

Advanced Artificial Intelligence Self Balanced Robot for Home Security



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Declaration

We, hereby declare that this thesis is based on results we have found ourselves. Materials of work from researchers conducted by others are mentioned in References. This is to affirm that this thesis report is submitted by the authors listed for the degree of Bachelor of Science in Electrical and Electronic Engineering to the Department of Electrical and Electronic Engineering under the School of Engineering and Computer Science, BRAC University. We hereby declare that the research work is based on the results found by us and no other. Materials of work found by other researchers have been properly acknowledged. This thesis, neither in whole or in part, has been previously submitted elsewhere for assessment.

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Abstract

Artificial Intelligence brings intelligent behavior in the field of Robotics. It enables robot to provide services for human in this modernized and changing world and assuredly it can work faster and better at every sector than human beings. In this modern era, by the help of technology, large numbers of AI robots are being created but most of the robot is very costly and not suitable enough for Home appliance over the world. The main reason behind this research is to make an artificial robot in very low cost with attractive and essential features. This work proposes an AI robot which is designed with low cost materials and also commonly available in our country. Though some problems were detected but the main goal of the project was achieved to build a robot using low cost material and that could be used for home appliance purpose. Advanced artificial intelligence process and computation, operated by an Android operating system, is the main feature of this research. This robot has 5 megapixel front-camera for face detection and person tracking by image processing. This Robot can navigate autonomously to follow human face and move inside the home according to the direction. It can travel to different places and can run comfortably by balancing on two wheels. The robot's coding platform is python, which will provide the excellent private transport device. The robot can talk with its built-in microphone and permits to send voice message. The onboard Raspberry pi can transmit real time video of the home through online to the owner from any place within internet connection of home Wi-Fi. The robot has two different modes which can switch by online command according to user need. It can be used for security of any important place and also as a representative of any person. As like, we can monitor our home or office from outside. The robot has such capability that with small changes, we can use it in many multi-dimensional purposes.

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Chapter: 1: Introduction

1.1. Introduction:

Artificial Intelligence (AI) has been studied for decades and is still one of the most exciting fields in robotics. AI refers to the ability of a computer or a computer enabled robotic system to process information. It's certainly the most controversial topic of recent time. In an assembly line a robot can effectively work but there is always a question lies that whether a robot can be intelligent enough or not like human being. AI is one of the recreations of human thought process which is all about a man-made machine with the enlightened, intelligent abilities what humans have. Accordingly, AI embeds the ability to learn, work and decide in machines, software, and systems so that they can respond smartly in various situations. From home appliance to self-driving cars, day by day artificial intelligence (AI) is progressing rapidly. While science fiction often portrays AI as robots with human-like characteristics, AI can encompass anything from Google's search algorithms to IBM's Watson to autonomous weapons. It has the capability to learn about anything like how to use different types of language, reasons even how to formulate original ideas and so on. In this modern era, Robotics is very near to achieving this level of Artificial Intelligence but they are making it more upgraded and easier by the help of limited AI. The basic idea of AI problem-solving is very simple, though its execution is tricky enough. Firstly, through different types of sensors or human output AI robot or computer gathers information about a situation. Then stored the data by compares this information signifies by the process. Later, depends on the collected information it predicts which function will be most successful one after runs various steps by computer [2]. The real challenge of AI is to understand how naturalintelligence works. Scientists give much importance on why we learn, how we think and according to that they experiment with their ideas using robots.AI research is useful for understanding how natural intelligence works. In early age, use of AI was limited to the computers. Later on, robotics came into the picture. In our day, it becomes an integral part of human life by expanding its technical proficiency for robotic platforms. For some robotics, this perception is the main goal of constructing an artificial intelligent robot. Artificially intelligent robots are the bridge between robotics and AI [1]. Day after day AI robots are getting more technologically advanced and autonomous even they can do much more faster and better jobs

than human beings. AI enables machine to think, act and work like human brains and by analyzing the human behavior it also make various decision. In the coming decades, the significant impact of AI robot will spread out also in the industrial, scientific world as well as into our daily life as like the same way, during 1900s when the computers spread rapidly into the world. Furthermore, people in the coming future could load their minds into a sturdy robot and live for thousands of years. In addition, the formations of advanced robot are creating significant impact at every sphere and we can make it more modified by artificial intelligence. This paper proposes an Artificial Intelligence robot which is self-balanced on two wheels and it can navigate autonomously to follow human face and move inside the home according to the direction. Besides we can monitor our home or office from far away and in future it will also be able to talk with its built-in microphone and permits to send voice message.

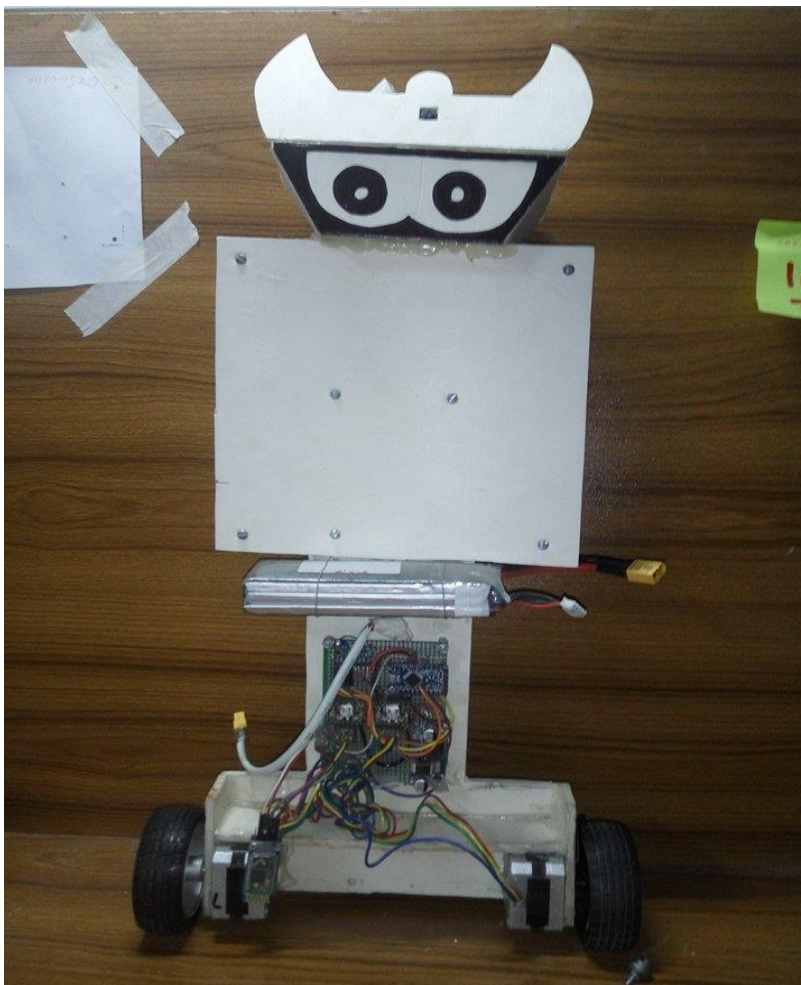


Figure 1.1: Our Artificial Intelligence Robot

1.2. Motivation

Home automation has become a broad success by the using of internet device (IOT) nowadays. For this spreading of technology we can accelerate it more by combined robotics with this flow. Our robot will bring the IOT facility more near to the people and make our life more comfortable. Accordingly, AI embeds the ability to learn, work and decide in machines, software, and systems so that they can respond smartly in various situations. In early age, use of AI was limited to the computers. Later on, robotics came into the picture. AI robots becoming more technologically advanced as their precision, perfection and endless energy makes them better companion than human being for a wide variety of jobs. If we look on some works by Ai, we can find out how Artificial Intelligence robot making our lives more secure. For example, one of the life savior robots is military robots which are the most high-tech and upgraded robot used for performing extremely dangerous tasks without endangering humans. Advanced Robots are also used in automobile industry to assist in building cars. It can make car manufacturing safer because they can take on dangerous and difficult jobs in place of humans. Automotive industry robots are also capable of performing a wide range of tasks such as installation, painting and welding. One of the most amazing areas of robotics is the use of robots in space. This state of the art machines gives astronauts the chance to explore space in the most effective way. Underwater robots have radically changed the way we see the world from the ocean floor. For instance, one of the most common underwater robot is ROV (Remotely operated underwater vehicle), which is totally controlled by human and till then the greatest robot for gathering data and image of life under water. These are robots which are controlled by AI programs and also motivating us more and more towards the greatest invention of Artificial Intelligence. While this technology is still fairly rudimentary at the moment, we can expect sophisticated AI to one day significantly impact our everyday lives. There are a lot of things that machines can do better than human being. Artificial intelligence research has been going through a recent revolution. Because of the arrival of updated robots, work has been shared between man and machine in this modern era. In coming future, by dint of AI robot will also be able to transfer or upload their digital minds from one robot to another. The key applications of Artificial Intelligence are in any area that involves more data than humans can handle on our own. In our day, it becomes an integral part of human life by expanding its technical proficiency which makes our project goal stronger.

1.3. Related Work:

Artificial intelligence machine means to, designed and programmed in such a way that can act, connect and work like human. Nowadays, AI has become an important topic by which our life is getting changed and more upgraded in a wide range. The influence of AI is getting more widespread in the coming decade. There are many examples by which we can feel that AI is making our life more comfortable and easier. One of the best recent inventions of Artificial intelligence is XiaomiNineBot Segway Robot. Recently Xiaomi has introduced the coolest Ninebot Segway Robot which is two wheeled self-balanced and has an adorable robot face.



Figure 1.2: Ninebot Segway Robot

It has some interesting features like it is able to detect person and also can follow and monitor as the mobility point is way much interesting of this self-balanced robot. It has hardware extension at the back so that different parts like robotic arm can easily be attached. Via Ultrasonic sensor it can be able to detect object as well as it has distance measuring ability. Moreover, it is a one touch transformer robot as it can also work as scooter mode. It can move 18 kilometer per hour and it has also speed limit this is also secure enough.

