

NOVEL WHEEL CHAIR FOR PHYSICALLY CHALLENGED USING IOT

G. S. Uthayakumar

Research Scholar, Department of Electronics and Communication Engineering, St. Joseph's Institute of Technology,
Chennai, India

ABSTRACT

Great people like Stephen Hawking and Max Brito have been suffering from this crippling phenomenon. Our project is an attempt to make lives of the physically challenged people by our extravagant project. We mean self-reliant, which will thereby reinstate their confidence and their happiness. The idea is to create an Eye Monitored System which allows movement of the patient's wheelchair depending on the eye movements. We know that a person suffering from quadriplegia can partially move his eyes and tilt his head, thus presenting an opportunity for detecting those movements. We have created a device where a patient sitting on the Wheel Chair assembly looking directly at the camera, is able to move in a direction just by looking in that direction. The camera signals are monitored by a MATLAB script, which will then guide the motors wired to the AtMega1284P Microcontroller over the Serial Interface to move in a particular direction. The system is cost effective and thus can be used by patients spread over a large economy range. We have implement a Smart mobile application to paramount our project and thereby we justify our project name "The Smart Mobility For Physically Challenged"

KEYWORDS: IoT, Hardware, Software and Artificial Intelligence

Article History

Received: 31 May 2021 | **Revised:** 02 Jun 2021 | **Accepted:** 08 Jun 2021

INTRODUCTION

The number of persons who are paralyzed and therefore dependent on others due to loss of self mobility is growing with the population. The development of the wheelchair for paralyzed users is surprisingly recent starting with the conventional manually powered wheelchairs and advancing to electrical wheelchairs. Conventional wheelchair use tends to focus exclusively on manual use which use which assumes users still able to use their hands which excludes those unable to do so. Diseases or accidents injuring the nervous system also frequently because people lose their ability to move their voluntary muscle. Because voluntary muscle is the main actuator enabling people to move their body, paralysis may cause a person not move their loco motor organ such as arm, leg and others. Paralysis may be local, global, or follow specific patterns. Most paralysis are constant, however there are other forms such as periodic paralysis (caused by genetic diseases), caused by various other factors. Scientist Stephen W. Hawking is perhaps the most well-known victim of major paralysis – Stephen Hawking was diagnosed with incurable Amyotrophic Lateral Sclerosis (ALS) in 1962, thereafter using a wheelchair to move. Many of those suffering close to or complete paralysis usually however still can control their eye movement which inspired us to develop an eye-controlled electric wheelchair. The idea of an eye-monitored wheelchair was inspired by a past project of one of the group members, V.ANISH BABU and KARTHIK.M where we had created a

glove based wheel chair. In that paper, the finger movements of the handicapped person were used to guide the wheel chair in the desired direction. We wanted to take the idea forward by making the system completely isolated from the person physically, and extend the usability of the system to a person suffering from quadriplegia

Figure 1 shows Also in order to justify our Project name “Smart Mobility For Physically Challenged” we have implemented a Smart Mobile Application which can be use by any person who feels difficult to move from one place to another. This Smart mobile application replaces the most trivial joysticks thereby reducing the delays enabling the comfort to the user.

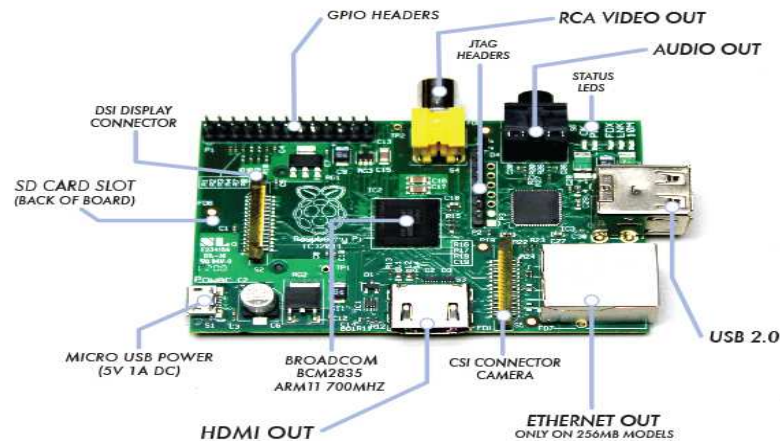


Figure 1: Raspberry Pi.

Problem Statement

Thus, we can summarize our project as follows: the main of this project is to design a vision based wheelchair system. Using the camera to acquire user images and analyzing user intent using head gestures. To implement the Smart Mobile application to make the project more beneficial to the user and to justify the title.

