A SMART CHAIR WITH VARIOUS FUNCTIONALITIES FOR PEOPLE WITH RESTRICTED MOBILITY

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Abstract- The Smart chair is a step taken with an intention to make a difference to the lives of people with restricted mobility. Smart systems are devices that incorporate functions of sensing, actuation and control through their capability of describing and analyzing a situation, and taking decisions based on the available data in a predictive or adaptive manner, thereby performing smart actions. This paper is based on a project work which aims at achieving cost effectiveness in automated wheelchairs by providing the patients with the facility of incorporating need based individual modules into the chair so as to customize as compared to an integrated one commonly available in the market.

Key words- Accelerometer based activation, Obstacle Detection, mobile control (DTMF based), Voice Activation, Joystick control, Chin Control.

I. INTRODUCTION

Quadriplegia is a medical condition characterized by partial or complete paralysis of the four limbs and torso. Paraplegia is a variant of quadriplegia where only waist downwards is non-functional. The smart chair is an improved version and extension of work already carried out where motion control had been achieved using neck movement, joystick, voice activation and mobile phones. The earlier work done on the chair used Arduino (Atmega 8) for the sensor inputs and to produce control signals. Though Arduino is a simple platform to use, it lacked certain qualities needed for a robust reliable controller. Hence in this work Raspberry Pi, an efficient hardware platform has been used which apparently overcomes the limitations of Arduino. This is well established by the comparison made in the features as shown in Table.1. The programming language needed for Raspberry Pi adds to the versatility and simplicity of its use.

Table.1

FEATURES	ARDUINO (Uno)	RASPBERRY PI
Programming Language	Wiring Based(C++)	Python, C++ etc.
Architecture	8-bit	32-bit
Clock Rate	16 MHz	700 MHz
RAM	2KB	256 MB
ROM	32KB	SD
Audio	-	Stereo Out, In w/ USB Mic
Video	-	HDMI,NTSC,PAL

II. ACCELEROMETER MODULE USING ADXL345

An accelerometer is an electronic component that measures tilt and motion. ADXL345 is a small, thin, low power, 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16 g. Digital output data is formatted as 16-bit twos complement and is accessible through either a SPI (3- or 4-wire) or I2C digital interface. We have used I2C to connect ADXL345 to Raspberry Pi. The following functionalities are accomplished.

i) An accelerometer chip attached to the user's head detects the inclination of the head
ii) According to the inclination, the wheels of the wheelchair move forward or backward or turn to the right or left.

This module is thus aimed at improving the mobility of the chair and reducing the human effort required for the same. The motion of the head/neck is detected by the accelerometer and according to the direction and magnitude of motion, the wheelchair will move either forward or backward, or turns right or left. The corresponding range of accelerometer input is as shown in Table.2

Table.2

Function	Range of Accelerometer input
Forward	-1< x <-0.2 and -0.2 < y < 0.2
Left	-0.2 < x <0.2 and 0.2 < y < 1
Right	0.2 < x < 0.2 and -1< y < -0.2
Reverse	0.2 < x < 1 and -1< z <-0.2
Halt	Any other input

III. OBSTACLE DETECTION USING ULTRASONIC SENSOR

An ultrasonic sensor is mounted on front and back of the wheelchair which continuously measures the distance of the obstacle and updates the user so that user can take appropriate control.

Ultrasonic sensors (also known as transceivers when they both send and receive, but more generally called transducers) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object. The signal received and the estimated distance of obstruction is obtained as shown in Fig.1

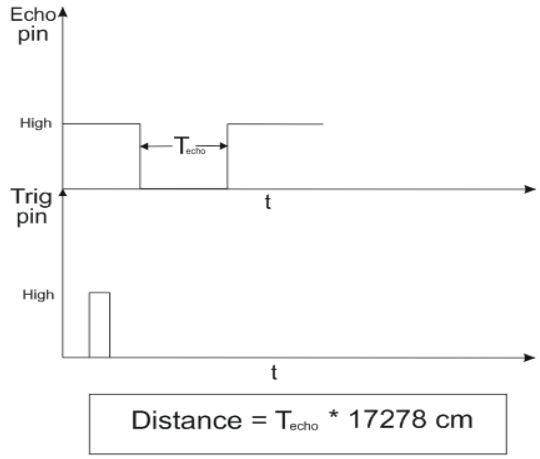


Fig.1.The ultrasonic signals and the distance of obstruction (T_{echo} is in µs)

