REAL TIME BALL TRACKER AND GOALKEEPER

Capstone Project Report

End-Semester Evaluation

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ABSTRACT

In this report we will discuss our project of autonomous goalkeeper in detail. All the diagrams and every little detail needed to understand the concept of autonomous moving target tracker and interceptor. Our basic approach to dealing with this problem would be to use OpenCV to track the ball and use a bot that would stop the ball in turn. The blocking commands will be transferred from the PC to the bot via a zigbee. The Python script we developed was able to detect the presence of a colored ball, followed by the track and the position of the ball as it moved around the screen.

As it shows, our system was fully robust and capable of tracing the ball, even if it was partially stopped when viewed by hand. The script was also able to operate at extremely high frame rates (30 fps), concluding that color-based tracing methods are very suitable for real-time detection and tracking.

Ball-tracking is classified as follows: -

Dense optical flow: These algorithms help us to estimate the vector of every pixel in a video frame.

Sparse optical flow: These algorithms, such as the Kanade Lucas Tomashi (KLT) tracker, detect the location of some characteristic points in a digital image.

Kalman filtering: It is a popular signal processing algorithm that is used to predict the location of a moving object based on the final motion information. One of the most commonly used applications of this algorithm is missile guidance, as described here, "The on-board computer that directed the landing of the Apollo 11 lunar module on the Earth's moon was a Kalman filter". .

Meanshift and camshift: These are algos for detecting the maxima of a density function. They are also used for tracking. Single or One Object Trackers: In this category of trackers, the first frame is marked using a rectangle to indicate the position of the object we wanted to track. The object is then tracked into the following frames using a tracking algo. In most real-life applications, these trackers are used with the help of an object detector. Finding Multiple Object Tracking Algorithms: In cases when we have a fast object detector, it makes sense to detect multiple objects in each frame and then run a track finding algorithm that identifies rectangles in one frame. is.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled "Real Time Ball Tracker and Goalkeeper" is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr.Raman Kumar Goyal during 6th semester (2019).

Date: 17th.Dec.2019

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We are also thankful to Dr. Maninder Singh, Head of Computer Science and Engineering Department(HOD), the entire faculty and staff of Computer Science and Engineering Department, and also our colleagues who devoted their valuable time and helped us in all possible ways towards successful completion of this project. We thank all those who have helped either directly or indirectly towards completing this project.

Lastly, we would very much like to thank our families for their unyielding love and encouragement. They always want the best for us and we deeply admire their determination and sacrifice.

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LIST OF ABBREVIATIONS

CNN	Convolutional Neural Network
OpenCV	Open source computer vision
DIP	Digital Image Processing
API	Application Programming Interface
UTF	Unicode Transformation Format
KLT	Kanade-Lucas-Tomashi
MOSSE	Minimum Output Sum of Squared Error
MIL	Matrox Imaging Library
KCF	Kernelized Correlation Filter
TLD	Tracking, learning and detection
GOTURN	Generic Object Tracking Using Regression Networks
CSRT	Channel and Spatial Reliability Tracker
UI	User Interface
DRDO	Defence Research and Development Organisation
WAP	Wireless Application Protocol
USB	Universal Serial Bus
AI	Artificial Intelligence
ML	Machine Learning
Wi-Fi	Wireless Fidelity
PPE	Prediction, Planning and Execution
TCP	Transport Control Protocol

INTRODUCTION

1.1 Project Overview

Object Tracking using OpenCV (C++/Python) What is Object Tracking?

Simply put, locating an object in successive frames of a video is called tracking.

The definition seems straightforward but in computer vision and machine learning, tracking is a very broad term that incorporates ideologically similar but technically different ideas. For example, all different but related views are typically studied under object tracking and detection.

Dense Optical flow

These algorithms help in estimating the motion vector of every pixel in a video frame.

Sparse optical flow: These algorithms, such as the Kanade-Lucas-Tomashi (KLT) feature tracker, track the location of certain feature points in an image.

Kalman Filtering: A very popular signal processing algorithm is used to predict the location of a moving object based on previous motion information. One of the earliest applications of this algorithm was missile guidance! As noted here, "the on-board computer directing the descent of the Apollo 11 lunar module on the moon had a Kalman filter".

Mean-shift and Camshaft: These are algorithms to find the maximum range of a density function. They are also used for tracking.

Single object trackers: In this class of trackers, the first frame is marked using a rectangle to indicate the location of the object we want to track. The object is tracked in subsequent frames using a tracking algorithm. In most real-life applications, these trackers are used in conjunction with an object detector.