Range of Solutions

We wanted to come up with the system that is not expensive and thus can be afforded by all. The main task in the design was to accurately detect the eye movements. Since, the system is for human use we have to take an extra care about the safety of the system. For the eye detection, we came up with multiple strategies. One was to detect the eye moments using the infrared light. The idea behind this method was to concentrate the infrared light onto the eyes from the forehead. The voltage rating of the infrared light is under the permissible levels that can be used to concentrate in the eyes. The infrared light concentrated through the forehead of the user will be collimated through the pupil of the eye and we can use this collimated light to obtain a voltage drop across the photodiode which will drive the motors. We built the photo detector circuit and tested this method on one of the group members. During the testing of the circuitry, we found that we were not able to obtain accurate results and the voltage drop across the photo diode was not constant and kept on varying. Thus, the issue with this idea was that the voltage drop obtained across the diode was just 0.7 Volts and it was not sufficient to detect accurately. Thus, we had to come up with an alternative in order to obtain an accurate method to detect the eye as that is the most crucial part of the system and needs to be done with great precision. The second alternative that we came up with was to connect the web camera to the Raspberry Pi directly which would then process the snapshots, eliminating the need to have the camera attached to the laptop. But, we found out that the time taken to understand the new controller board is a lot. Also, normally these days such users have a laptop somehow attached to their wheel chair and thus we decided to

rather go ahead with a microcontroller board that we already understand. The alternative design which we finalized, captures the images using a webcam that will be attached to the laptop placed on the wheelchair of the user. These captured images will be used to detect the eyes and hence detect the movements using a MATLAB script running on the laptop, which then sends serial commands to the microcontroller circuitry driving the motors attached to the wheel chair. For the above mentioned reasons, we finalized to work with this idea.

PRODUCT DESIGN OVERVIEW

We decided to use the web camera to detect the eye movements which will be further processed to drive the motors. For the simplicity and to make a prototype, we are going to design a small, motorized, wooden platform and we will attach the web camera on the helmet. We will use serial communication to communicate between the web camera and the microcontroller. The microcontroller will be placed on the wheel chair which will be connected to the motors, driving the wheel chair in the direction the person sitting on the chair desires to move in.

Product Design

There are two major components from the system design standpoint

- Eye-Detection and Motion Tracking.
- ATmega328P Controlled Wheel Chair Assembly.
- Eye-Detection and Motion Tracking

A webcam is mounted on a cap, continuously staring at the user's eyes. The webcam wired to the patient's laptop is running a MATLAB application designed to monitor and react to eye movements. Based on a series of snapshots taken and thereafter processed, the motion of the user's eyes are detected, decision to move the Wheel Chair in a particular direction is taken and communicated serially to ATmega1284P microcontroller. MATLAB 2013 has an image processing toolbox which we utilized for the eye detection. We used the 'Cascade Object Detector' capable of detecting eye-shaped objects based on their shape and size. It uses the Viola Jones Algorithm for the same. A description of the Algorithm is given in the software section of the report. Continuous snapshots of every 25th frame are taken and feature points extracted are saved i.e. we capture approximately 1 snapshot every second and process it. Based on the position of the feature points in previous snapshot and current snapshot, a movement is detected and this is communicated to the wheelchair assembly via the serial port.

- **ATmega328P controlled Wheel Chair Assembly**

A decision based on the processing done by the MATLAB application is communicated and received by the ATmega1284P. The controller on reception forces the port pin high on which the motors have been connected for desired motion of the Wheel Chair. So, now we will have a look at the overall code structure of our algorithm and the logic behind the decision making. There are two parts in the code structure. The first part is to detect the eye movements and the other part is to drive the motors. The code structure can be explained in the following steps:

Initialization

Initially we set up the serial communication that will be used later for the interface between MATLAB and the controller, the video capture and the program variables.

Image and Video Processing

We then take continuous video frames and sample the input and save it as the screen shots. Each frame is then converted into the black and white frames. For the accurate results, we perform contrast stretching on each frame to make the dark region darker and bright region brighter. This will enable the detection of the eyes better.

Estimation

Now, after working on the each frame we try to detect the eyes. This we do by estimating the position of left as well as the right eye. Thus, we set the threshold and detect the position of the eyes which can be used for the further processing.

