTW algorithm were used to process speech samples to accomplish the recognition. The algorithm is tested on speech samples. The system is then applied to recognition of isolated word in English language that is used to control robot for specific application. In a design by [4], a voice recognition and touch screen control based wheelchair was developed to be used by paraplegic persons. The system used voice recognition kit which consists of HM2007 voice recognition module, 3 buffer ICs, a static RAM, LED display, a microphone, 12 keys in which 10 keys are used for input selection, one key for training the kit and one key to clear memory. The voice recognition IC HM2007 is operated in speaker dependent recognition mode. In this mode, the unit responds only to the current user. If another person needs to use the same system, a new training phase must be applied. [5] designed a voice controlled smart wheelchair using embedded system for physically disabled persons incorporating manual operation. Arduino microcontroller and HM2007 speaker dependent voice recognition processor have been used to support the navigation of the wheelchair. The direction and velocity of the chair are controlled by pre-defined Arabic voice commands. Arduino receives the coded digital signals from the voice recognition module in order to control the function of the wheelchair accordingly. The overall mechanical assembly is driven by two D.C motors. In a design by [6], a voice controlled wheelchair using ATMega8 microcontroller was achieved. This is a dual input type operated wheel chair that is made to work based on voice and touch screen commands. The voice recognition was achieved by HM2007 voice recognition module, which has a microphone connected at its analog input keeping the mode selection key in the record mode. The microcontroller ATMega8 was used along with motor driver L293D to drive and control the two D.C motors. To select a specific input device, a switch is powered high and low. When the switch is high (logic 1), the voice recognition system will be activated and when the switch is low (logic 0), the touch screen is activated. The output of the touch screen is analog in nature. To digitize the signals, six in-built channels of ADC of ATMega8 micro controller were used. On receiving the Signal the microcontroller directs the motors through the control circuit. For the motion of the wheelchair, two D.C brushless motors were used for controlling the two wheels of the chair independently. The work of [7] explained an Evolutionary Approach for Smart Wheelchair System with efficient and easy to use control interface. The wheelchair can be used by handicapped individuals with arms, legs or spinal cord injury as well as nervous system disorder, caused by war and ageing. The wheelchair will improve their ability to live independently. Since controlling of electric wheelchair using joystick is difficult for people with complete paralysis, the use of Human-Machine Interface (HMI) was developed for automatic navigation of the wheelchair using voice commands and simple movement of the patient's fingers with remote control. The wheelchair can apply automatic brake when an obstacle is detected along its path by the action of ultrasound system, which serves as obstacle detector. **[8]** designed an electric wheelchair that can be controlled using the human eyes to support the movement of the disabled persons. Most of the computer input system with human eyes only consider specific conditions and do not work in a real time basis, but this system can be controlled by human eyes with high level of accurately and safely. The design procedure also considered the problems of robustness against different user types, illumination changes, user's movement and vibration. The system utilizes infrared (IR) camera which is mounted on user's spectacles so as to eliminate the problems of illumination changes, user's movement, and vibration. Furthermore, the pupil detection based on pupil knowledge also serves to improve the robustness against different users. **[9]** succeeded in developing an intelligent wheelchair to help patients using speech recognition system to control the movement of wheelchair in different directions by using voice commands and also the simple movement of the patient's fingers with keypad control. Automatic obstacle detection is done using an ultrasound system. [10] worked on Intelligent Wheelchair (IW) interface to be used by people with disability. Since the introduction of control and navigational intelligence made robotic and intelligent wheelchairs to go beyond the capabilities of the traditional powered wheelchairs with joystick, their work is based on the control mechanism of the intelligent wheelchair in accordance to the signals from the input source. They also discussed the different control mechanisms, their advantages, limitations, strengths and weaknesses. In the work of [11], a novel adaptive method to improve Brain-Machine Interface (BMI) based robotic wheelchair navigation was designed. The system can detect and avoid obstacle along its route by a laser range finder sensor. It can also read assistive information on the floor and autonomously navigate the robot using a computer vision. The system can also be switched between assisted and unassisted navigation mode depending on the user’s intention and environment context. The design of a smart wheelchair for physically handicapped people was achieved by [12]. The wheelchair can be controlled by voice commands as well as with the help of gesture recognition system. The system is divided into the voice recognition unit, the gesture recognition unit, the obstacle avoidance unit and the wheelchair control unit. Voice recognition module V2 is used for recognizing voice commands while the hand gesture module uses the triple axis accelerometer sensor ADXL 335.for gesture recognition. The ultrasonic sensors are used to detect obstacles in the path and the design of the wheelchair control unit is achieved using ATMega2561 microcontroller, motor drivers and D.C motors. [13] designed a touchpad and voice command based wheelchair using the bluetooth module. The system is designed to control a wheelchair using the voice of users who are disabled or handicapped and elderly people. The wheelchair design is achieved using ATMega328p microcontroller and direct current motor to movement of wheelchair. Alternatively, the touch-pad interface could be used to move the wheelchair in the desired direction. To ensure the safety of the user, IR sensor is used for obstacle detection and the wheelchair stops automatically if there is an obstacle along its path. [14] described the design of a voice controlled wheelchair and devices control as an assistive technology to be used by the old and disabled persons. The design was based on converting audible voice into unique data as a command to ATMega16, which serves as master micro-controller for the voice recognition. Speech synthesis module (HM2007) was used to train the user’s voice through the microphone of the module. Also, ATMega328p was used as a slave to turn the device on and off remotely. The main system on the wheelchair takes command from the speech synthesis module and sends it through a Radio Frequency Communication Module (CC2500) to the switching microcontroller to actuate the device corresponding to that command.