1.4. Literature Review

Artificial intelligence is a branch of computer science and discipline in the study of machine intelligence which is developing intelligent machine or system. Technologists believe that, this is not so far when machine intelligence will overtake human. Our main goal is to make an advanced artificial robot for home security which can track real time faces, pictures through its front camera [8]. It will permit people to send voice instruction and live streaming to owner. Moreover we have looked on balancing robot structure and the method of it. We try our own way to implement the balancing system depend our own study. We have provided necessary tools to the Robot so that the robot can move and balance at any different surface area. The main feature of this project is, this is a two wheeled self-balanced robot. We used stepper motor to make the robot balanced [2]. The reason of using stepper motor is, this motor is precise enough and when the battery voltage drops, performance loss is less in stepper motor that is why we are using stepper motor instead of DC motor for the self-balanced [4]. In addition, we have created face detection by several algorithms such as Viola-Jones algorithm [13]. For image processing, we used several steps for fast and exact detection. First one is image integral for feature processing. Second is AdaBoost to select critical visual features from a larger set and lastly Haar-cascade for efficient computational resource allocation [11]. Mainly, our research shows how the robot acts in different surface as well as diverse face patterns. The data of different acts in different conditions will provide the scientific analogy of the intelligence.

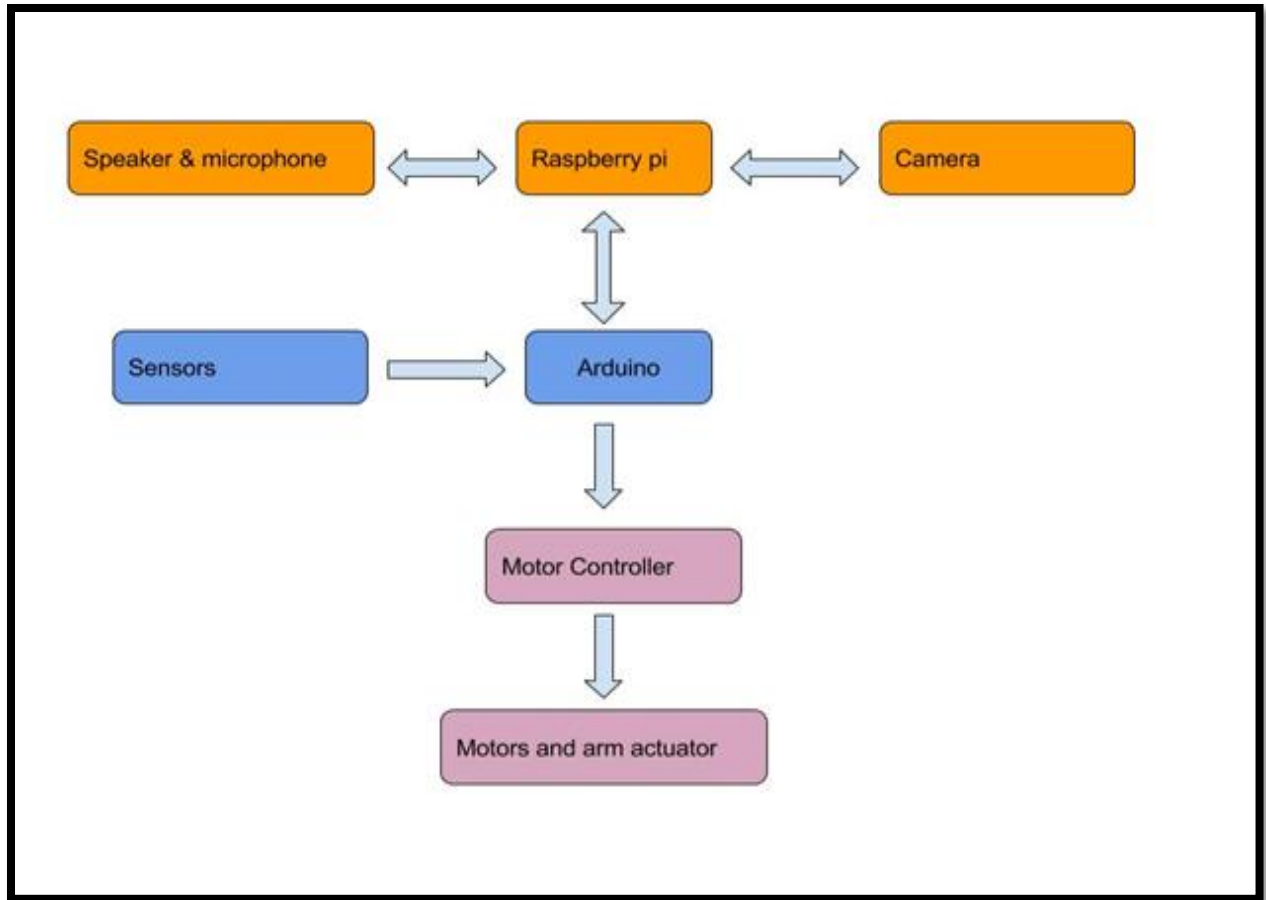


Figure 1.3: Block Diagram of Proposed System

Chapter 2: System Design

2.1. Architecture Review

To build the Robot, we are using several Equipment including both the hardware and software. The hardware includes Arduino pro mini as a controller, MPU6050 gyro sensor, HC 05 Bluetooth for transparent wireless connection setup, Raspberry Pi, high resolution camera, stepper motor, lipo battery and GPU system to create the multipurpose features of the robot. For software part, we are using Arduino C program, python for raspberry pi and image processing in autonomous mode after that PHP for web controlling when it is in manual mode.

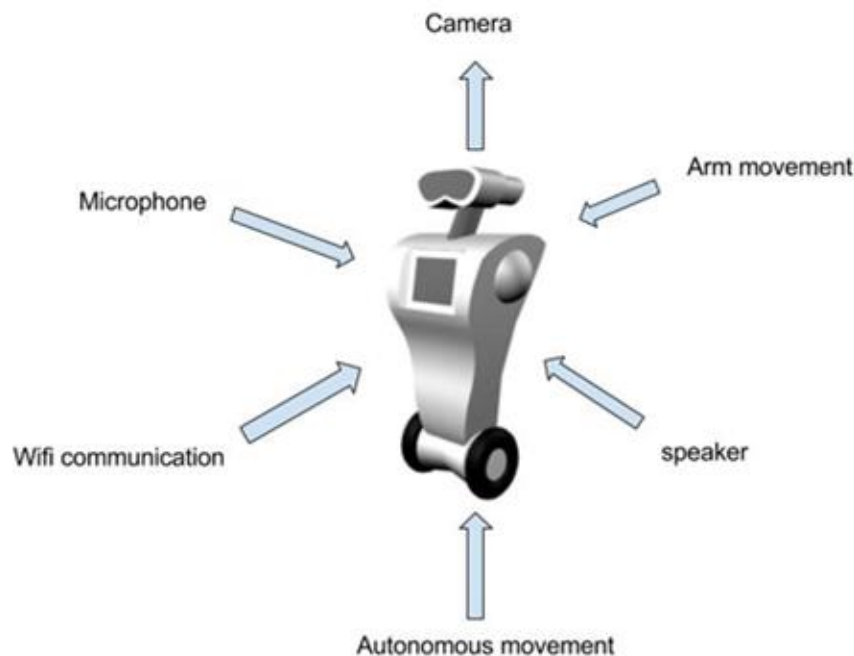


Figure 1.4: Block Diagram of Proposed Design

For Image Processing and movement, we have used 'Viola-Jones face detection algorithm' from Open CV to take data with Python code and Bounding Box technology to enable the robot to make decision regarding movement.

2.2. Mechanical Design:

Frame:

Chassis frame consist of eternal object and exclusive outlook which contains useful part of robot. Our chassis mainly have motor wheel and circuit component assembled in architectural way. We made the prototype model of wheel by PVC board to make the robot's main frame rigid; all equipment need to carry in a balanced way besides materials need to be in light weight. The main height of our frame is 29 inch and width is 15.5inch. The frame contains two motors, two wheels at the lower side, above that main controlling balancing circuit with Arduino motor driver and gyro sensor along with one lipo battery. Middle part of the frame is 8.5 inch. The head part is consists of Raspberry pi and camera. We have made few channels to distribute the wire inside the robot in a secure way so that the EMF cannot interrupt in the motor speed. Figure of the frame is given below:

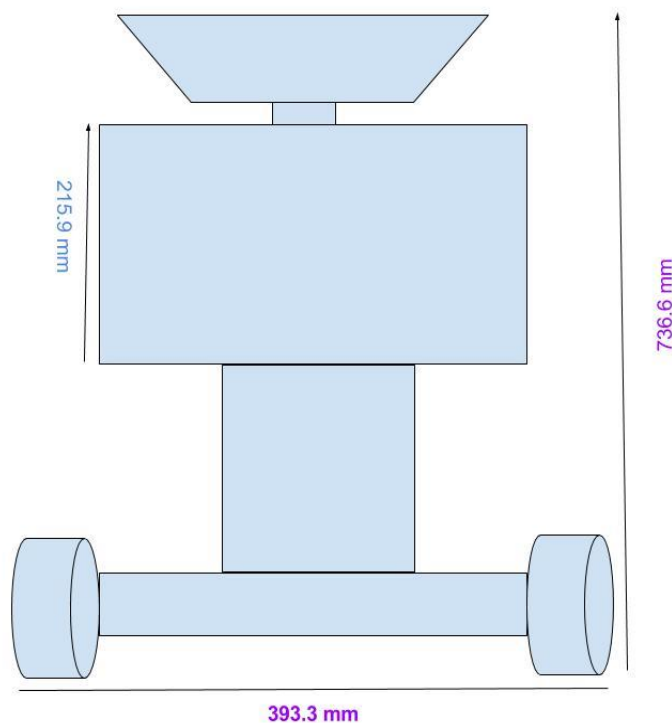


Figure 2.1: Chassis frame

Wheel:

As it is a self-balanced robot, we are using two specific sizes of wheels which have good friction and it can balance easily. The radius of the wheel needs to be accurate for balancing and moving the robot simultaneously. The distance between two wheels center to center is 393.7 mm. The radius of wheel is 33 mm and diameter is 66mm.