Multiple object track finding algorithms: In such cases when we have a fast object detector, it makes sense to detect multiple objects in each frame and then run a track finding algorithm which identifies which rectangle in which frame is the one in the next frame. Corresponds to the rectangle.

Tracking and Detection

If you've ever played with OpenCV face detection, you know that it works in real-time and you can easily detect faces in every frame. So, why do you need tracking in the first place? Let's explore the various reasons you want to track the objects in the video, not just the repeated detection.

Tracking is faster than detection: Tracking algorithms are generally faster than detection algorithms. The reason is simple. When you are tracking an object that was found in a previous frame, you know a lot about the object's presence. You also know the location and direction of motion in the previous frame. Therefore in the next frame, you can predict the location of the object in the next frame using all this information and do a small search around the expected location of the object to find out the correct position of the object. A good tracking algorithm will use all the information about the object up to that point, while a detecting algorithm always starts from scratch. Therefore, when designing an efficient system the detection of an object is usually run on each NT frame, while tracking algorithms are employed in between n-1 frames. Why don't we locate the object in the first frame and track it later? It is true that tracking benefits from additional information, but you can lose track of an object even when they go behind an obstacle for an extended period of time or if they move so fast that the tracking algorithm Can not catch. It is also common to accumulate errors for tracking algorithms, and the bounding box that tracks the object slowly moves away from the object it is tracking. To fix these problems with the tracking algorithm, a detection algorithm is run each time. Detection algorithms are trained on a large number of object instances. Therefore, they have more knowledge about the general class of the object. On the other hand, tracking algorithms know more about the specific instance of the class they are tracking.

Tracking can help if it fails to detect: If you are running a face detector on a video and the person's face collides with an object, the face detector will most likely fail. A good tracking algorithm, on the other hand, will handle some level of occlusion. In the video below, you can see the author of MIL tracker Dr. Boris can look at Babenko to see how the MIL tracker works as a snag.

Tracking preserves identity

The output of object detection is an array of rectangles that contain an object. However, there is no identification associated with the object. For example, in the video below, a detector that detects red dots will produce rectangles corresponding to all the dots it has detected in one frame. In the next frame, it will produce another array of rectangles. In the first frame, a particular point can be represented by a rectangle at position 10 in the array and in the second frame, it can be at position 17. When using detection on the frame we do not know to which object the rectangle corresponds. On the other hand, tracking literally provides a way to connect the dots.

OpenCV 3 Tracking API

OpenCV 3 comes with a new tracking API that has an implementation of multiple single object tracking algorithms. OpenCV 3.4.1 has 8 different trackers available - BOOSTING, MIL, KCF, TLD, MEDIANFLOW, GOTURN, MOSSE and CSRT.

Note: OpenCV 3.2 has implementations of these 6 trackers - BOOSTING, MIL, TLD, MEDIANFLOW, MOSSE and GOTURN. There are implementations of these 5 trackers in OpenCV 3.1 - BOOSTING, MIL, KCF, TLD, MEDIANFLOW. OpenCV 3.0 has implementations of the following 4 trackers - BOOSTING, MIL, TLD, MEDIANFLOW.

Update: In OpenCV 3.3, the tracking API has changed. Checks the code for the version and then uses the corresponding API.

Before we provide a brief description of the algorithm, let us look at the setup and usage. In the comment code below we first set up the tracker by selecting a tracker type - Bosting, MIL, KCF, TLD, Medianflow, Gothorn, Mosey or CSRT. We then open a video and hold a frame. We define a bounding box containing the object for the first frame and initialize the tracker with the first frame and the bounding box. Finally, we read the frame from the video and update the tracker in a loop to get a new bounding box for the current frame. Results are displayed later.

1.2 Need Analysis

Our Autonomous goalkeeper can be generalized as an Autonomous target interceptor. It has a number of uses in sports and entertainment industry. But most importantly it can be used in defense to develop Ballistic missiles and target interceptor for the Indian forces. Currently, the technology is under research by DRDO. This technology has already been developed by Israeli military to counter any Arabic missiles and Palestinians attacks. To develop it in 3d is close to impossible thus, our group is trying to make it in 2d as a first step to improve the technology.