Detection

Now, in this step we actually detect the eye movements. The idea is to compare the current position of the eye with the previous position. Thus, the difference in the coordinates will help us to predict the motion in the particular eye. But sometimes, it may be possible that only one of the either eye will be detected. In that case, we will give preference to the eye that is detected currently.

Error Handling

To avoid detection errors, we incorporated an error handling mechanism, which specifies a threshold for the height and width of a valid eye, by calibrating it for the user. If the detection results give a height and width value lesser or greater than the threshold, the value is avoided and not considered for the decision making.

Smart Mobile Application

For people who are facing other difficulties in moving can make use of Smart mobile application which has specialized keys to enable the movement. Pressing the keys the Bluetooth device are paired a connected to the motor's movement

Motion

Now after detecting the eye movements, we have to come up with a decision algorithm that will help the controller to drive the motors accordingly:

- **Valid Left:** The decision to turn left will be considered as valid if the eye turns left and stays there for a cycle. This action will be detected as a left turn request. After that, the patient will turn right to again look forward. Thus, this signal should be considered as void.
- **Valid Right:** Similarly, the decision to turn right will be considered as valid if the eye turns right and stays there for a cycle. This action will be detected as a right turn request. After that, the patient will turn left to again look forward. Thus, this signal should be considered as void.
- **Valid Straight:** The signal to go straight is when a person looks left and right or right and then left. This will be detected as to go straight.

Safety Considerations

Given the application of the system, we incorporated a safety mechanism, wherein based on the blink detection the wheel chair halts. If the user wants to halt the wheel chair in case of an emergency, he can blink thrice, causing the wheel chair to halt.

Serial Communication

Now according to the detected command, the MATLAB application will transmit 0, 1 or 2 for left, right and straight respectively to the controller which will drive the motors

RESEARCH METHODOLOGY

Software Design

There are multiple aspects to the software design of this project. Since majority of computational work is done in software, a lot of our time went in software design and testing. The MATLAB component is responsible for capture of regular snapshots, processing of those snapshots, determining the movement of eyes, algorithm for movement of wheelchair and serial transmission of the decision to move. The firmware component deals with receiving the serial signal, based on which drive the motor connected to the port pins, forcing the wheelchair in the direction it is supposed to move in.

MATLAB Component

The MATLAB design can be structured into many small sub-parts each of which is described below -

Initialization of Variables and Setting Up Serial Communication

MATLAB 2013 can easily be configured to serially transmitting data on the Port mentioned in the code. Initially all the already set up serial ports are disabled. After which, we need to mention the current port, by checking the 'Device Manager' which indicates the port in use. The baud rate of communication is set to 9600. The communication is set to have no flow control and parity check is disabled. After setting up the serial communication to enable the data link between MATLAB and AtMega1284P, we reset the variables needed in the course of the program to their initial values.

Image Capture and Eye Detection

MATLAB 2013 equips an Image Processing Toolbox, which we have used majorly in this section of the Software Design. We use a Microsoft Life Cam HD-5000 web camera which is connected via a USB cable to the Computer on which the MATLAB script is running. We can stream continuous video signals on MATLAB coming from the camera using the video processing toolbox available. The function 'imqhwinfo' is used to recognize all video capture adaptors. Identifying the correct device and then using it to stream the video signal is the next step. The requirement of our design was to continuously look at different frames, based on which determine motion. It is practically impossible to do a lot of processing on a per frame basis. That is why we try to sample every 25th frame. So, a snapshot of every 25th frame is captured and processed. We used the 'get snapshot' command to capture these snapshots. The image is then converted to grayscale image, as we do not need color information to detect eye feature points. The conversion intact makes the detection easier. The 'imadjust' command is used then to contrast stretch the image to make darker sections even darker, enhancing the eye feature points useful for the application. This pre-processing of the image makes the image easier to process and extract the eyes from. After the initial pre-processing, we move towards the eye detection. The Eye Detection is done using the Viola-Jones Object Detection Algorithm. Primarily this algorithm was designated for face detection though it is used for all sorts of object detections. The algorithm is designed to work on sum of pixels in a rectangular area. Viola-Jones algorithm says that face can be detected by looking for rectangle. And then the large rectangle is made up of many such smaller rectangles, which are fundamentally feature points on a human face. The 'cascade object detector' [6] on MATLAB, utilized this algorithm to extract and detect the eyes of the person. We then show the detected eye by plotting the rectangle at the appropriate position of the eye.