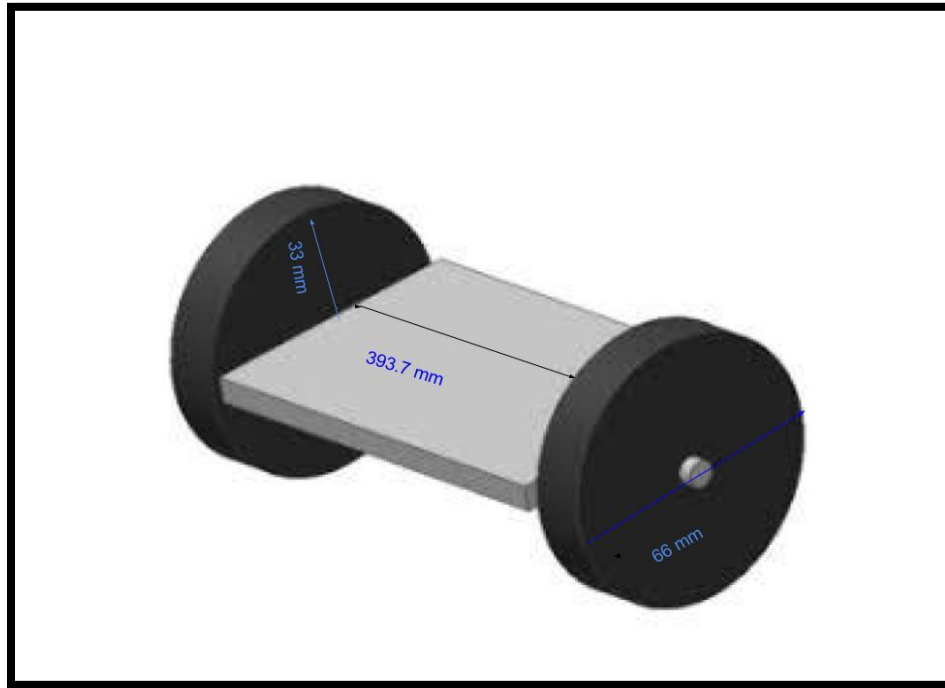


Figure 2.2: Wheel

Motor:

In contrast to most self-balancing robots, we are using stepper motors instead of regular DC motors. The main reason is that stepper motors are much more precise and have less performance loss during voltage drops. One pulse is always an exact amount of motion. As regular DC motor has different mechanical and electric resistance. Regular DC motors can have mechanical friction and electric resistance differences. Because of the performance difference the robot will not move in a straight line.



Figure 2.3: Nema 17 stepper motor

BASIS	STEPPER MOTOR	DC MOTOR
Nature of loop	Stepper motors are operates in Open loop.	DC Motors are operates in Closed loop.
Controlling	Easily controlled with microprocessors and microcontroller	DC motor control is not easy and it needs more electronic component
Brushes	Stepper motor are brushless motor	DC motors are contains brushes.
Motion and displacement	Its motion is incremental and resolution is limited to the size of the step.	They have continuous displacement and can be controlled accurately.
Response time	Response time is slow	Feedback control with DC motor gives a much faster response time as compared to a stepper motor.
Effect of Overloading	Stepper motor can be slipped if overloaded and the error cannot be detected.	If an overload occurs, it can be detected.

Table 2.1: Stepper Motor VS DC Motor

To make the robot balanced the robot must prevent the fall of robot. DC motors can give more power and speed though it can be very difficult to control it precisely. Besides, rotational

encoder is needed to get feedback from DC motor. As encoder is not attached to each DC motor to make each wheel spin at same speed is quite difficult. When the floor changes grade or a tire hits bump or the floor changes its texture required voltage needed to make the DC motor spin so that it can changes fast. Some DC motor has this capability though it is not much available in our country.

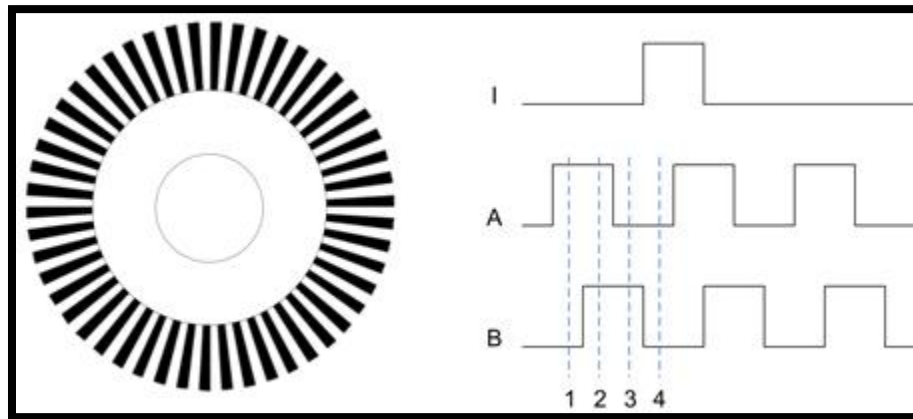


Figure 2.4: Rotary Encoder for DC Motor

Moreover, DC motor has high torque but RPM is not the same. Besides we can implement inverse pendulum by this. Gear reduction is needed to provide torque for most robotic applications as its standard is also poor enough in sizing and mounting arrangements. Now the fact is why we used Stepper motor. First of all, stepper motor is suitable for autonomous robot controlling and comparatively it has low power consumption

Balancing point:

Balancing point is very important and need to precise enough for this self-balanced robot. The concept of balancing point is similar like center of gravity. Center of gravity is the point which weight is evenly dispersed and all side has to be balanced enough. Our balancing point value is 1200, and only on that value our robot balanced on two wheels.

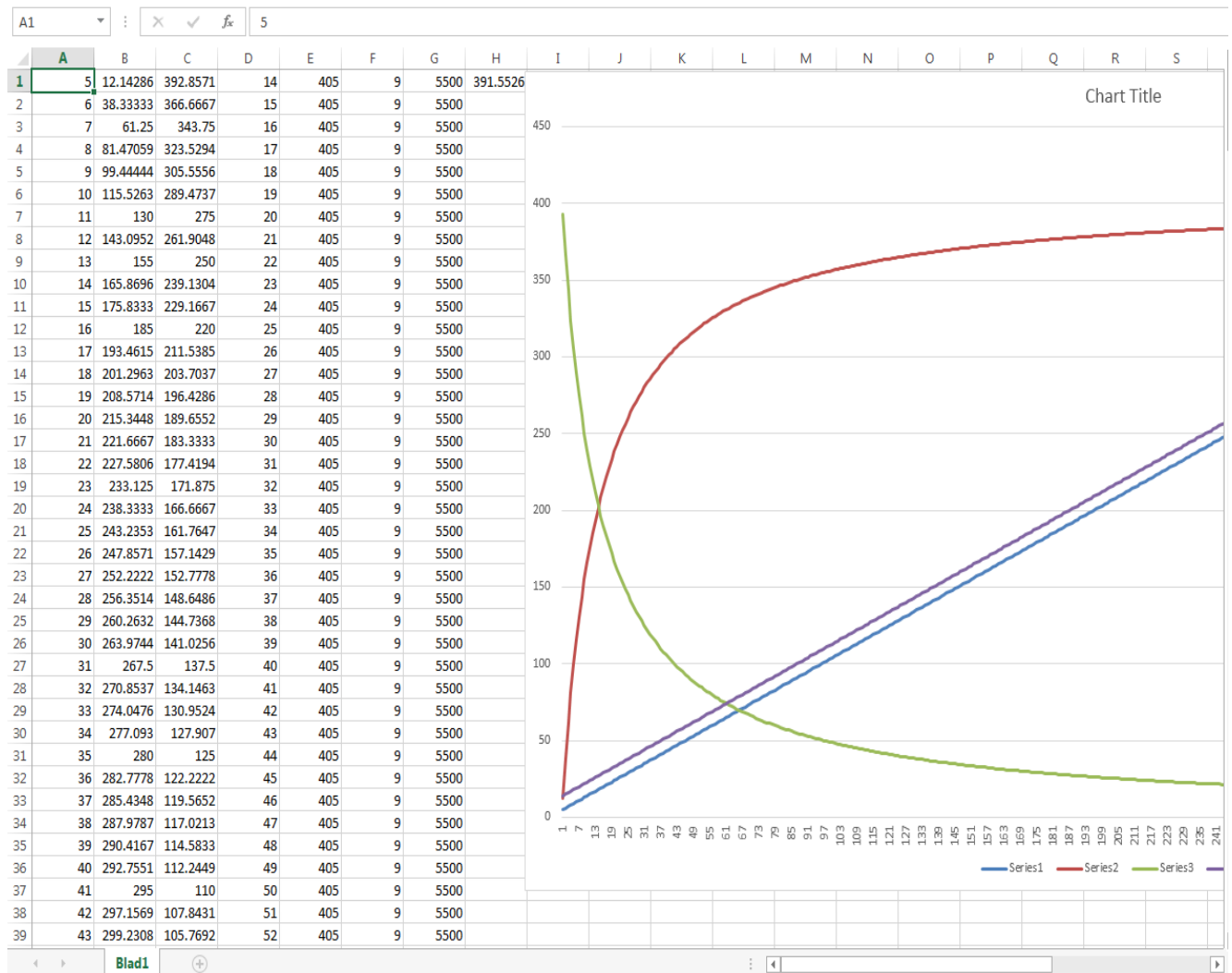


Figure 2.5: Balancing Point attached graph

Head (Camera position):

The robot has a head and it also has a camera in the forehead and between the eyes there is a camera for image processing. It takes image in front of it for face detection and live streaming. To views live streaming we have made a gui and on board Wi-Fi communication. It needs to maintain a minimum distance according to diagram.