IV. DTMF USING DTMF DECODER IC

Dual-tone multi-frequency signaling (DTMF) is used for telecommunication signaling over analog telephone lines in the voice-frequency band between telephone handsets and other communications devices and the switching center.

The DTMF system uses eight different frequency signals transmitted in pairs to represent 16 different numbers, symbols and letters. The DTMF keypad is laid out in a 4×4 matrix in which each row represents a low frequency and each column represents a high frequency. Pressing a single key sends a sinusoidal tone for each of the two frequencies. For example, the key 1 produces a superimposition of tones of 697 and 1209 hertz (Hz).

Initial pushbutton designs employed levers, so that each button activated two contacts. The tones are decoded by the switching center to determine the keys pressed by the user.

The advantages of the DTMF module are as listed below.

- In the DTMF module, external control can be achieved
- A mobile phone is integrated or attached to the wheelchair.
- An outsider can call this mobile phone, and by the press of the push-buttons, the wheelchair can be controlled.
- In case of any untoward incident involving the person on the chair, the mobile phone that is integrated to the wheelchair can be called in, and by the press of the button, the wheelchair can be controlled.

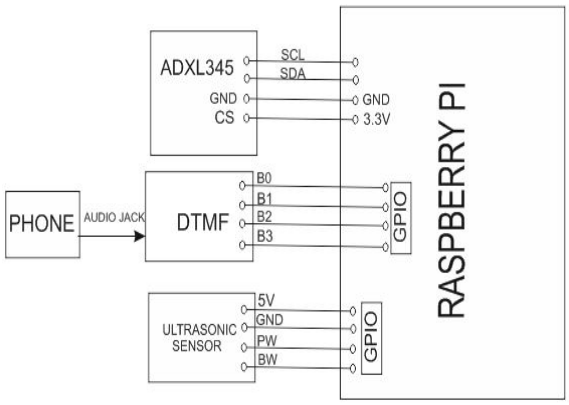


Fig.2 Block diagram of sensors and GPIO connection

Fig.2 shows the interconnection of the accelerometer, mobile (DTMF) and ultrasonic sensor to the Raspberry PI through the GPIO (General purpose input output) pins.

V. JOYSTICK CONTROL

Paraplegics can use this method of control by using their hands. This control is accurate and precise. The joystick is connected to the Raspberry Pi through USB cable, python program addresses the joystick and looks for interrupts. Any variation in the input from the joystick triggers a corresponding configured-output in the Pi. Joystick has 3 parts

1) Enable: A push button is programmed to enable or disable the joystick
2) Control: It has two ways of control one is paddle control another is button control. In paddle the movement of chair is according to the direction of tilt of the paddle. Acceleration of the chair is depended on the amount of the tilt
3) Application: Along with the joystick, External hard key interrupts can be fixed along with the joystick to enhance the usability of the chair
    a) Hard key to invoke voice activation
    b) Hard key to trigger the siren(call for help)
    c) Hard key to call close ones over Skype
    d) Hard key to play songs or videos (entertainment)

Fig.3 shows the joystick and its associated control buttons that can be configured for various functionalities.]