5. Materials Used

The materials adopted in the design and implementation process are;

1. Voice recognition module V3 with microphone
2. Arduino Uno board with AVR ATMega328p microcontroller
3. D.C motors
4. Motor drivers
5. Power supply (12 V rechargeable battery)
6. Ultrasonic sensors
7. Arduino IDE software
8. Livewire circuit design software.

5.1 Voice Recognition Module

This is the device used for receiving the input voice commands. The module used in this work (ELECHOUSE voice recognition module V3) is Arduino compatible. It has an inbuilt microphone which used for detecting and receiving the voice commands. It is a speaker dependent voice recognition module and has the capability of storing up to 80 voice commands of which 7 commands can be used at a time. Before connecting it to the Arduino, it was trained so as to recognize and respond to the voice commands properly. The voice command record contains all the 80 voice command with the index from 0 to 79. The recognizer, the central part of the module, stores a maximum of 7 voice commands. The recognizer index refers to the 7 different regions where these commands are saved with the index labeled 0 to 6, each corresponding to one region. “Train” is the procedure of recording the acting commands, “load” copies the trained voice to the recognizer and “signature” involves the text comment for the record. The commands are organized into groups with 7 commands each.

Plate I: Voice Recognition Module V3 with Connectors and Microphone.

5.2 Arduino Board

The Arduino Uno is a single microcontroller circuit development board that provides an easier for the design of electronic circuits. It has a 32 KB flash memory, fourteen digital input/output pins of which six can be used as Pulse Width Modulation (PWM) outputs and six analog input pins. It is used to perform a wide range of operations using the software kit provided with it. It can be used to convert ultrasonic sensor signal into vibrator signal. The main feature of the Arduino board is that programming is easier when compared to the other devices such as the PIC16FX series microcontroller and the circuit size is reduced.

Plate II: Arduino Uno Development Board with ATMega328p Microcontroller.

5.3 D.C Motors

These constitute the most important components when it comes to the motion of the wheelchair. Motors with high power consumption may cause inefficiency and waste the limited power supplied by the battery, while motors with low power demand may have low torque to drive the wheelchair. The optimal rotation speed and the available speed range of the motor must also be taken into consideration.