Still resolution	5 Megapixels
Video modes	1080p30, 720p60 and 640×480 p60/90
Linux integration	V4L2 driver available
C programming API	OpenMAX IL and others available
Sensor resolution	2592×1944 pixels
Sensor image area	3.76×2.74 mm
Fixed focus	1 m to infinity
Focal length	3.60 mm +/- 0.01
Horizontal field of view	53.50 +/- 0.13 degrees
Vertical field of view	41.41 +/- 0.11 degrees

Table 2.2 : Specification of Camera

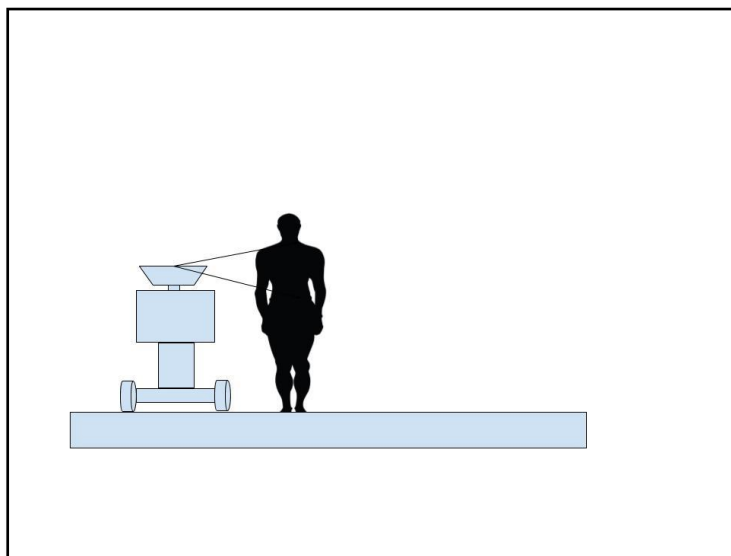


Figure 2.6: Very close detection by robot in 0.5 meter

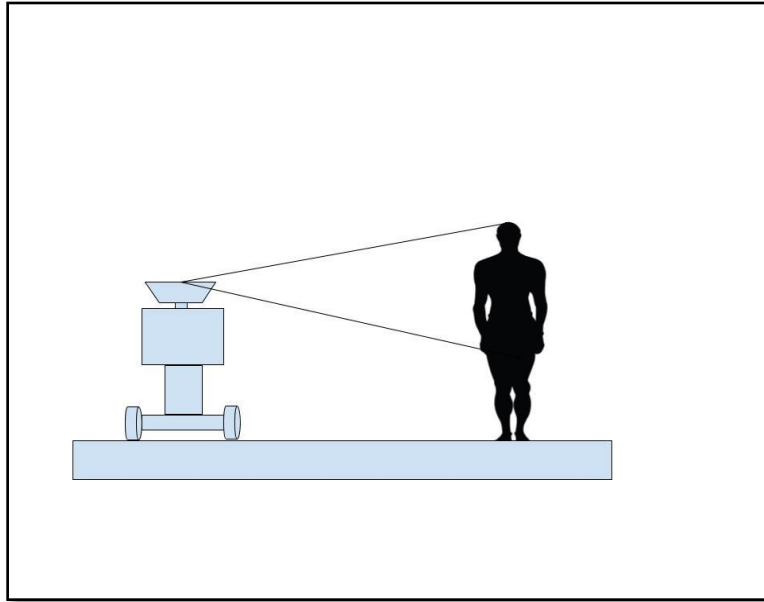


Figure 2.7: This is the perfect scenario of detecting face in 1 meter

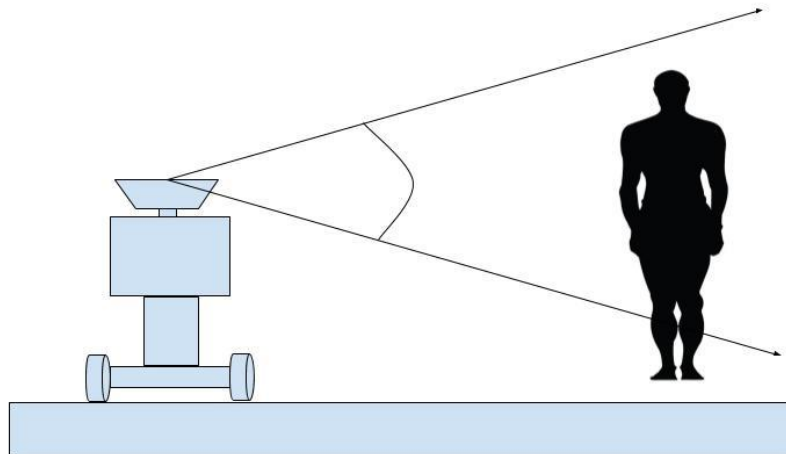


Figure 2.8: Maximum Range of Detecting Face in 1.5 meter

2.3: Electrical Design

Circuit:

Our main circuit Diagram is given below; here we are using Arduino pro mini as a controller. Arduino pro mini is a small electronic device it contains 14 input output, input pin, 6 analog input. Its price is reasonable enough, documentation sufficient and great compatibility, even power consumption is way much low. It has Atmega328 microcontroller which has 16 MHz processing power good enough for our balancing robot. There are also two stepper motor controllers and one gyro. Our stepper motor model is DRV8825 Stepper Motor. It can be used as a high-performance drop. It has adjustable current limiting and over temperature protection capability. Without heat sink it can deliver up to approx 1.5 A per phase.

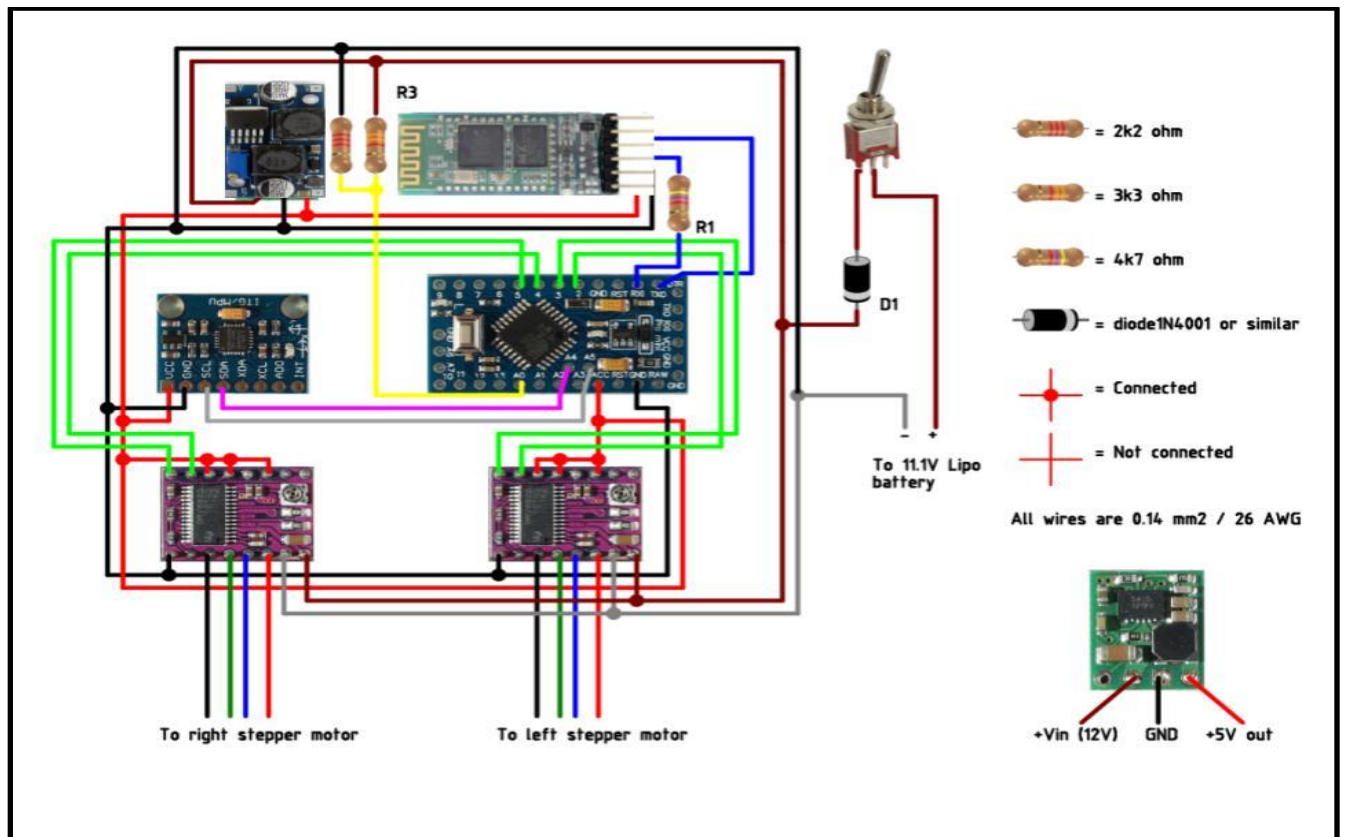


Figure 2.9: Main circuit Diagram

We are using MPU6050 gyro sensor which is a single chip and accurate enough. It captures x,y and z channel at the same time .MPU-6050 is not expensive it combines both accelerometer and a gyro. We connect the gyro with i2c connection for gyro value. We are using HC05 Bluetooth is designed mainly for transparent wireless connection setup.It contains 3Mbps modulation with complete 2.4GHz.Its footprint is way much small like 12.7mmx27mm. Here is one Bluetooth for communication with raspberry pie when it is in autonomous mode.