Image Processing

Initially, all we do is monitor if any eye feature points have been detected or not. If not set a flag and display it on the debug screen. To increase the detection accuracy, we wanted to neglect all other points on the screen except the actual eye of the person. The reason being, if anyone except quadriplegic person comes in front of the camera, the person should not affect the system. Also certain things seemingly looking like eyes should be rejected as well. The way we incorporated this is taking into account the height and length of the eye. After repeated testing, we decide a length and height of a valid eye, sets a range around the threshold and reject everything which is outside it. The blink detection section is not compute intensive. We use a flag which is set each time no valid eyes are detected. If in corresponding frames the flag value sets, it indicates a blink. A series of 3 such blinks command the motors to freeze, halting the wheel chair. What is assumed is that the position of the camera is fixed, relative to which the left and the right eye approximate positions can be estimated. Using this, we try to distinguish and store left and right eyes in different matrices. This helps getting a clear discrimination between both the eyes, helping in easy movement detection.

Movement Detection

The movement detection is done with a very basic principle. We take in the feature points for both left and right eyes and save it. Thereafter take the difference in pixels of the left eye position and right eye position in the current snapshot from the previous snapshot. We define the threshold for the minimum movement of the eye required to be qualified as a valid attempt. In each snapshot the difference is evaluated, and if this difference above the threshold in any direction left or right, the flags indicating left movement or right movement are set. If the difference is not above the threshold, the flag which says that no Sometimes due to non-linear-ties, both the eyes are not detected. At such instances while evaluating the difference for detecting movement, we would give a bias to the eye which was detected in the previous snapshot. After detecting the eye movements, we can proceed to determining and sending serial signals to the micro-controller.

Motor Signals

The way we qualify a valid right, left and straight attempts to move, we need to incorporate many factors. The way a valid right is recognized is by tilting face on the right side and stay there for a second, after which the wheel chair starts moving. But the person's face is still tilted on the right. If the person now tries to go back to the initial position by tilting left, the system will detect it and lead to an otherwise invalid left movement of the chair. This has to be avoided. We set flags for left and right movements each time the wheel chair moves, avoiding precisely this unwarranted behavior of the system. The way a valid straight movement is detected is titling in corresponding frames in left and right directions. Over here as well, the effect of the offset coming into picture are avoided in the same fashion with the help of flags. As already mentioned, three corresponding blinks should halt the motors. Along with the motion command, a halt command is also transmitted to the microcontroller assembly which thereby halts the motors as per the user's desire. After determining which direction the wheel chair has to be moved in, the decision is transmitted to the micro-controller via the serial port. The only thing sent is a one digit decision, saying right, left or straight movement.

Firmware Design

The firmware design is fairly straight forward as all the computation has been done on MATLAB and the only thing which the micro-controller has to do is control the motors to move in a particular direction. The firmware constantly monitoring the serial input. The firmware turns ON the port pin based on this received signal. After turning ON the port pin, a small

delay is given, giving the chair time to move for a fixed time in the desired direction.

As far as the firmware design is concerned, it is fairly simple. All that is required is take in the serial input, move in a direction, give a delay and keep doing this repeatedly.

Hardware Design

The hardware part consists only to control the motor. The motor controller circuit is given below. The signals that we obtain from the MATLAB script, we then use that to drive the motors. The MATLAB program does all the decision making for the motor to run in which direction. So, the script sends the bit 0,1 and 2 for left, right and straight direction. The circuit shown below is fairly safe and used to drive the motors. An opto isolator completely isolates the microcontroller from the motor. The diode placed across the motor shorts out spikes when the motor is turned off. The resistor grounding the base of the phototransistor is set for best fall time, probably around 1Mohm. The motor capacitor should start around 0.1uf. The pin out of the 4N35 opto isolator and BUZ73 are also shown. Note that the bandwidth of the 4N35 is very small, so we use a low PWM frequency, perhaps about 1000 Hz.