The main requirements to make it a success are:

a. The Bot(goalkeeper) must have a motor that can allow the bot to move quickly.

b. A camera that can record the ball movement in at least 40Fps.

c. The camera must employ a raspberry Pi to process the live feed, we can also transfer the live feed to laptop computer via Bluetooth or Wi-Fi.

d. The computer (laptop / raspberry pi) must compute the predicted the landing point for the ball and must instruct the bot to move accordingly.

e. The computer will communicate with the bot through a wireless communication device namely, ZigBee.

To elaborate on this point, this ball tracker or live object tracker model can be used in various other fields. Such as in prisons to keep track of all the prisoners. In Zoos, to keep track of all the animals, especially animals like Lions and Tigers. It can be used in Self driving cars to track the objects in the front to take actions if necessary. There can be an infinite number of fields where this technology can be used.

1.3 Research Gaps

As of now, our project is to develop a live object tracker and real time tracker. Our aim includes technologies like Python, machine learning, artificial intelligence, OpenCV and Arduino. To mention the research gap currently present, we can say individual developers have been successful in developing certain technologies required to make this project however there are still some things that have not developed , for instance the live object tracker has to be trained under the constraint that the background will remain the same and will not change during the course of the target's movement.

Also the bot that our team is working on required very high technology that has not been developed yet. To make our project work in 3d, it will require spring configuration and jump control which is still in research at Cambridge and other foreign optimized.

The AI Gap study, a PYMNTS and Brighton collaboration, analyzes survey response data from more than 200 financial executives from commercial banks, community banks, and credit unions across the United States to provide comprehensive information on how financial institutions leverage AI and ML technology gives. Optimize your businesses. For this, we collected over 12,000 data points on financial institutions with assets ranging from $1 billion to over $100 billion. This report details the results of our extensive research.

Key Findings from the research include: 70.5% part of Fis that used data mining to fight fraud, 4.1 Average number of algorithmic things used by banks with more than $100 billion in assets and 2.5% Share of Fis that used AI systems is to empower payments services.

1.4 Problem Definition and Scope

Our Group is determined to design an Autonomous goalkeeper capable of intercepting balls that are aimed towards the goal post, the keeper is programmed to protect. The Project involves a number of state-of-the-Art technologies like ball tracking and motorized optimized movement. Our design will only work in 2 dimensions. We will employ a number of Machine learning algorithms and image processing algorithms. In this project we present the design and implementation of our Small Size Robotic Soccer Goalkeeper. We explain the three main components of our architecture: Vision System, AI System and Robots. Each element is an independent entity and therefore the explanation focuses on the improvements made to our object tracking techniques and the way these changes interact with the rest of the elements in the architecture.

Keywords: Small-size, robo-football, autonomous, vision, architecture.

The final project will include a camera module optimized to a frame rate that will be transferred to the computer immediately and a machine learning algorithm drafted in Python 3 that will take in frame recorded from the camera and will determine its locations and angle, speed with respect to the previous location. The angle and speed calculated will be stored in a database that will be used to predict the final landing point of the ball. The Python program will trigger the Arduino program that will calculate the distance, speed and direction of the bot required to stop the ball from hitting the target. The instructions will be transferred to the bot via a zigbee and the bot will execute the instructions with the help of an Arduino attached to it. The bot will be made by reverse engineering a wireless remote controlled car or will be designed from scratch with a high speed motor at the very base.

1.5 Assumptions and Constraints

TABLE 1: Constraints

S.No.	Constraints
1	The Ball shot by the player must not gain any height, that is, the design will work only in two dimensions and not in 3 dimensions.
2	There must be a minimum lag between the live feed of the ball's movement and the final machine learning prediction of the ball's landing position.

TABLE 2: Assumptions

S.No.	Assumptions
1	The Ball will move in 2 dimensions only, i.e There will not be any height involved.
2	Since the acceleration by the motor will give rise to unpredictable error, we will assume that motor will have no acceleration.
3	The speed of the ball will not exceed a certain maximum speed due to technical limitations of computer.
4	The ball will be moving on a plain, uniform friction surface and surface will be of uniform color to ease the image processing computations.
5	The ball will be of spherical shape, of tennis ball's size and not of any other shape or size.
6	The live feed will have some delay and frame stuttering.

1.6 Approved Objectives

The aim of the project is to design an Autonomous goalkeeper System such that:

- The system will be able to successfully detect the presence of the ball in live camera feed.
- The system should be able to accurately predict the future location of the ball.
- The system should be able to control the bot properly with commands.
- The goalkeeper bot shall be able to intercept the football before it hits the goal post.
- The camera-computer combination will be able to track the ball's position accurately and predict its route.
- The bot will have high speed motor to ensure quick movement.