Communication:

The communication of the robot is two types: one is Bluetooth and another is Wi-Fi. For manual operating we control the robot with Bluetooth and video feed from Wi-Fi. On the other hand, autonomous driving requires Wi-Fi forget the data of detection and turn it off or on. Manual driving control with android app and we can see the video from web on local network or custom GUI. Autonomous driving movement can be activated by a switch on the robot. Manual driving android app GUI is shown here.

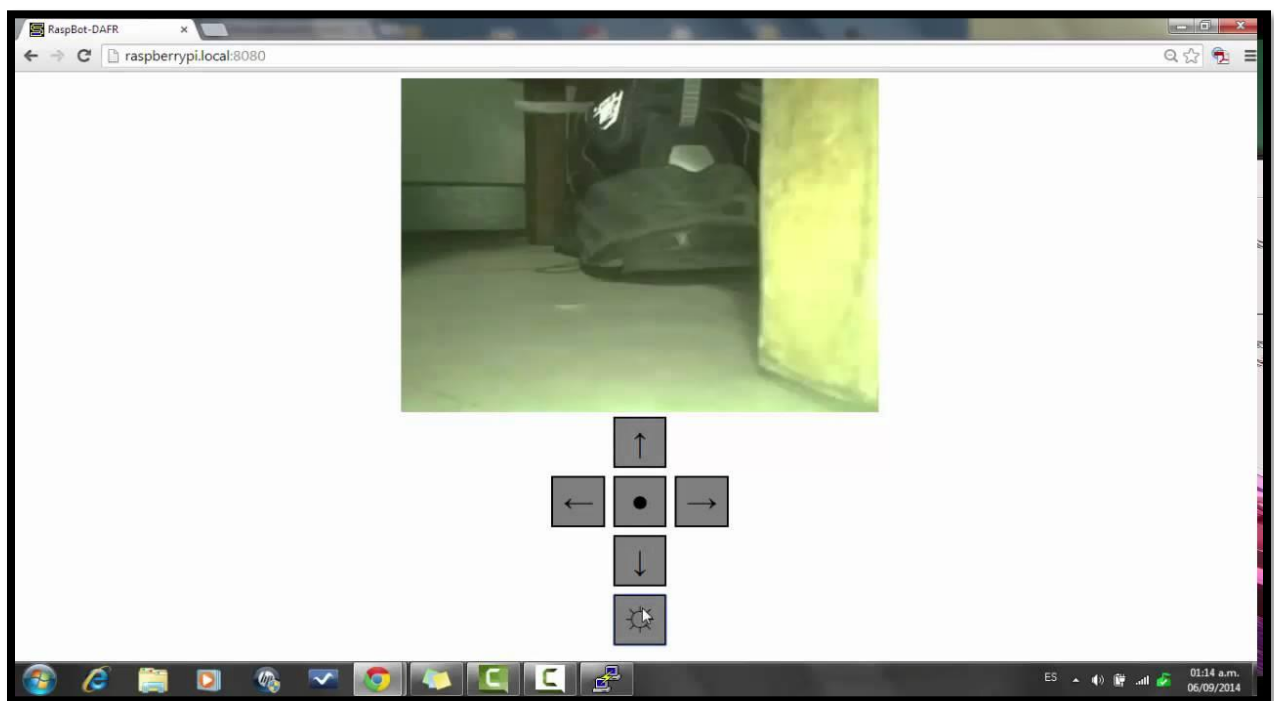


Figure 2.10: Manual Controlling process

Autonomous movement will be activated by user command when needed. Raspberry pi 3 has built in Bluetooth and Wi-Fi module. It makes pair with the control Bluetooth and sends command as string format to the balancing and moving part. For moving we need to send 4 several string like left, right, forward and backward. The autonomous communication block diagram is given below:

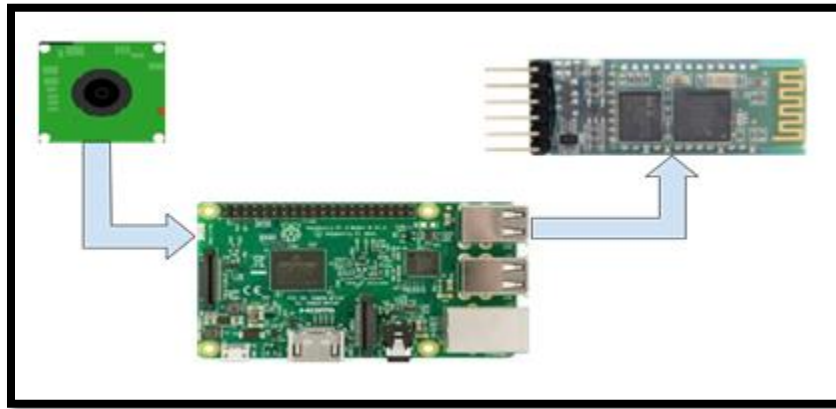


Figure 2.11: Autonomous communication block diagram

Chapter 3: Balancing Mechanisms

3.1: Balancing Process of Two wheel self-balancing Robot:

Two-wheeled balancing robot is an unstable dynamic system. Unstable means that robot is free to fall forward or backward without any applied forces. The word balance means the robot is in equilibrium state, which its position is like standing upright 90 degrees. However, the system itself is not balance, which means it keeps falling off, away from the vertical axis. Therefore, a combination of gyroscope and accelerometer is needed to sense angle position of the robot and input into the microcontroller, which implements the balancing procedure to Self-Balancing Robot.

3.2. Problems faced with DC motor:

To keep the robot balanced, the motors must counteract the fall of the robot. This action requires a feedback and a correcting element. DC motors can give considerably more power and speed, but can be tricky to control as accurately. We need rotational encoder to get feedback from DC motor. If encoder is not attached to each DC motor, it'll be very difficult to make each wheel spin at the same speed. Moreover, if encoder is attached, wind up needed to code some type of constant comparison between the two encoder speeds and adjust the individual motor voltages to make the speeds match. Every time the floor changes grade, or a tire hits a bump, or the floor changes texture, the required voltage to make that DC motor spin the same fast changes. Some of the DC Motor Control Boards have this built in. It may be worth paying extra to have this feature and besides is not available in our country. Moreover, in an inverted pendulum, it also requires gear reduction to provide torques needed for most robotic applications, and it is Poor standards in sizing and mounting arrangements. In addition, current draws by DC motor is not fixed .so we cannot supply constant current to this motor for perfect balancing. Besides because of EMF, motor will be jerking that is why we could not stop this perfectly.

3.3. Self-balanced steps by stepper motor:

In contrast to most self-balancing robots, this one uses stepper motors instead of regular DC motors. The main reason is that stepper motors are precise and have no performance loss when the battery voltage drops. One pulse is always an exact amount of motion. Regular DC motors have mechanical friction and electric resistance differences. This can cause performance differences. As a result the robot will not move in a straight line. In that case, stepper motor can move exactly same speed because it has poll drive as a result, the robot always can move in a straight line. We are using PID algorithm for balancing robot taking gyro value for calculating the balancing set point.

3.4. Application of PID:

PID stands for Proportional-Integral-Derivative algorithm which is the most common algorithm in balancing robot project. Three types of controllers combined in such that it produces a control signal.

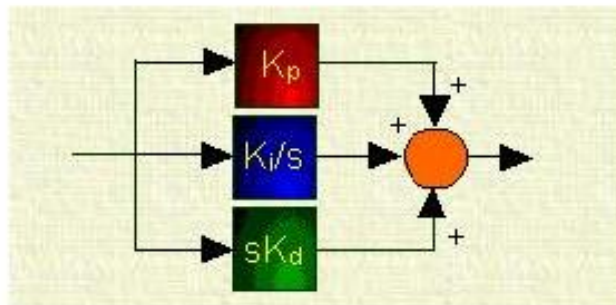


Figure 3.1:PID control parameters

Where,

K_p = Proportional gain

K_i = Integral gain

K_d = Derivative gain

Every element of PID controller indicates a particular function, taken from the error of PID controller reducing error by adjusting the control parameters, which is the difference between output and given reference [4].

Each element of the PID controller refers to a particular action taken on the error. In order to demonstrate the performance of the PID controller in locating the balancing robot to its desired position and angle, PID controller processes the "error" as the difference between a measured output and a desired given references and tries to minimize the error by adjusting the control parameters. We are using PID for backward, forward and left right movement.

PID controller at closed loop system feedback:

The quantity of the total output that is measured, called the feedback signal and the control signal that uses feedback signal is called a Close-loop system. The quantity of the output being measured is called the “feedback signal”, and the type of control system which uses feedback signals to both control and adjusts itself is called a Close-loop System.

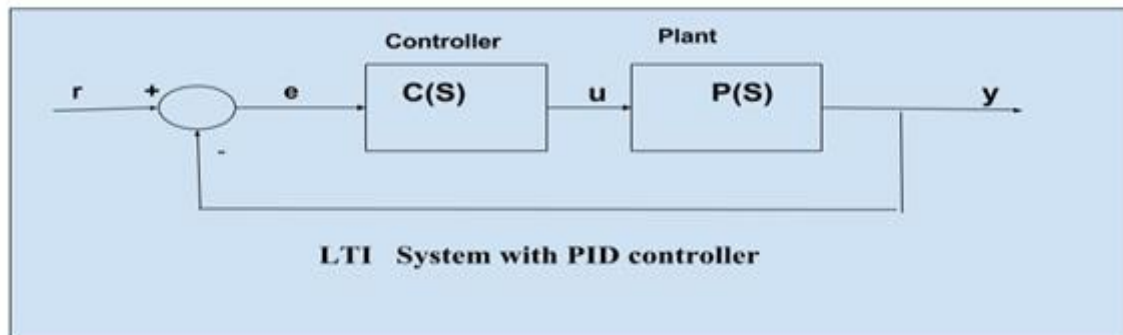


Figure 3.2:LTI System with PID controller

In the time domain, the PID controller's output will be equal to the control input.

$$u(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de}{dt} \quad (1)$$

PID controller works in a closed loop system using the schematic shown above where variable (e) represents the tracking error and (y) is the actual output. The proportional component depends on the error and the proportional gain (k_p) indicates the ratio of output. Furthermore, proportional gain K_p is equal to the control signal (u). When control signal (u) is sent to the plant, then the value of new output (y) will be able to obtain. This new output (y) is the feedback. By taking the Laplace transform of the above mentioned equation, we are getting the transfer function of PID controller on eq. (2).

$$K_p + K_i/s + K_d s = (K_d s^2 + K_p s + K_i)/s \quad (2)$$

Effects of derivation gain in a closed loop feedback system:

$K_p=15$

$K_i=1.5$

$K_d=30$

Max target speed: 150

Feedback signal represents the variable process and the derivation component can make the system unstable.