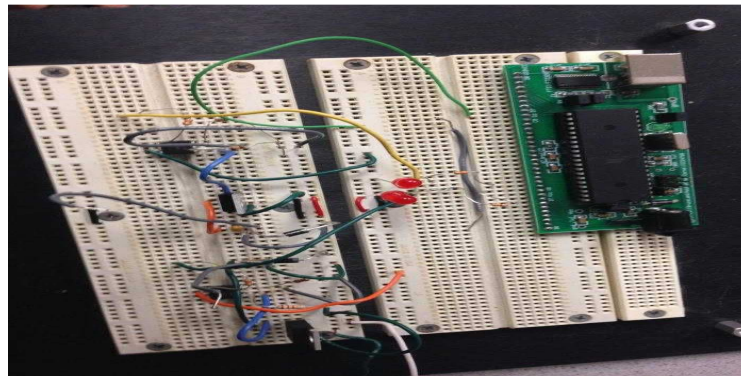


Figure 2

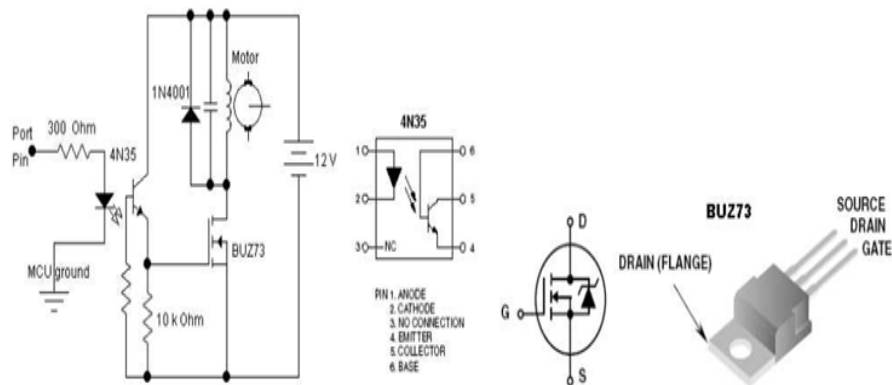


Figure 3: Circuit Diagram.

Mechanical Design

For the mechanical part, we worked on two things: the wheel chair prototype and the web camera mount. For the wheel chair mount, we have tried to build the small prototype from wood with four wheels that are connected to the motors. The photo shown below shows the wheel chair prototype.

Now, in order to detect the eye movements, we need to have a web camera in front of the user. For simplicity, we are attaching the web camera onto the head mount like helmet that will be used to detect the eye motion. Since, we are not making the actual wheel chair, thus, we have to use an independent head mount. Otherwise, we can use the web cam directly attach to the chair. The photo of the head mount is given below.

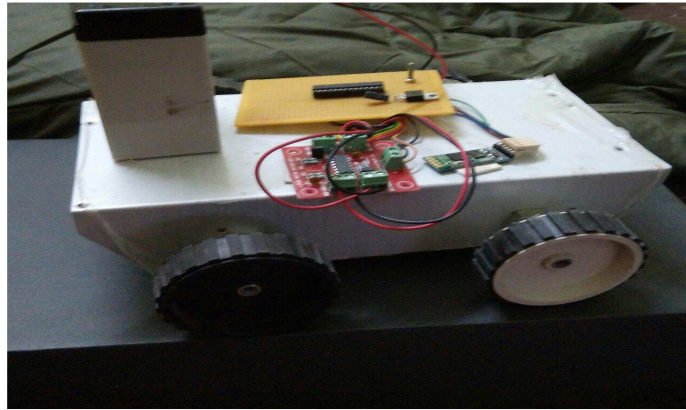


Figure 4: Kit Diagram.



Figure 5: Camera Mounted on a Helmet.

RESULTS AND DISCUSSIONS

Testing Strategy

The debug screen was the most useful aspect of our testing strategy. The debug screen showed whenever nothing was detected as a valid eye by the cascade object detector. When a valid eye is seen, the length, height, x and y pixel coordinates are displayed on the debug screen. This is done for every snapshot. After taking the difference between two snapshots, a tilt movement is indicated by either saying ‘moved right’ or ‘move d left’.

After determining if the motor has to be moved or not and before transmitting the serial signal, on the debug screen, we indicate the intended motion of the motor. This allows us to debug if any error. If the movement suggested on the debug screen and then movement of the wheel chair are in conjunction. This allowed us to test consistently with ease.

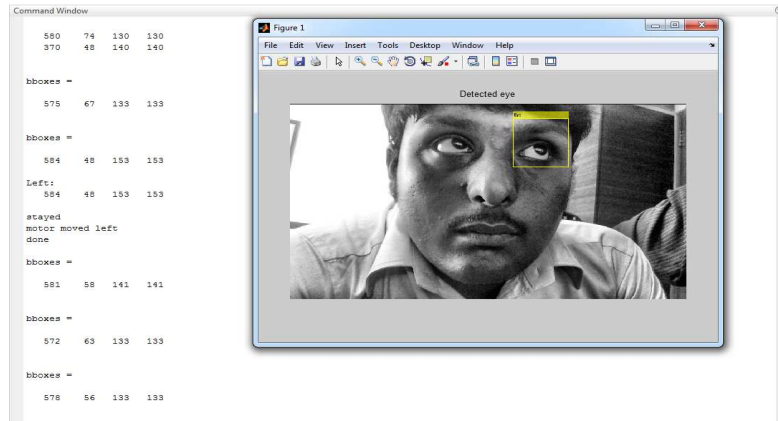


Figure 6: MATLAB Analysis.