1.7 Methodology Used

Use State of the art object tracking technology to track the movement of the ball shot by the player.

- Employ a camera that will transfer the live feed of the ball's movement to the computer.
- The computer will predict the most probable final landing position of the ball by employing various machine learning, neural networks and image processing technologies.
- The computer will ascertain the bot's current location and accordingly compute the direction and time in which the bot must move to intercept the target or the ball.
- The bot will communicate with the computer through a Zigbee.
- The bot will employ an Arduino that will provide all the control signals.

1.8 Project Outcomes and Deliverables

There are various outcomes to this project:

- The player or the user will kick or strike the ball.
- The ball will be tracked by the camera-computer arrangement,
- An ML model which will be used to compute the final landing position of the ball.
- A computer will communicate with the goalkeeper bot and order it move accordingly so as to intercept the ball before it hits the target.
- The computer program will assume that the bot has successfully intercepted the target and will loop to the beginning again.

1.9 Novelty of Work

Many individual developers have made strives in this field, ie. Object tracking. However, no one has yet combined all the progress into one massive project that works in real time. The project is unique to an extent, the field of object tracking is very old, it was first introduced in the 1980s as a sub-part of Artificial intelligence but remains theoretical till date,no one has made strides to make a working project that involves arduino, zigbee, artificial intelligent Bot and ball tracking.

2.1 Literature Survey

2.1.1 Theory Associated with Problem Area

Interception (approaching a moving object until collision) and tracking (approaching a moving object while matching its location and velocity) are important tasks in a wide range of applications, such as robotic soccer and automated surveillance. In addition, they represent a challenging test bed for the integration of various technologies including image processing, filtering, control theory, and AI strategies. Interception and tracking have been largely addressed in the literature based on targeted motion characteristics as well as robot kinematic. And dynamic models. The instantaneous target location and velocity can be known in advance as part of a reference trajectory or can be estimated and inferred through sensory data.

2.1.2 Existing Systems and Solutions

A common strategy known as PPE (prediction, planning, and execution) focuses on time-optimal blocking, possible when the target speed is fully (or substantially) already known; In this case, the problem is essentially planning a robotic trajectory leading to a suitable trajectory. For example, a time-optimal technique for free-flying interceptors and targets. Such an approach can be extended to manipulations to achieve smooth grasping inhibition with terminal-well matching by pairing with traditional tracking methods. An active PPE technique for the 6-dof manipulator is designed to improve the basic PPE strategy. When the target speed is not already known and / or can change abruptly, it is necessary to rely on some kind of estimate of its position and velocity coming from the sensor data. A particularly interesting situation is the use of visual feedback. In the position-based visual servo, the target pose is estimated based on visual data and geometric models. For example, a ubiquitous indirect vision system is used to determine robot posture from feature extraction, so that the basic tasks of a robot goalkeeper can be accomplished in terms of trajectory and posture stabilization. In this context, Kalman filtering is often used to derive a strong prediction of target motion. In image-based visual servings, the spatial relationship between the target and the robot camera is directly estimated on the image plane, and the error signal is expressed in terms of image features. Originally developed for robotic manipulators equipped with eye-in-hand systems, image-based visual servos have also been applied to non-economic vehicles such as wheel mobile robots.

2.1.3 Research Findings for Existing Literature

TABLE 3: Research Findings

S. No.	Roll Number	Name	Paper Title	Tools/ Technology	Findings	Citation
1	101603364	Utkarsh Chugh	Visual Servoing of Wheeled Mobile Robot for Intercepting a Moving Object.	Camera, Ball Tracking Algorithm	The required resolution and frame rate to track moving ball.	Agin, G.J. [4]
2	101603364	Utkarsh Chugh	Mechatronic Design of Soccer Robot for the Small-Size League (RoboCup)	Construction of soccer bot	The required configuration of motors (rpm)	Sanderson[7]
3	101610093	Vaibhav Sood	Robot GoalKeeper	Python, Image Processing using MATLAB, Arduino, Motors	Object tracking algorithm implementation using Python	Watanabe [5]
4	101610093	Vaibhav Sood	Real time OpenCV Ball Tracker	Python, OpenCV	Object tracking algorithm implementation using Python	Anderson, Peterson, Shenker, Turner [1]
5	101610091	Taranjeet Singh	Arduino controlled Robocar	Arduino, Bluetooth, RC Car, Wireless Communication	Assembling the RC Car and running it using Arduino	Al-Husseiny, Appelgren, Mustini [3]
6	101611057	Tushar Mahajan	Small Size Soccer Robots	Camera Network	Object Tracking techniques currently in use	Chaumette, Hutchinson [6]
7	101611057	Tushar Mahajan	Controller Design for High-Performance Visual Servoing	Camera Configuration, Robot Configuration	Object Tracking for high speed moving objects.	Duncan [2]