For the moving mechanism, we increment 0.5 values with the balancing value which helping the robot to moving forward, we are using here the PID and the robot will balance at the same point.

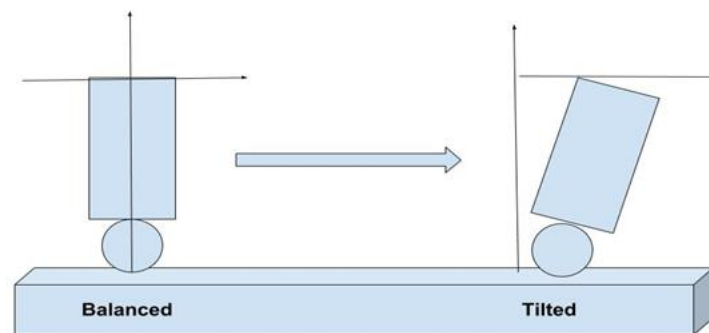


Figure 3.3: Sense tilt and drive to make robot erect

Chapter: 4: Autonomous Mechanisms

Autonomous system of our robot includes Image Processing and movement. We have used the ‘Viola-Jones face detection algorithm’ from open CV to take data with Python code and then implemented our own Bounding Box technology to enable the robot to make decision regarding movement.

Concept of Face Detection:

Face detection has been one of the most studied topics in Computer Science which includes different software and hardware based technology. Given an arbitrary image, the goal of face detection is to determine whether or not there are any faces in the image and, if present, return the image location and extent of each face. Face detection refers to the process of automated locating of the presence of human faces in digital media (image and video). A face is detected via graphical orientation of the face and after that the algorithm searches for landmarks. Detecting a face seems natural task for human being for Robot it requires image processing which deals with location, view point, illumination, occlusions, etc. There are numerous number of face detection algorithm but we preferred the ‘Viola-Jones’ algorithm as it has faster and more accurate detection rate than the others.

4.1: Principle of Viola-Jones Face Detection Algorithm:

Viola-Jones Object detection framework is the first ever real time object detection method. Speed and accuracy are the two key features to define performance of face detection system. Viola-Jones proposed a novel approach to rapid object detection. This object detector is one of the most successful and widely used object detectors. A popular implementation used by the community is the one in Open CV. Viola-Jones algorithm has three major components to ensure faster detection [5]. They are as follows:

I. Integral Image: It enables our detector to compute the image and creates ‘integral image’ from input images.

II. Adaboost: Works as feature selector which reduces the number of images to a smaller scale from a larger set. Consequently, It produces absolute efficient classifier using a Adaboost based learning algorithm.

III. Attentional Cascade: It combines more complex classifiers in a "cascade" which allows background of the image to be discarded fast while spending more computation on promising face-like regions.

The task of the face detector is to locate a human face from an arbitrary image. If a human face is founded, it needs to locate the exact location. The main framework considering this issue is built by forming a classifier so that it can reduce the risk of misclassification. The algorithm needs to minimize the false negative and false positive rates in order to achieve an acceptable performance. The reason is that it is impossible to mark the actual prior probability for a given image to have a face. The task demands an accurate numerical description to get that identifies the unique features of human faces and then extract the faces among all the objects. It turns out that these characteristics can be extracted with a remarkable committee learning algorithm called 'Adaboost', which relies on a committee of weak classifiers to form a strong one through a voting-mechanism. An operational algorithm must also work with a reasonable computational budget. Techniques such as integral image and attentional cascade provide the Viola-Jones algorithm higher performance.

4.1.1: Haar-like feature:

At first 'Haar-like features' is used by The Viola-Jones algorithm. In brief this feature refers to a scalar product between input image and various Haar-like samples. Haar like features tracks the difference in the dark and light portion of the image. This computation draws a rectangle over the face. Then, it forms a line close to the nose or forehead depending on the color shade. In mathematical term, let I and P denote an image and a pattern respectively, with the equal $N \times N$ sized image. The feature is expressed by the following:

$$\sum \sum I(i,j) 1_{p(i,j) \text{ is white}} - \sum \sum I(i,j) 1_{p(i,j) \text{ is black}}$$

Here, I is the image of pattern P.

Initially images must be mean and strafe normalized in order to compensate the effect of variant lighting environment. Those images with variance under a specific one are discarded from the selection.

We can see five haar-like continuous patterns in the image. Considering the equal dimension of the black and white rectangles and the fact that they keep their relative position, size and location of a pattern's support is continuous. This constraint enables the amount of features can be drawn from an image in manageable situation. For example, a 24×24 image contains 43200, 27600, 43200, 27600 and 20736 features of five different categories. In total, 162336 features in all. The figure 4.1 shows three different features of image pattern.

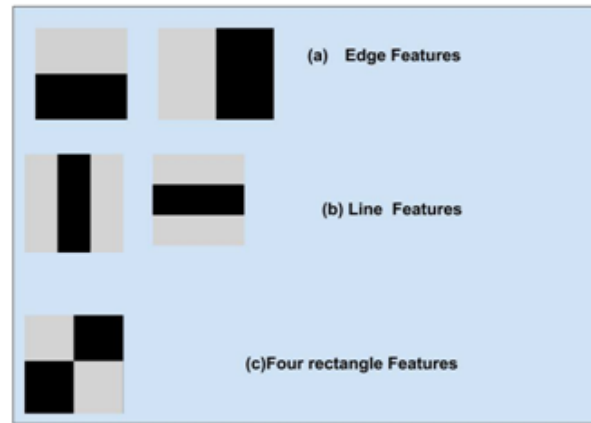


Figure 4.1: Different Features of Image Pattern

The regions have the equal size and identical shape and are adjacent in both horizontal and vertical way. The sum is calculated by a 3 rectangle feature. 2 of them are in outside and subtracted from the sum in other rectangle. Then other features of four rectangle finds out the disparity between the diagonal pairs. Finally these executed features are proved to contain all the necessary information for face characterization. After that a box classifier brings out the features of the face by using integral image which is described in the next section.

4.1.2: Integral Image:

Precision and speed defines the success of a face detection algorithm and the algorithm must put this two key feature which is actually a tradeoff between them, in top priority. There is generally a trade-off between the two. Viola and Jones aims for the most efficient trade off by introducing fast feature evaluation in image representation. Making of integral image seems to be an effective system to speed up the detection rate. The first step of the Viola-Jones face detection algorithm is to evaluate an integral image from the image given as input. Integral image is also familiar with the name ‘summed area table’ because of the addition based computation process. This process is ensures a fast and effective calculation of the sum of values from a pixel grid rectangle subset. This is represented as follow:

$$ii(x,y)=\sum i(x',y') \quad (3)$$

The integral image at location x;y contains the sum of the pixels above and to the left of x, y. The integral image is proved to be extremely efficient for the computation the sum of any rectangular area as shown in Figure. From a rectangle WXYZ The sum of pixels can be calculated with only four values from integral image:

$$\sum i(x,y) = ii(Z) + ii(W) - ii(X) - ii(Y) \quad (4)$$

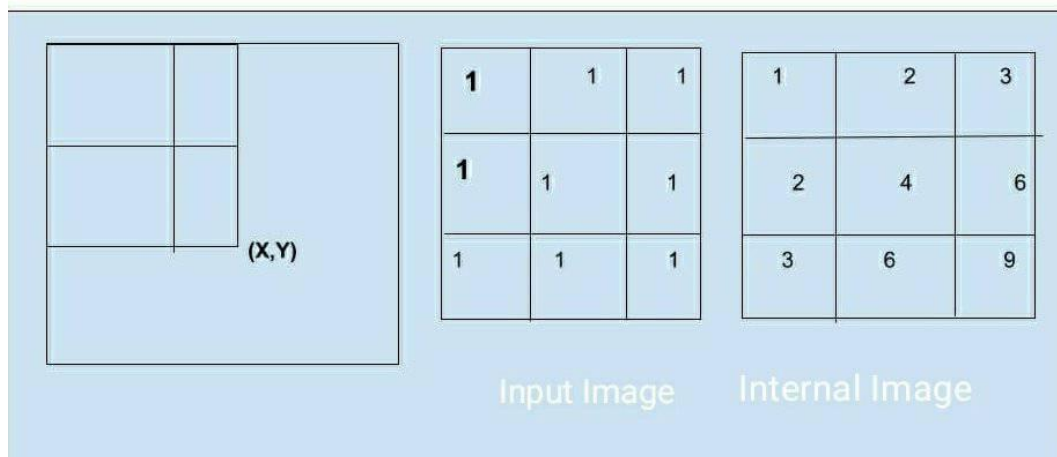


Figure 4.2: Rectangle Area of Integral Image

To illustrate figure4.2, let 1,2,3,4 be the values of the integral image at the corner of a rectangle, next the sum of original image values within the rectangle can be computed as the eq. (5) & (6).

$$\text{SUM} = 4 - 2 - 3 + 1 \quad (5)$$

$$\text{Value} = \sum (\text{White area pixels}) - \sum (\text{Black area pixels}). \quad (6)$$

Another example of the illustration of integral image from input image is given below:

5	2	3	4	1
1	5	4	2	3
2	2	1	3	4
3	5	6	4	5
4	1	3	2	6

Figure 4.3: Input Image

5	7	10	14	15
6	13	20	26	30
8	17	25	34	42
11	25	39	52	65
15	30	47	62	81

Figure 4.4: Integral Image

Another very important property of Viola and Jones algorithm is that the integral image is actually evaluated from the double integral of the input image. First integral is performed along the rows and second, along the columns. Any rectangular sum can be computed in four array references using the integral image any. So, in total, eight references are required to compute the subtraction of the two rectangular sums. The two-rectangle features can be computed in six array

references, eight in the case of the three-rectangle features, and nine for four-rectangle features since it involves adjacent rectangular sums. One alternative motivation for the integral image is that in the case of linear operations, any invertible linear operation can be applied to f if its inverse is applied to the result. For example in the case of convolution, if the derivative operator is applied both to the image and the kernel the result must then be double integrated:

$$f * g = \iint (f' * g') \quad (7)$$

Along with that the speed of the convolution can be effectively increased by enabling the derivatives of f and g to be rare. A similar insight shows an invertible linear operation can be applied to f if its inverse is applied to g such as:

$$(f') * (\iint g) = f * g \quad (8)$$

As mentioned earlier, the calculation of the sum of the rectangle can be expressed as a scalar product, $(I \cdot P)$, where I is the image and P is a sample pattern. This operation can be rewritten:

$$I \cdot P = (\iint I) \cdot P'' \quad (9)$$

To sum up, the integral image is in fact the double integral of the image where first derivation is occurred along the rows and columns respectively. Then the derivation of the rectangle which results in four delta functions at the corners of the rectangle. Finally, four array accesses evaluates the second dot product.