Speed of Execution

We were never actually limited by the speed of execution. We could go up to 15 frames a second, evaluating and determining the face tilt. But there were couple of issues because of which we limited the speed of execution. One being, we do not want the person to get a jerk whenever he wants to move. Hence we compute and drive the motor at a slow pace, as compared to the ability we can escalate the speed to. Also, we want to keep the system secure by taking a while to evaluate the movement and thereafter making a decision, given the criticality of the application.

Accuracy

The project performs satisfactory with performance accuracy of around 84-90%. The results after testing it for 100 to 200 attempts to move in a random direction were made by both the project members. The results were tabulated as shown.

The system was calibrated for Karthik’s eyes, because of which the accuracy is higher for him as compared to Anish Babu. Better lighting can improve the accuracy by providing brighter snapshots to process. The initial pre-processing contrast stretches the image around the mean, which helps in improving the accuracy by making the detection more accurate. Successful attempts were counted as all those attempts which resulted in movement of the wheel chair in the desired direction. For the system to be accurate, each time a system is configured for a person, alter the height and length of the specified eye so that the system recognizes the eye of the person with high precision

Table 1

Name	Number of Attempts	Successful Attempts	Accuracy
V.Anish Babu	25	22	88%
M.karthik	25	23	92%
Thalapathy.S	10	8	80%

CONCLUSIONS

Performance

The system functions with an accuracy rate of 84-90 % which was above our expectations. The image capture, eye movement detection and the algorithm for validating movement attempts perform very reliably as our results suggest. The usage of smart mobile application even more adds the value to it. And our work justifies the Project name “Smart Mobility FOR Physically Challenged”. The aim of this project is to contribute to the society in our small way by setting out an idea for a system which could actually better the lives of millions of people across the globe. We believe we have done great justice to the idea, and ended up getting more than satisfying results. We have given a valuable justification to our project.

Future Modifications

Though our prototype performs satisfactorily, but a lot of work needs to be done before making the product commercially viable. Some sort of sequence of events should trigger start of detection, because we do not want the wheel chair to move when the person is just casually glaring in different directions. A lot of testing needs to be done before making such a product a reality.

Appendix A - User Manual

- **Step 1:** Install the webcam that is mounted on the helmets ETUP.
- **Step 2:** Connect the hardware circuit (motors connected to the controller) to the 6 volt supply and also power the micro controller.
- **Step 3:** Wear the helmet on the head that will have the camera attached to it.
- **Step 4:** Program the microcontroller with the code given and also run the MATLAB script. This will initiate the serial communication between the MATLAB script and the microcontroller.
- **Step 5:** Make the eye movements that will be tracked which thereby will control the motors to move in the expected direction.
- **Step 6:** Follow the **safety rules** and get benefitted.

REFERENCES

1. S. Tameemsultana and N. Kali Saranya, "Implementation of Head and Finger Movement Based Automatic Wheel Chair", *Bonfring International Journal of Power Systems and Integrated Circuits*, vol. 1, Special Issue, pp 48-51, December 2011.
2. Manuel Mazo, Francisco J. Rodriguez, Jose L. Lazaro, Jesus Urena, Juan C. Garcia, Enrique Santiso, Pedro Revenga and J. Jesus Garcia, "Wheelchair for Physically Disabled People with Voice, Ultrasonic and Infrared Sensor Control ", *Autonomous Robots*, vol.2, no. 3, pp. 203-224, Sep 1995.
3. Tabasum Shaikh, Naseem Farheen Sayyed, Shaheen Pathan, "Review of Multilevel Controlled Wheelchair", *4th National Conference On Electronic Technologies*, pp. 275-279, April 2013.
4. Motor Controller circuitry from ECE 4760 web page for lab 4 - <http://people.ece.cornell.edu/land/courses/ece4760/labs/f2013/lab4.html>
5. Viola Jones Algorithm -http://en.wikipedia.org/wiki/Viola%E2%80%93Jones_object_detection_framework
6. Cascade Object Detector <http://www.mathworks.com/help/vision/ref/vision.cascadeobjectdetector-class.html>