2.1.4 The Problem That Has Been Identified

The problem identified in literature survey is that in most of the surveys, high end devices are used which are not easily available in the current market and are too expensive to be used in our project. Moreover, some surveys have used a ready-made soccer-bot with built-in wheeled motors and camera. The actual tracking algorithm and the technology used are not mentioned in any of the survey. Only the essence behind tracking the ball is discussed.

2.1.5 Survey of Tools and Technologies Used

To carry out with the literature survey the methodology used by the members is to read all the research paper to get the wide idea about what all the research is done till now and how the specified project is innovated by the members.

Our research is more focused on ideas rather than research paper. We used various tools for making literature survey:

i. Web Browser to look for research papers.

ii. Mendeley for references and to manage literature.

iii. Adobe Crater for making PDF.

iv. Microsoft word to format and write the literature survey.

2.2 Standards

❑ISO 20954 – Image Stabilization standard for camera

❑ISO 20490 – Auto Focus Standard for Camera

❑ISO 19093 – Low Light Performance Standard

❑IEEE 802.11 – Wireless Communication

❑ISO 10218-1:2011 specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots.

2.3 Software Requirements Specification

2.3.1 Introduction

This section introduces about the project. It describes about the specifications of project. It also states about requirements of the project.

2.3.1.1 Purpose

This Software Requirements Specification (SRS) documents the key specifications, which describe a prototype in terms of functional and non-functional requirements for autonomous documentation. The documented information helps the intended audience to design and develop the product. We are launching an official prototype version and modifying it according to user needs.

2.3.1.2 Intended Audience and Reading Suggestions

The primary readers of this document are IoT researchers, software and hardware developers, and intended audiences. This document is for:

Developers: To be assured they are developing the right project meeting the requirements provided in this project.

Examiner: To keep an accurate list of features and functions, which will react according to requirements and diagrams provided.

Documentation Author: To know what the features are and how they will explain. What technologies are required, how the system will respond to each user's action, etc.

System Administrator: Correct input and output and feedback in error situations to know what they would expect from the system.

2.3.1.3 Project Scope

The scope of this project will be to produce a product that allows real time target tracking and accurate target interception. If developed further, this project can be utilized by Sportsmen like football players, rugby players and cricketers mainly for the purpose of training and practice. This technique can be further developed to manufacture a missile interceptor for Indian Defense. A weapon that no country posses , not even USA. This weapon can give any country massive advantage over its enemies. Anti- missile weapon is the ultimate protection any country can hope for. The techniques involved in autonomous goalkeeper are very similar to techniques that will one be used to develop the ultimate anti missile project. Currently, Israel is the only country that has openly invested in this project and even has developed a working prototype with respectable accuracy and hit scores.

2.3.2 Overall Description

The description about the project is mentioned below under different sections. The section mainly explains the product perspective and Product features.

2.3.2.1 Product Perspective

As a matter of fact, sports is a multi billion dollar industry , every player professional or not strides to improve his/her performance and most of these players are ready to pay for a device that can allow them to improve without the need of another trainer, example automatic ball throwing machine used in baseball and cricket.

However, no matter how weird it may sound, there is no product available that can allow a football player to practice his/her kicks without any external help, thus our team decided to work on this project “Autonomous Goalkeeper and object tracker”.

This project’s prototype if developed further can be used to develop a product that can allow the football players to practice without external help.

2.3.2.2 Product Features

Use State of the art object tracking technology to track the movement of the ball shot by the player.

- Employ a camera that will transfer the live feed of the ball’s movement to the computer.
- The computer will predict the most probable final landing position of the ball by employing various machine learning, neural networks and image processing technologies.
- The computer will ascertain the bot’s current location and accordingly compute the direction and time in which the bot must move to intercept the target or the ball.

• The bot will communicate with the computer through a Zigbee.
• The bot will employ an Arduino that will provide all the control signals.

2.3.3 External Interface Requirements

The section explains about the External interface requirements. Under this section, Some light is shed on the user, hardware and software interfaces.

2.3.3.1 User Interfaces

The User interface includes the person to hit the ball in the direction of the goalpost. Also user can see the process of path prediction of the ball in real time by looking at the PC's screen.