4.1.3: AdaBoost:

Next goal of the Viola Jones approach is to train the classifier. Machine learning approaches can be used to build and train the classifier providing a feature set and number of positive and negative images as training set.

In Viola Jones, AdaBoost is used as the feature selector as well as classifier trainer. AdaBoost is a learning algorithm which is used to enhance the classification performance of a simple learning algorithm. To achieve high performance the AdaBoost combines a bunch of weak classification functions and create a much stronger one. Here the general learning algorithm is referred as the weak learner. Since classifying the training data set with better accuracy is nearly impossible even with the best classification function, the learner is called weak. For example a given problem the best perceptron may only classify the training data correctly 52% of the time). For boosting the weak learner, it performs to solve a sequence of problems. The examples are re-weighted to mark those which were incorrectly classified by the previous weak classifier after the first dice of learning. A single AdaBoost classifier is the combination of multiple weighted sums of weak classifiers. The weight associated with a given sample is stabilized based on whether or not the weak classifier correctly classifies the sample. Each weak classifier is a threshold on a single Haar-like rectangular feature. A single weak classifier is defined as:

$$h(x, f, p) = \{1 \text{ if } f(x) < p\} \quad (10)$$

Where f implies the feature value, p is the threshold and also the polarity indicating the direction of the inequality. Despite being process is quite efficient; the amount of weak classifier is extremely huge. As there is single weak classifier for each unique threshold combination, there is total KN number of weak classifiers, where K denotes the number of features and N is the number of examples put. In order to appreciate the dependency on N , suppose that the examples are sorted by a given feature value. Total number of distinct thresholds is N because any two thresholds that lie between the identical pair of organized examples is equivalent. For example approximately 3.2 billion distinct weak classifiers can be found with the value $N=20000$ and $K=160000$. The wrapper method can also be used to learn a perception which utilizes M weak classifiers (John et al, 1994) the wrapper method also runs incrementally adding one weak

classifier to the perception in each count. The weak classifier added is the one which when added to the current set yields a perception with lowest error. Each round takes at least sixty Trillion operations the time to enumerate all binary features and evaluate each example using that feature. Based on the feature value, the examples are sorted for each feature. Then an optimal feature can be computed in a single pass by the AdaBoost over this sorted list. There are four sums performed and evaluated to put each element in the list. Sum of positive example weights in P^+ , while the total sum of negative example weights P^- , the sum of positive weights below the current example D^+ and the sum of negative weights below the current example D^- . The range between the current and previous example in the sorted list is divided by an error equation for a threshold.

$$E = \text{MIN} (D^+ + (P^- - D^+), D^- + (P^- - S)) \quad (11)$$

These sums are continuously being updated with the continuity of search. Our final application demanded a very aggressive process which would discard the vast majority of features. For a similar recognition problem Papageorgiou et al. (1998) proposed a scheme for feature selection based on the variance of each feature. They established better by separating only 37 features out of a total 1734 features. Though the reduction is a notably significant, the number of features evaluated for every image sub-window is still larger than expectation. So, we decided to use a different method in our project which is described on the later part.

4.1.4: Attention Cascade:

An algorithm is established to construct cascade classifiers which achieve increased reduction performance by radically abating computation time. The key insight is that boosted classifiers that is small in can be efficiently constructed which discards many of the negative sub-windows while detecting almost all positive features. To gain low false positive rates simpler classifiers are used which reject most of the sub-windows before more complex classifiers are called upon. Stages in the cascade are constructed by training classifiers using AdaBoost. Starting with a two-feature strong classifier, an effective face filter can be obtained by adjusting the strong classifier threshold to minimize false negatives. The initial AdaBoost threshold, designed to yield a low error rate on the training data. Comparatively, lower threshold produce higher detection rates and false positive rates. Bases on performance which has been measured by validation training set, the classifier can be detecting 100% of the faces with the false positive

rate of 50%. When the weak classifier for each feature is calculated, it requires one threshold operation for per feature. Finally combination of weak classifier is also needed to have an addition and a threshold.

In addition, there are nearly 60 microprocessor instructions for a two feature classifier and to scan a simple image template it requires not less than 20 times as many operations for each sub-window. So, normally It is hard to imagine that any simpler filter could achieve higher rejection rates. The overall form of the detection process is that of ad e generate decision tree, what we call a “cascade” [3].

4.2: Implementation of Viola-Jones in Robot:

We have improvised the Viola-Jones algorithm in our process using several tools. With the help of the algorithm, we generated real time image sequence from a standard webcam and achieve improved performance . We used OpenCV framework as our coding platform , a bluetooth chip, an XML database and finally we implemented our own ‘Bounding Box’ method to detect desired face and move the Robot accordingly.

4.2.1: Advantages of Open CV and Installation:

Open Source Computer Vision Library, in short, OpenCV is a library of machine learning applications aiming at real time computer vision. Open CV is implemented on applications that are related to image. It reads and writes images to process it. The Open CV Library contains over 2500 image processing-algorithms, each of them are optimized and includes an extensive set of machine learning algorithms and computer vision. The algorithms are capable of recognizing faces, objects, classify human actions in videos, track camera movements, track moving objects, extract 3D models of objects and many image processing related activities. The platform supports C++, Java, Python and MATLAB as coding interfaces in Windows, Linux, MAC and android Operating Systems. It can alleviate some of the scraps programmers face while computer vision based coding. Since the basic image processing concept of artificial intelligence depends on OpenCV and its does not require higher hardware compatibility, we have chosen to this to implement.

To initiate the autonomous feature to the Robot we have used Raspberry Pi to install Open CV using Python code. Open CV can work without any difficulties in the Raspberry Pi processor. We have preferred Python because the language was designed for teaching language which is suitable for our Robot since it is AI based. In summary, the Viola-Jones algorithm which we implemented is used in Open CV with Python code put in the Raspberry Pi. After that a Bluetooth mechanism is installed with the R-Pi.

4.2.2: Face detection using Haar-cascade in Open CV:

Our primary goal of the autonomous feature is to detect the face of people using Haar feature-based cascade classifiers, the object detection method from the Viola-Jones algorithm we have discussed. With The Open CV library we have installed, detection of a frontal face in an image using its Haar Cascade became easier.

A wrapper function is used as the function is a bit tedious initially. Before that, a huge number of positive images and negative images are the prerequisite of the algorithm. The reason for that is the Haar classifier needs a lot of training. Positive image refers to the images of the face and the ones without the face are the negative image. Then, multiple features are extracted from the trained classifier. Open CV already contains many pre-trained classifiers for face, eyes, smile etc, as we are dealing with face; we have downloaded an XML file database which contains 2000 faces, all of them having different features. After that our challenge was to locate the relevant image with limited number of features meaning the exact location of the face. As we have already discussed that the viola Jones face detection contains a plenty of features, most of them are irrelevant. As a result the face detection process becomes huge time consuming as well as poor performance. For example a 24x24 window results over 160000 features.

At first we wanted to use the AdaBoost feature learning algorithm. For this, we apply each and every feature on all the training images. For each feature, it finds the best threshold which will classify the faces to positive and negative. But obviously, there will be errors or misclassifications. We select the features with the lowest error rate, which means they are the features that best classifies the face and non-face images. (The process is not as simple as this. Each image is given an equal weight in the beginning. After each classification, weights of misclassified images are increased. Then again same process is done. Also, new error rates and

weights are calculated. The process is continued until required accuracy or error rate is achieved or required number of features is found. Classifier is a weighted sum of these weak classifiers. It is called weak because it alone can't classify the image, but together with others forms a strong classifier. A research says that even 200 features provide detection with 95% accuracy. Their final setup had around 6000 features. So, reduction from 160000+ features to 6000 features is indeed a standard gain. On the other hand we still need to apply 6000 features to it each 24x24 image to detect the face. As a result, it still remains time consuming as well as inefficient even after the implementation of AdaBoost [5]. So we have used different technique known as 'Bounding Box'.

4.2.3: Implementation of “bounding box”:

We have divided the detected face into multiple pixel area after drawing a box on the face so that we can separate the face from other features depending on the color. The color puts a great deal of contrast between the face and the background. Also, with the rotation of the face, the color does not change. Once a face is identified, as a position which is tenured in the output area in term of geometric coordinators, we can split the real face shape and its correspondent background. In this way, the number of locations in the image that need to be searched for faces is reduced. First, we put the probability of being a face to every pixel in the image. We have utilized the training data to determine the allocation of RGB-space of the face pixels and the background pixels. Figure 4.5 shows the bounding regions for face pixels and background pixels based on the training images.