Since the typical power supply for the wheelchair is a D.C battery, then D.C motors will be chosen, as they are commonly used for low power demanding projects.

Plate III: D.C Motor for Wheelchair Drive.

The speed of the motor measured in rpm can be determined using (1)

$$N = \frac{Em - ImRm}{K\Phi} \quad (rpm) \qquad \dots (1)$$

Where N is the motor speed in revolution per minute (rpm), E_m is the motor voltage source in volt (V), I_m is the motor current in Ampere (A), R_m is the motor resistance in Ohm (Ω), K_Φ is a constant which depends on design factor.

For the motor used, $E_m = 12$ V, $I_m = 14.4$ A, $R_m = 0.8$ Ω and $K_\Phi = 6 \times 10^{-3}$

Therefore $N = \frac{Em - ImRm}{K\Phi}$

$= \frac{12 - 14.4 \times 0.8}{0.006}$

$= \frac{0.48}{0.006}$

= 80 rpm

The angular velocity, ω in radian per second (rad/s) can be determined by (2).

$$\omega = \frac{2\pi N}{60} \qquad \dots (2)$$

$= \frac{2 \times 3.142 \times 80}{60}$

= 8.379 rad/s

The expected power in Watt (W) to be supplied by the motor can be calculated using (3)

$$P = \tau\omega \quad (W) \qquad \dots (3)$$

Where τ is the torque in Newton-metre (Nm) and ω is is the angular velocity in radian per second (rad/s) of the motor. For the motor used, τ = 45 Kg-cm = 4.4145 Nm

Therefore P = 4.4145 x 8.379 = 36.989 W

5.4 Motor Driver

This unit consists of the H-bridge L298 relay drivers, as shown in Plate IV. It requires 12 V supply to control the motors for the bidirectional motion of the wheelchair, as it enables the current to flow in both directions. Free welling diode can be used to protect the relay contact and prevent damage to the transistor when the relay switches off. An intermediate stage between the control signal and motors consists of a combination of component relays, transistors, diodes, capacitors and resistors used to protect parallel port against any expected damage.

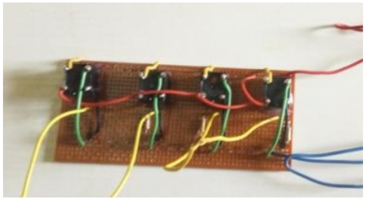

Plate IV: H-bridge Motor Driver Circuit.

5.5. Power Supply

The battery used in this work is the 12 V, 7.2 A rechargeable batteries. Two batteries were connected in parallel thereby giving the system a total of 14.4 A current, which is sufficient to drive the motors.

5.6 Ultrasonic Sensors

For the detection of obstacle, the wheelchair uses ultrasonic sensors. These are sensors that use ultrasound for sensing objects, pits and any obstacle located on the path of the wheelchair. They operate based on the phenomenon of transmission and reflection and calculate the distance using the time taken between each transmission and reflection. To maintain a safer distance from the obstacle a set of sensors are placed at the front side (for forward detection) as well as the back side (for backward detection) of the wheelchair. The sensors will be triggered up by supplying a short pulse to the trigger input and that will automatically make the module send out an 8 cycle burst of ultrasound at 40 KHz and raises its echo. If there is any obstacle in the path of the signal this will return as an echo to the sensor receiver part. The test distance can be calculated using (4).

$$\text{Test distance} = \frac{\text{High level time (s)} \times \text{Velocity of sound in air (340 m/s)}}{2} \quad (m) \qquad \dots (4)$$

For this design, High level time = 2.5 ms

Therefore $\text{Test distance} = \frac{0.0025 \times 340}{2}$

= 0.425 m
= 42.5 cm

For convenience, the test distance is taken as 40 cm. This implies that if the distance between the wheelchair and the obstacle is 40 cm, the ultrasonic sensor receives the echo signal from the obstacle and communicate with the microcontroller that obstacle has been detected and the microcontroller will, in turn, send a command to stop the wheelchair automatically.