2.3.3.2 Hardware Interfaces

A hardware interface is an architecture used to interconnect two devices together. It includes the design of the plug and socket, the type, number and purpose of the wires and the electrical signals that are passed across them.

The solution makes extensive use of several hardware devices. The camera module is connected to the PC using USB version 2.0/3.0. The PC is connected to rc bot using wireless connection through Wi-Fi. The bot itself has connections for power supply which is done using battery.

2.3.3.3 Software Interfaces

Software interfaces (programming interfaces) are the languages, codes and messages that programs use to communicate with each other and to the hardware.

In this project the live video stream is transferred to a PC using machine code sending pixel values, which are in bits, in 30fps refresh rate and then PC process the live stream. We use python through which the machine learning model trains and predicts ball’s path and PC uses machine code to communicate with rc bot through wireless connection.

In RC bot also it uses information in bits 0 and 1 to tell the motors to rotate and in which direction.

2.3.4 Other Non-functional Requirements

2.3.4.1 Performance Requirements

a. USB camera must get updates about the visual after a certain period.
b. Goal-Keeper Bot should remain active during movement of ball.
c. Camera response time is in the range of 3ms to 5ms according to ping received.
d. Using a Wireless system, Latency is minimized during capturing of frames.

2.3.4.2 Safety Requirements

a. Bot is rubber coated to withstand any physical damage when hit by a ball.

b. Ball should not be kicked at very high speed.
c. Electricity should not be shut-off as camera would fluctuate.

2.3.4.3 Security Requirements

a. Tampering of camera should be avoided as results generated would be inaccurate.
b. Data is saved directly in the database protected with password.
c. Only relevant data should be send to the server.

2.4 Cost Analysis

USB-Camera for recording and transferring the feed live - Rs2000, RC car(required for assembling the goalkeeper) - Rs2000, Arduino(fitted with Zigbee/Bluetooth) for receiving live commands from the Processor - Rs1000, Zigbee module -Rs980, Total cost - Rs5980/-

2.5 Risk Analysis

Though our project is taken care of every causality but certainly there can be many flaws and further risks involved if not checked every part of our project's functioning. Some of the major can be-

a. Missing the information of objects in front of camera due to usage of low pixel camera
b. Improper Object detection after detecting them by camera due to some errors in algorithm used or some modifications may lead to mixing of objects which are closely related such as a bottle of water and a bottle of wine.
c. Sudden stoppage in working of product due to improper supply from poor quality battery used.
d. Communication error due to the use of Zigbee.
e. Delay in the response time of bot because of latency in camera-computer interconnection.
f. Background may interfere with the ball causing low accuracy in object detection.

3.1 Investigative Techniques

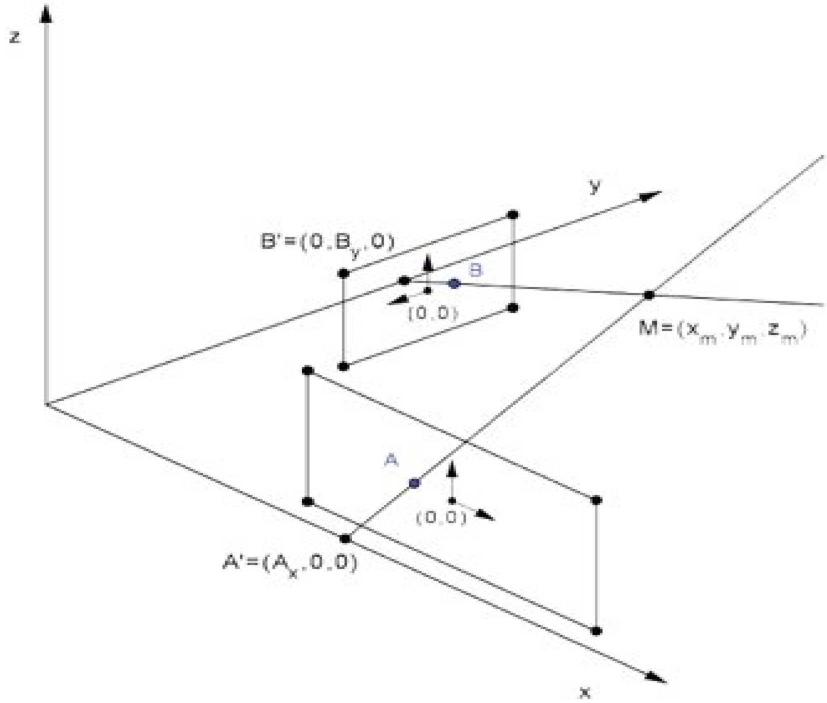

Figure 1: Using 3-D Algebra of positions of all entries

According to the mentioned above techniques this project uses the descriptive technique of the investigative techniques this is because as mentioned in the descriptive technique the new models, concepts and systems are designed. The system is designed keeping in mind that we need to stop the ball before it hits the goal post.