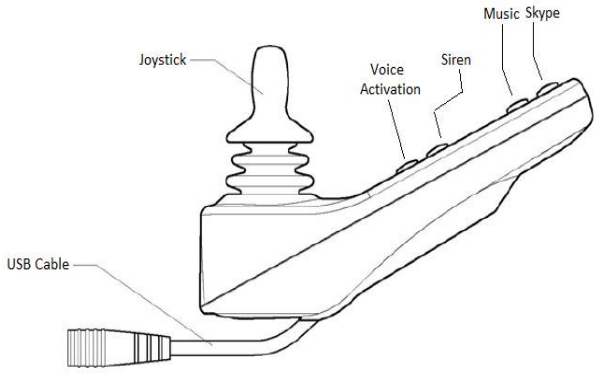


Fig.3 Joystick and Button control

VI. VOICE CONTROL:

Since joystick control cannot be used by Quadriplegics this module is used to control the basic movement of chair by voice of the user. When this module is triggered, Python program will enable the USB Microphone, listens to the voice of the user and refreshes every 10 seconds. It sends the recorded voice to Google speech to text converter over the internet. When the program receives the text version of speech, direction of the chair is controlled accordingly. Program is configured only for Forward, Reverse, Left and Right. It can also be configured according to user's requirement

VII. CHIN CONTROL

This control module is an alternative for the joystick control for Quadriplegic. Here user can control the direction and acceleration of the chair by the movement of his head. A touch pad will be mounted near the chin of the user. User touches the pad with his chin when required and navigates the wheelchair. When chin control is triggered Python program continuously senses any movement on the touch pad, touch pad can sense only skin hence any external stimuli other than the patient will not be sensed. Fig.4 shows the interfaces of joystick, voice and touch pad that are connected to the raspberry Pi through the USB port.

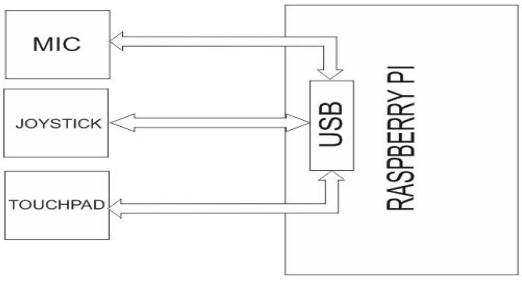


Fig.4. Block Diagram of Input devices and USB of Raspberry Pi

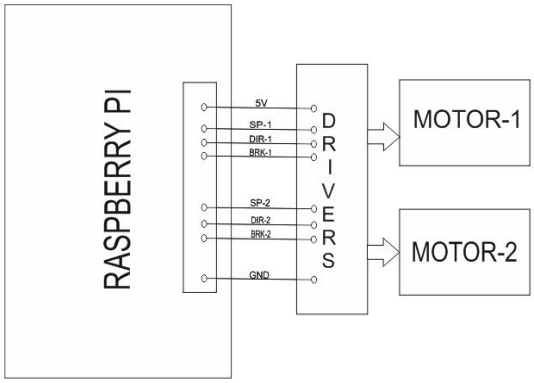


Fig.5. Block Diagram motor connections to the Raspberry Pi through drivers.

Fig.5 shows the GPIO pins of Raspberry Pi that are connected to drivers of the motors. Drivers are used to control the speed, direction and braking of the motor hence three GPIO pins are required for each motor.

VIII. RESULTS

The above control methods are successfully tested on a prototype as shown in Fig.6. Prototype includes two hobby motors which are driven by dc supply and control signals given from the Raspberry Pi through a motor driver IC L293D and all the modules mentioned above.