Plate V: Ultrasonic Sensor for Obstacle Detection.
The parameters and their corresponding specifications of the ultrasonic sensors used are shown in Table 4.

6. Circuit Diagram

The circuit diagram of the voice command control, as shown in Figure 2, was drawn using the livewire software.

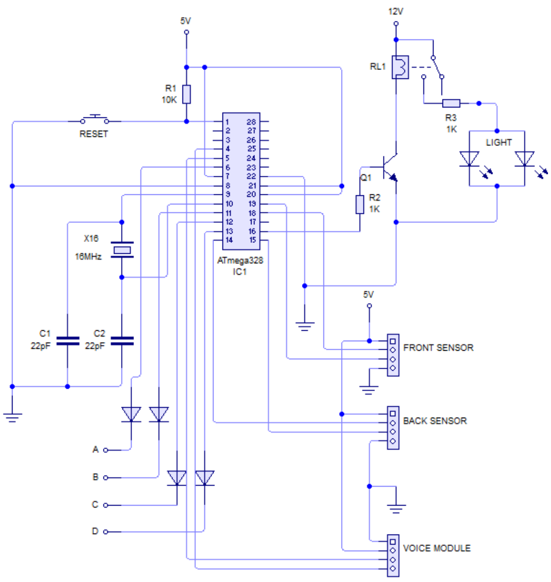

Figure 2: Circuit Diagram of the Voice Command Control

7. Results

Te result taken based on ten (10) trials of each voice command showed the number of commands that responded correctly, as in Table 1.

Table 1: Response of the Voice Recognition Module to the Voice Commands.

S/N	Voice Commands	Number of Issued Commands	Number of Accepted Commands
1	Forward	10	9
2	Backward	10	8
3	Left	10	10
4	Right	10	9
5	Light On	10	9
6	Off	10	10
7	Stop	10	9
	Total =	70	64

From Table 1, the percentage accuracy of ELECHOUSE voice recognition module V3, as used in this research, can be determined as

Percentage Accuracy,

$$P.A = \frac{\text{Total Number of Correctly Responded Commands}}{\text{Total Number of Uttered Commands}} \times 100\%$$

$$= \frac{64}{70} \times 100\ \% = 91.43\%$$

The percentage accuracy obtained from the designed wheelchair under real condition is 91.43%, while the percentage accuracy, as obtained from the manual of the module is 99% under ideal condition.

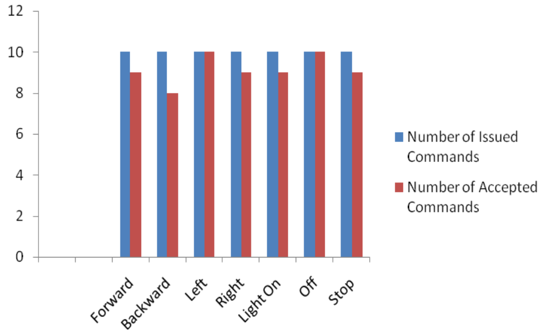

Figure 3: Bar Chart Showing the Number of Issued Commands Compared with the Number of Accepted Commands.

The bar chart in Figure 3 showed that the voice recognition module responded correctly to all the ten commands issued for left and off commands. However, for forward, right, light on and stop commands, nine out of the ten commands responded correctly while for backward command, two out of the ten commands failed to respond.

8. Conclusion

At the end of the research work, the objectives have been achieved as a standard adult size wheelchair has been designed and constructed. The wheelchair has two batteries connected in parallel as its power supply. It has two ultrasonic sensors one from the front and the other from the back for the detection of obstacle while in motion. For the lighting section, two torch-lights are used and connected in parallel so as to receive the command at the same time and function as a single entity. .

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