Raspberry Pi Based Voice Controlled Smart Wheelchair

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***Abstract*—Voice signals are the most important means of communication among human. Every conversation and interaction is done employing voice signals. Voice signals can be converted into electrical signals using a microphone. This electronic document represents a project which aims to design and construct a wheelchair that can be controlled by human voice. This is for paralyzed people that are severely injured and can't even use their hands to control the joystick wheelchair. Physical disability can occur due to multiple reasons like injuries from an accident, age-related & health problems. A wheelchair is used to provide a mode of transportation for disabled people with impairments in hands and legs. This project will provide smooth self-drive indoors and outdoors. It can detect objects, stairs, or any constraint and can stop autonomously. The prototype of the wheelchair is constructed using a microcontroller, chosen for versatility and performance in operations and communication with other electronic devices. This project is based on the basic principle of motor controlling system and voice processing using a microcontroller. The system has been designed in a cost-effective way so that it can be commercialized and needy users may benefit from it.**

***Keywords*— voice processing, motor control, image processing, machine learning.**

I. Introduction

Disabilities have several types that vary from mental, intellectual, behavioral, cognitive, and physical. Physical disabilities are also known as mobility disabilities which refer to any severe conditions that affect someone's body movement and control [1].

For people who are physically challenged, a power wheelchair is very useful and essential [2]. Joystick-controlled power wheelchairs are widely available, although those chairs need physical power in the hands and arms to get the wheelchair to be directed [3]. Hence it's tough to use for patients who have problems with their hands [4]. As a result, a power wheelchair, operated by voice commands can assist paralyzed and crippled persons. The project aims to control a casual wheelchair through a human voice. It enables a disabled or highly injured patient to move around without being served by anyone, using a voice processing mechanism interfaced with motors. Furthermore, our project consists of a camera and ultrasonic sensors to prevent objects collision, stair falls, etc. Different techniques have been proposed by many papers to control the wheelchair with different methods such as the face-direction-recognition [5], oral motion [6], gaze of eye [7], pressure of tongue [8], the bio-signals-inference [9], Electromyography also known as EMG [10], Electrooculography also known as EOG [11] and electroencephalography also known as EEG [12]. However, the best method, we believe, is to utilize the human voice to get the wheelchair be operated since the voice is the most natural and feasible way of communication [13].

There is an intense need for a wheelchair with voice command processing in order to aid people having physical disabilities [14],[15]. Hence, in this paper we represent the design and reconstruction of a voice-controlled-wheelchair by altering a wheelchair that can be operated by the words pronounced by the user. Additionally, it can stop the movement when any constraint is detected which is a safety to the users.

II. Methodology

This wheelchair comprises several electronic features and parts. This creates the electromechanical relation between the components, executing our goal. The components are explained below.

A. Raspberry Pi

The Pi 3 Model B+ is a Raspberry Pi range product. It is a low-cost computer of the credit-card size that plugs into a computer monitor, keyboard, and mouse interface. It is a small but capable device letting people learn to compute and program in several languages such as Python and Scratch. It can do everything a desktop computer can, such as brows the internet, play HD videos and games, make spreadsheets, and word-processing.

With a 1.4GHz processor of 2.4GHz dual-band, WLAN, Bluetooth, and Ethernet, the Raspberry Pi 3 Model B+ footprints the same as the Raspberry Pi 2.

B. Battery

The 12V batteries of 30Ah are used in each motor to operate each motor for the required load.

C. Casual Wheelchair

A normal wheelchair, used in homes and hospitals, is altered to fit the gears on its wheel's hubs.

D. Motors

The 12V DC motors are used to drive the wheelchair. This motor gives 55rpm at 12V. 55rmp gives a normal walking speed if the radius of the wheel is 0.3m which maintains a normal walking speed for humans. These motors are also used in the wiper mechanism of cars. The motors have high torque. Each motor could load and lift about 25Kg of weight. Figure 1 shows the motor we used.

Fig. 1. DC Motor

E. Relay

This relay module contains four 5V relays and the switching plus isolating components making it interface with the microcontrollers such as Arduino and Raspberry Pi etc for switching purposes. The relay contacts are specified for 250VAC and 30VDC with 10A in each case. Table 1 represents the specified functions of the motor controlling. Table 1 represents the different phases in which the two motors were directed to accelerate simultaneously in different and same manners, e.g. the 'Forward' commands accelerated both motors in 'Forward direction' to move the wheelchair in forward direction. Similarly, 'Left' and 'Right' commands direct the motors to move in clockwise and counter-clockwise.

Table 1. Commands for Motor Direction

	Motor Diretions	
Commands	**Left Motor**	**Right Motor**
Forward	Forward	Forward
Backward	Backward	Backward
Right	Forward	Stop
Left	Stop	Forward
Turn Around	Forward	Backward
Stop	Stop	Stop

F. Miscellaneous

Several miscellaneous electrical and mechanical components are used including chains, and gears, both for motors and the wheels. The electrical components used are, a constant 12V to 5V converter for the power usage of the microcontroller, the microphone for voice input, the voice processing module, the buzzer, the LEDs, and the ultrasonic sensors.