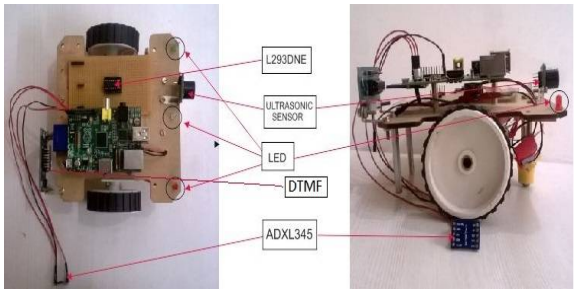


Fig.6 ADXL345, Ultrasonic Sensor and DTMF mounted on the prototype

Hardware buttons are given to enable each module so that the user can choose the type of control. Joystick is a simple and robust control, any fault in software is countered by exception handling mechanism of the programming language. Voice activation system involved here needs a good microphone and a noise cancellation device so that it can record good quality sound. Activation system runs based on detection of predefined keyword therefore even a guardian can activate and direct the chair. Touch pad placed near the chin can be made compact and detachable to reduce the inconvenience to the user. The touch pad input values are predefined with the limits so any random movement made on the touchpad will not cause any movement. Similarly the Accelerometer module works for a certain range of input from the accelerometer, hence any involuntary movement of the patient will not cause the wheelchair to move. The Ultrasonic sensor can measure up to 21 feet and by

adjusting the input sampling time even the dynamic obstacles can be detected and an alarm can be raised. The cell phone used for the DTMF module can be easily configured such that it auto answers the call from recognized phone numbers with all other numbers blocked. Cost for the control is the only drawback of this module. The pseudo code for each functionality is as follows.

```
Initialization;
while True do
    /*GPIO 19 and 12 are connected to BW and PW
    respectively*/
    /*19 is an output pin and 12 is input pin*/
    BW = 0;
    time.delay(0.001);
    BW = 1;
    while PW==0 do
     | start = notetime
    end
    while PW==1 do
     | stop = notetime;
    end
    distance=(start-stop)*17000; /*distance in cm*/
    if distance < 60 then
     | Glow Green led
    else if distance < 45 then
     | Glow White led
    else if distance < 30 then
     | Glow Red led;
    end
    [x, y, z] = get input from adxl345;
    if x < −0.2 and x > −1 and y < 0.2 and y > −0.2;
    then
     | Go forward
    else if x > −0.2 and x < 0.2 and y > 0.2 and y < 1;
    then
     | Turn left
    else if x > −0.2 and x < 0.2 and y < −0.2 and
    y > −1;
    then
     | Turn right
    else
     | Halt
    end
end
```

Fig.7.Pseudo code for ADXL345 and Ultrasonic sensor control

```
initialization;
/* b0,b1,b2,b3 are bits from dtmf decoder ic */ ;
while True do
    read current;
    if b̄o and b1 and b̄2and b̄3 then
     | Go Forward;
    else if b̄o and b̄1 and b2 and b̄3 then
     | GO Left;
    else if b̄o and b1 and b2 and b̄3 then
     | GO Right;
    else if b̄o and b̄1 and b̄2 and b3 then
     | GO Reverse;
    else
     | Halt
    end
end
```

Fig.8.Pseudo code for DTMF control

```
initialization;
while True do
    read current;
    if music button is pressed then
     | play music using shell command;
    else if skype is pressed then
     | call skype app;
    else if voice activation button is pressed then
     | record voice for 10 seconds,convert speech to
     | text, Search for keywords
     | "Forward","Left","Right","Reverse","Halt" do
     | corresponding operation
    else if Touchpad is activated then
     | get current position x1, y1 final position x2, y2;
     | if x1 − x2 < 0 and |x2 − x1| > |y2 − y1| then
     |  | go right
     | else if x1 − x2 > 0 and |x2 − x1| > |y2 − y1|
     | then
     |  | go left
     | else if y1 − y2 > 0 and |x2 − x1| < |y2 − y1|
     | then
     |  | go reverse
     | else if y1 − y2 < 0 and |x2 − x1| < |y2 − y1|
     | then
     |  | go forward
     | else
     |  | halt
     | end
    else if direction key is pressed then
     | activate button control:
     | Up key for Forward
     | Down key for Reverse
     | Left key for Left
     | Right key for Right
     | Stop key for Halt
    else
     | use joystick control
    end
end
```

Fig.9.Pseudo code for Joystick, Touchpad control and other functions

CONCLUSION

The Smart chair is a boon to the physically challenged as it makes them less dependent on other people. Different features of the Raspberry Pi enables the user to connect to the internet on the Wheelchair, this enables the patient to have a better social life as well as a professional one. The control methods implemented on the prototype can be easily mounted on a real wheelchair.

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