The main objective is to catch the ball before it hits the goal. Therefore we need a system that can see and detect the ball's position, predict its future path and ultimately make the movable rc bot to stop it.

So the system needs to be able to see the ball somehow, this could be easily done with any camera module. The camera module would be connected to the system by either wireless or wired architecture.

The system needs to detect the ball and calculate its location relative to the frame of the camera, for this we can use existing technologies like object detection using machine and deep learning.

Also we need to predict where the ball is going and what its end point will be, before it is actually able to do that so we can take action in time to stop it. To do this we would need to use machine learning algorithms.

After predicting the ball's final position, system need to give instructions to the rc bot to stop it, For this we should use wireless communication like Wi-Fi.
After receiving the instructions from pc rc bot will stop the ball from hitting the ball and our objective will be complete.

3.2 Proposed Solution

- Use State of the art object tracking technology to track the movement of the ball shot by the player.
- Employ a camera that will transfer the live feed of the ball's movement to the computer.
- The computer will predict the most probable final landing position of the ball by employing various machine learning, neural networks and image processing technologies.
- The computer will ascertain the bot's current location and accordingly compute the direction and time in which the bot must move to intercept the target or the ball.
- The bot will communicate with the computer through a Zigbee.
- The bot will employ an Arduino that will provide all the control signals.

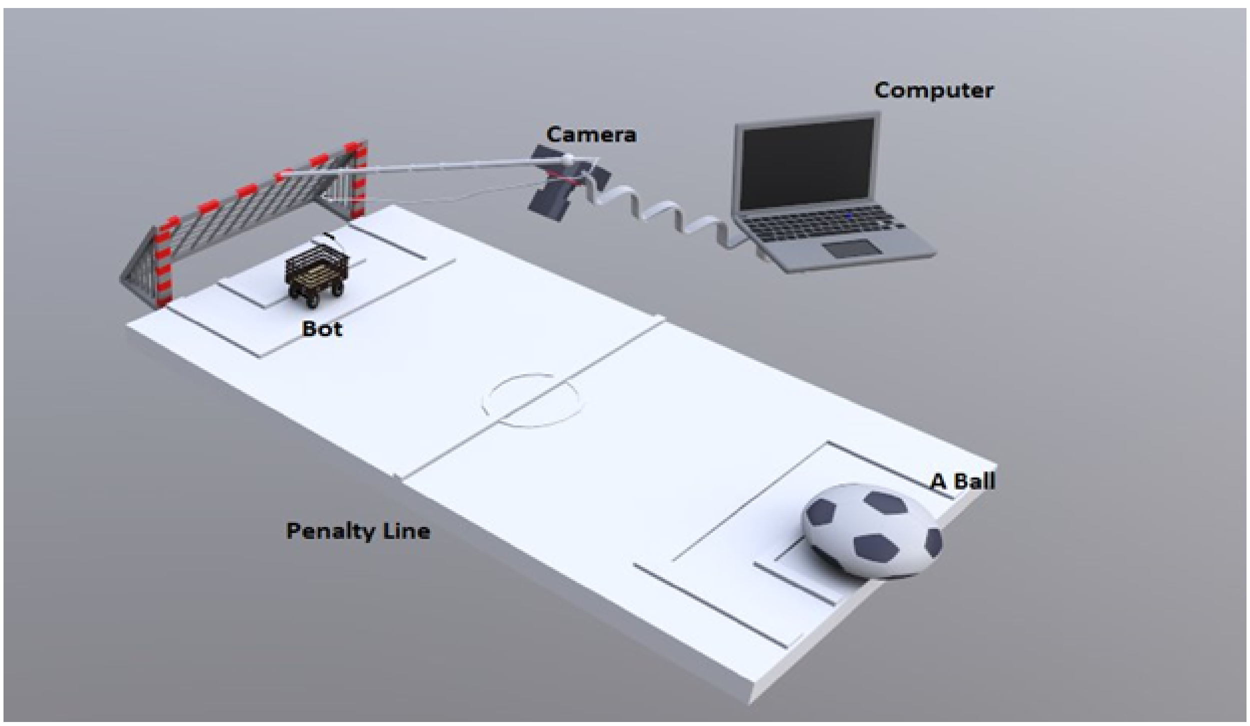

Figure 2: Methodology used

3.3 Work Breakdown Structure

A work-breakdown structure in project management and systems engineering, is a deliverable-oriented breakdown of a project into smaller components. A work breakdown structure is a key project deliverable that organizes the team's work into manageable sections.