III. Software Mechanism

It required the in-depth knowledge of machine learning for voice processing and collision avoidance. Given are the details. Figure 2 represents the model architecture of the mutual functionality and the correspondence of three simultaneous features commenced, e.g. simulation and results of execution of voice, camera, and ultrasonic sensor.

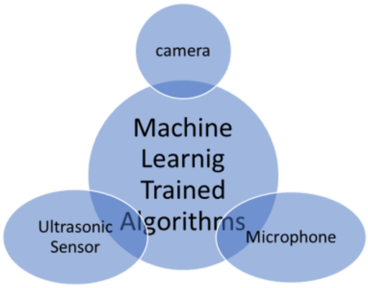

Fig. 2. Block Diagram of Algorithm

A. Machine Learning

It is a type of Artificial Intelligence in which the software and applications become accurate at prediction of specified outcomes without the explicit programming to do so. The algorithms of machine learning accept historical data as the input in order to predict new output values.

The construction of a learning system to handle a specific learning challenge is also known as applied machine learning. The learning issue is defined by observations which include input and output data, also an unknown but consistent connection between the two given parameters.

B. Voice Processing

The voice processing is done by using a pre-trained model of the VOSK library for python and machine learning. Figure 3 represents the graphical variations of voices how the machine has learnt to consider and differentiate the words and the graphical representation of waveforms with signal's amplitude height in time domain of two different words as they are processed, considered and saved by the model.

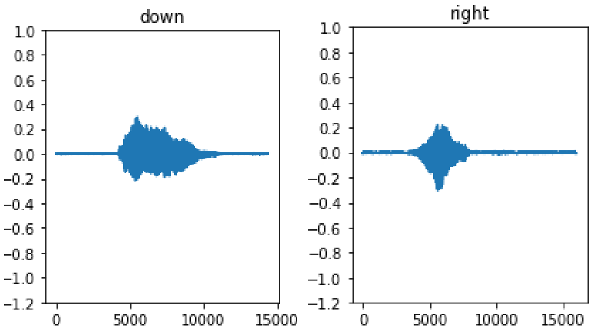

Fig. 3. Graphical Representation of Voice Signals

Vosk -a speech recognition toolkit-

1. Supports 20+ languages - English, German, French, Chinese, Russian, Turkish, Arabic, Farsi, Japanese, and Polish. More to come.

2. Uses pip3 install vosk, and works offline,

3. Per-language models of only 50Mb each.

4. Quick reconfiguration of vocabulary for better accuracy.

5. Figure 4 represents the voice module by which the analogue signal of voice is converted into the digital signal to be processed by the Pi.

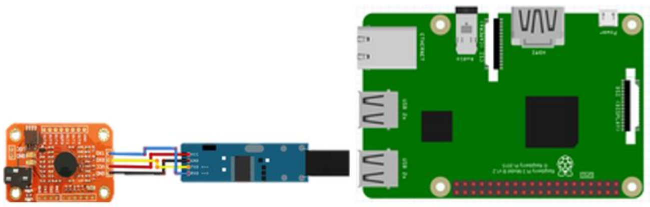
Fig. 4. Raspberry Pi with Voice Module

C. *Image Processing*

The image processing is done by real-time object detection using deep learning and OpenCV in python and machine learning. Figure 5 shows the experimented results the image processing has learnt to find the stairs in the way.

Fig. 5. Stair Detection in Via Collision Avoidance

To prepare our deep-learning-based real-time object-detection model with Open-CV, we needed access to a camera then apply object detection to all the available frames.

We classified not for the whole number of items but for some specific things such as the stairs, people, and the objects that are placed on the floor.

D. *Collision Avoidance*

The collision avoidance system development is motivated for increased wheelchair safety. Crashes could be prevented by collision avoidance systems. It can react to the situations that humans can not. So, it can reduce the severity of accidents. The rear-end collision avoidance system is developed via ultrasonic sensors because the patient can't see behind. The front side system has a camera to detect the stairs or the relevant objects. This is necessitated by the requirement that the motor control and warning algorithm becomes automatic. The method of delivering the warnings will also be the buzzer noise. These nominal criteria will then be modified based on environmental inputs. Figure 6 shows the ultrasonic sensors that are used to figure out the distance in centimetres of the objects in the path of the wheelchair by transmitting a wave and receiving it, and then it calculates the time after which the wave has been received. The calculated time, indeed, proposes the distance of the object.

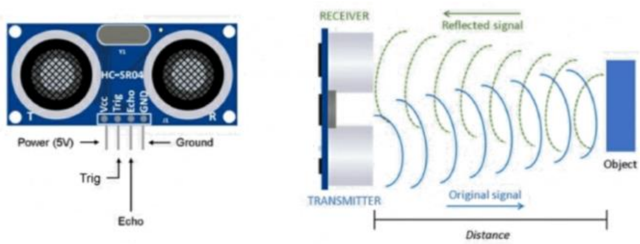

Fig. 6. Ultrasonic Sensor

Given below is the table to show the experimented values of the ultrasonic sensor. Table 2 represents the 8 experimented values the ultrasonic sensor has performed. It shows how much accuracy can an ultrasonic sensor can provide on the way.