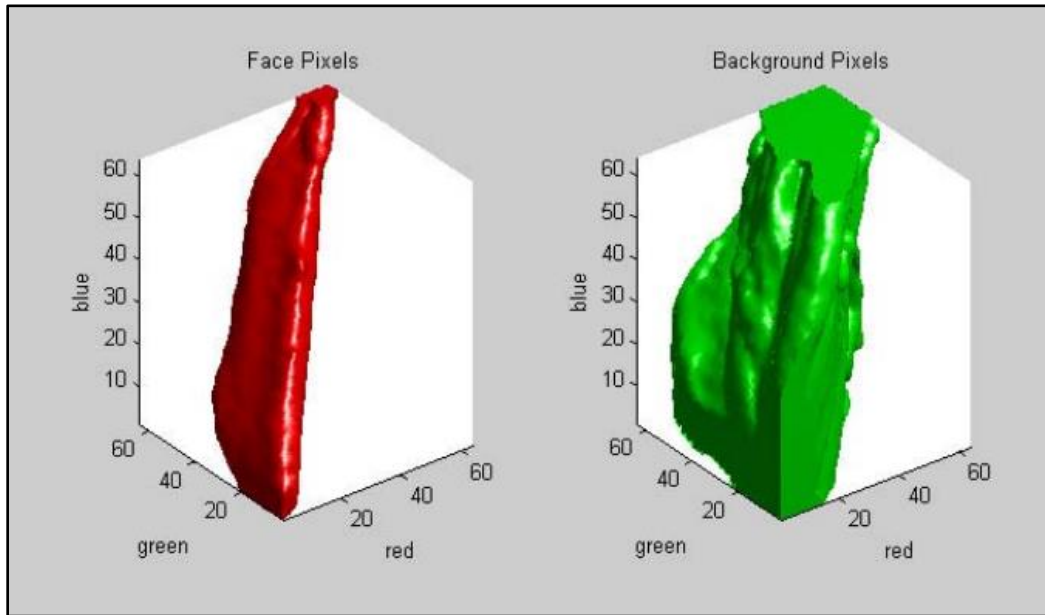


Figure 4.5: Bounding Regions for Face Pixels and Background Pixels

For each location in RGB space, we use the following formula to calculate the associated probability of being a face:

$$\text{Probability} = (\text{number of face pixels}) / (\text{number of face pixels} + (\text{number of background pixels})^{\wedge} \text{weight}) \quad (12)$$

The weight is used to compensate for the fact that there are many more background pixels than face pixels in the training images. It also provides a simple way to bias the function towards finding or rejecting background pixels. We need to split this mask up into regions which can be searched for faces after having a mask showing potential faces. After some very basic erosion and hole-filling steps, most of the faces are nicely contained in a single contiguous set of pixels. Some contiguous regions contain more than one face. We detect a single face from multiple faces based on priority. In this way, we have completed face detection which also works for multiple faces. More importantly, required time of face detection also decreases which is an improvisation of the Viola-Jones method.

4.3 Automated Movement of the Robot:

Immediately after detecting the face our goal is to move the robot autonomously by following the face. The movement depends on the look of the detected face and only follows his direction ignoring others. We have made the bounding box in the center of the box which creates the difference between area and command. To make the decision of movement, four commands are sent as String. The direction that the Robot should follow depends on the left-right and forward-backward movement of the person whose face is detected. If the Robot finds the face in upwards or in higher distance, it will start moving towards him. This will be robot's forward movement. The movement will be backward if it finds the face closer to him as well as located downward. Same goes for left & right movement. While finding face on its left it will move to right and finally the movement towards left if the face located in right. Thus, the robot moves autonomously depending on the position of the bounding box we created.

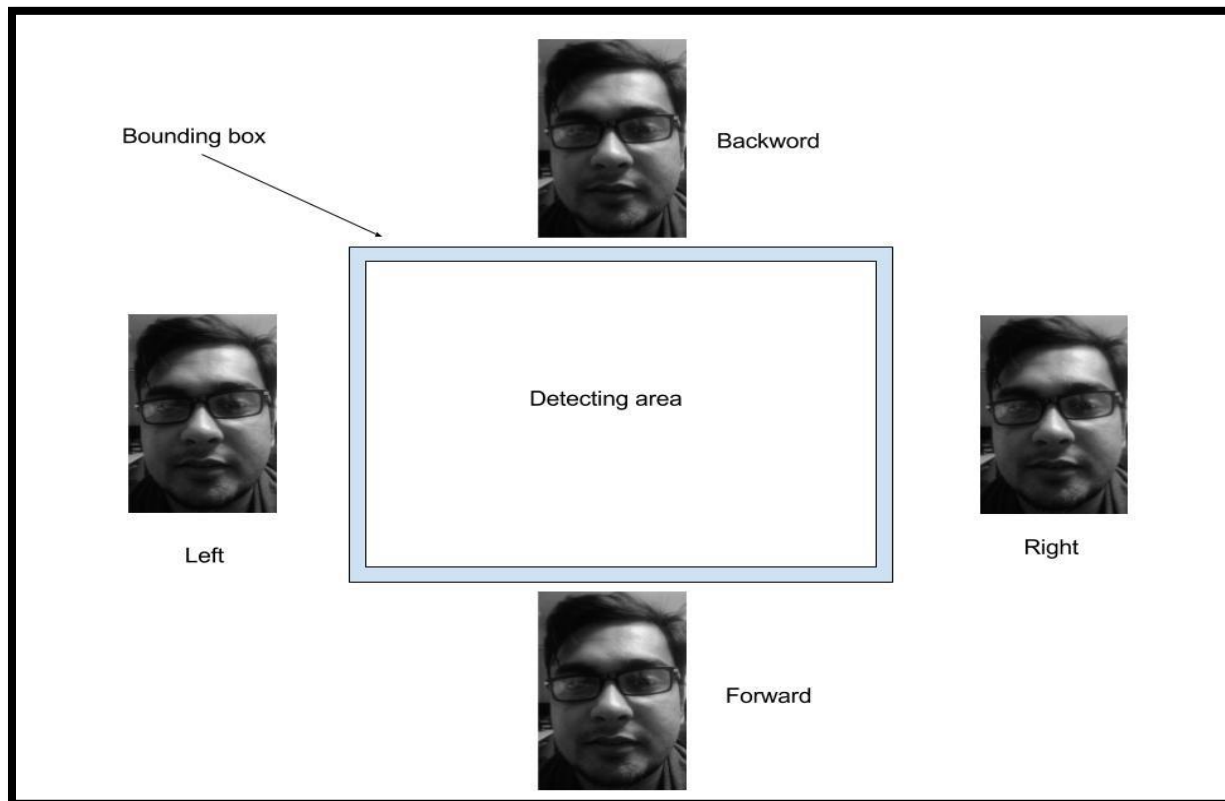


Figure 4.6: Bounding Box Detecting Area

In autonomous movement we have another feature that is color detection command from user. If a user wears any specific color in head like cap or hat, the robot will follow the color by RGB layer scale. User can select the RGB value of the color to follow the user instruction. Moreover, we are doing sign recognition for some special command from user or in absence of user.

Chapter: 5: Results and Implementation Challenges

5.1. Result Analysis:

We have taken several images for testing the viola Jones algorithm for face detection. For testing the detection algorithm, we took several peoples image. We had taken pictures from different angles and different gender and fixed a minimum distance to detect the face with some few modifications we got our expected result. Based on this result we modified the algorithm .Finally we came to few decision that this algorithm does not work at night and at a same time on multiple faces.



Figure 5.1: Output of Detecting Face and training algorithm

5.2. Limitations during Implementation and Solutions:

During building up the robot, we had to face some difficulties. That is the reason for what we had to bring some changes in the measurement of the robot. Even we could not use large type of stepper motor as it is too heavy. Firstly, we tried to make metal body but that was not possible due to overweight of the metal sheet, so that we had to build up the body of our robot by PVC sheet. In future if we want to make the robot's body with metal material than we need less weight metal but unfortunately this kind of metal is not that much available in our country. So, if we want to make this body with metal we need to import that kind of material from abroad.

Besides, we didn't make the robot that much big as the price of larger size stepper motor is way much high and weight will vary also for the big size of stepper motor which will create effect on our balancing point. For making the frame we didn't find light weight material, wheel, rotary encoder which are not available in our country.

As we had to make our robots body in a perfect measurement but when we tried to make different height of robot we were unable to balance the robot because of center of gravity. In future if we want to bring success in this sector, we need to study more and calculate the center of gravity more precisely.

Chapter 6: Conclusion and Future Development Scopes

Artificial Intelligence robot always inspires and surprises us with the new ideas, topics and innovations. Future work will seek to improve this self-balanced robot by controlling the movement through voice recognition and gesture. We will work on the voice command so that it will be able to answer some specific questions. In the future our proposed solution package will also include memory mode and through it can remember different faces and the recorded members will be called out by their name. We are doing image processing and self-balancing in different boards but in future we want to do it in single board as than the performance will be better in future .In present we are controlling our robot manually by balancing the set point. We have to work more on so that it can balance itself. We also like to add up some hardware extension part like robotic arm which will help this robot to carry things. Another modification can be added is, its Wi-Fi capability by which it can use updated information from the web. Besides we can also improve this electromagnetic robot by incorporating ultrasonic sensor, sonar, LM35 sensors by which it will also be able to detect object and can sense the weather temperature. In future, we can make our robot more updated by adding numerous features.

Artificial Intelligence and Robotics have a common root and have a long history of interaction and scientific business. Artificial Intelligence robotics is a technological field that enables machine to perform task usually done by human being. Robotics and artificial intelligence is the way of future .Let's, imagine robots are working at home ,factories, warehouse and laboratories as like as human being ,life will be become more easier. This type of self-balanced Robot is very rare in our country but very useful to make our daily life easy and comfortable. As technology improves with our modern era, there will be new ways to use AI robots which will bring new hopes and potentials to us.

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