Table 2. Experiment Values of Ultrasonic Sensor Data

Serial Number	**Actual Distance (cm)**	**Calculated Distance**	**Accuracy Percentage**
1	5	5	100.00
2	6	5	99.83
3	7	5.5	99.79
4	8	5.5	99.69
5	9	7	99.78
6	10	7.2	99.72
7	11	7.5	99.68
8	12	7.7	99.64

E. Process Fragmentation and Steps

- Enabling the power button turns on the Pi and automatic start-up apps execute the python script consisting of the code.
- The initial beep insures the code execution, the voice data loading, and the image data loading.
- Hence the chair becomes ready to get the voice commands.
- The command execution verifies the available path and judges if there is any constraint.
- Hence the chair does as directed. Figure 7 shows the input/output signals application of the overall functionality of the wheelchair. The multiple inputs are processed and then after the processes of decision making, the output signals finally control the motors.

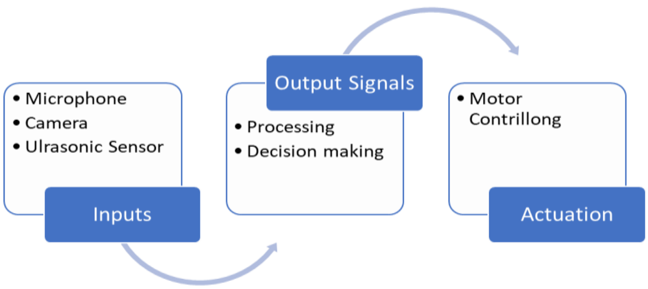

Fig. 7. Block Diagram of Input and Output Signals of Microcontroller

IV. MECHANICAL MODIFICATION

The second most important part, after the microcontroller programming, is the mechanical modification, since this project is a combination of numerous fields.

- In order to connect each motor with each wheel, two transmission gears of equal steps and a motorbike chain are used. The motorcycle chains have similar design. Chain and sizing are numbered 40, 50, and 60 as is the standard roller chain. We used 40 class = pitch is 0.5”, roller diameter 0.306” or 0.335” roller width is 0.312”.
- The front wheels performed as freewheels.
- All the weight of batteries is compensated in the middle bottom of the wheelchair. This helped in keeping the center of gravity in its right position.
- The camera is fitted at the front, ultrasonic sensors at the rear side, and the microphone was kept free to handle.
- Both the motors are fitted on the rear wheels of the chair. Figure 8 shows the feasible and space friendly fitting of the motor.

Fig. 8. Fitting Of Motors

V. ISSUES

Several issues were faced in electronic modification. Some of which are listed below.

- Motor’s speed synchronization had several problems. Since the same motors have the same specification, each motor can behave differently. This is due to the efficiency of motors and the usage time. In our case, one motor performed a bit slower and the other one was working in good condition. This caused the wheelchair to turn one side as both wheels were controlled by two motors. So, an electronic tool called RPM Limiter is used for the motor which actually performed well. Since we could not help the slower motor, so we reduced the RPM of the good condition motor. RPM Limiter inputs the given voltage and outputs the required voltage to meet the RPM of our need.

- Wheel alignment is another tough but mechanical issue. Both the wheels should be straight aligned. If any wheel is moving not correctly, the wheelchair becomes in trouble.

- Raspberry Pi power supply is a factor of performance. The Pi should get the actual rating of 5V DC and 3A current. If it doesn't then the power rating of Pi is disturbed and it becomes slower. It then also responds slower than the actual performance.

- Latency in the execution of commands has two factors discussed above; the power supply issue, and the overheating. This latency caused the wheelchair to act after a few seconds of the given command.

- Overheating of Raspberry Pi is also a factor of performance. The Pi can perform correctly for a time period of an hour. But it starts heating up if it is used for more than an hour. It requires a portable fan for Pi. This sometimes solves the problem. Table 3 show the execution delay in seconds as the time period, in hours, increases in the Pi. The performance of Pi is affected due to longer runtime.

Table 3. Time and Response Delay of Microcontroller

Time Period after which the microcontroller changes performance behaviour.	**Delay in command execution**
After 1.0 hour	0.2 sec
After 1.5 hour	0.3 sec
After 2.0 hours	0.5 sec
After 3.0 hours	1.0 sec
After 5.0 hours	1.5 sec
After 6.0 hours	3.0 sec

The last time period is a significant factor for which we need to reconsider the microcontroller choice.

VI. Future Goals

Considering the current features of this voice-controlled wheelchair, we can assume the upcoming improvements and advance features to make it more reliable, economic, and comfortable. Several types of microcontroller are available in market to make this project customizable.

Conclusion

Several efforts are under consideration to make it more reliable, feasible, and economic. Moreover, instead of using the ordinary wheelchair, we are planning to construct a new architecture for this to make it more tech-friendly. The futuristic approach of machine learning accelerates our project's goals to new horizons as this model predicts the electric cars in Pakistan in near future. Also, the weight lifter robot is the next idea that is under consideration as the successful completion of this project has commenced.

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