The work breakdown structure for the project is given below:-

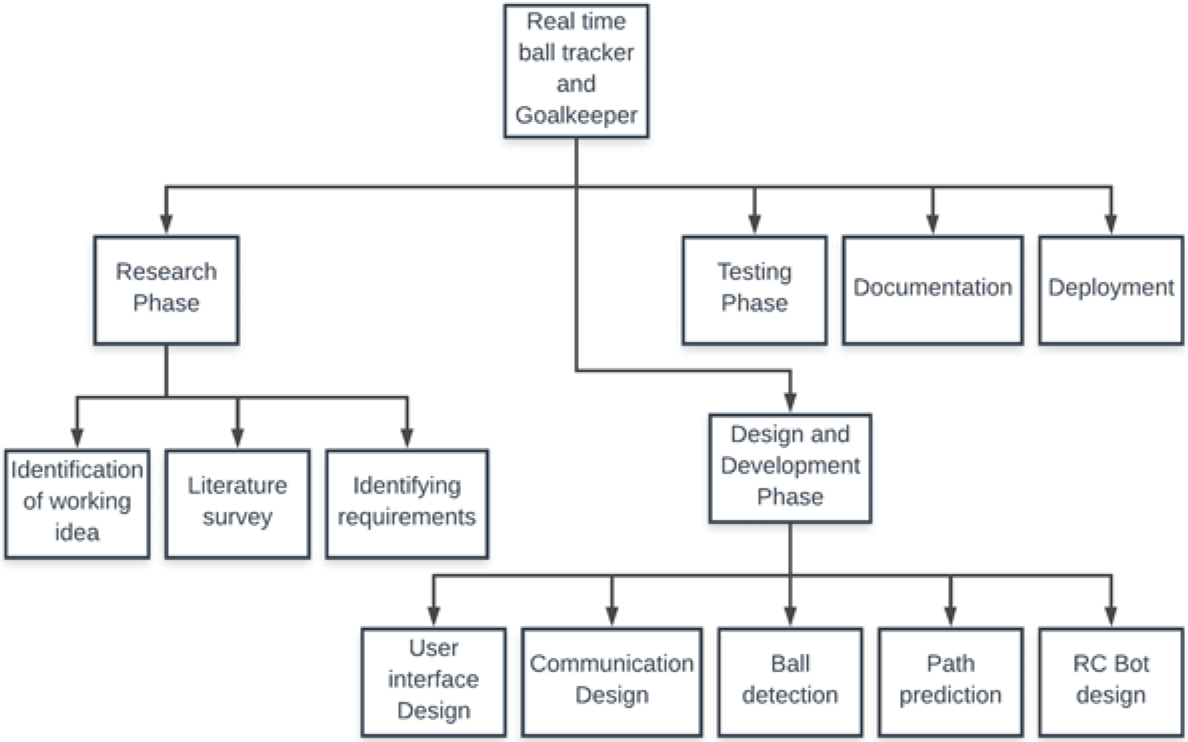

Figure 3: Work-BreakDown Structure

3.4 Tools and Technologies Used

- Camera module: A camera is required to give the live feed of project area to the computing device.
- Computing device: A powerful enough computer is required to do real time object detection of the ball and predict its path. It will also send instructions to the Arduino placed on RC car.
- Arduino: Arduino board is composed of a microcontroller, some LEDs, a reset button, and many pins that we can use for input/output operations. With so many pins available, we will read data from sensors, control different motors and actuators.
- RC car: It will move in a specific direction and for a specific time based on the instructions from the computer, so that it can intercept the ball and prevent goal.
- Goal Post: Some other physical things are required to complete the project like goal post.
- Microsoft Visual Studio: To make a nice and simple user interface for most of the people.
- MatLab: It could be needed to do some more complex calculations.
- Python: Python contain special libraries for machine learning namely scipy and numpy which great for linear algebra. The language is great to use when working with machine learning algorithms and has easy syntax relatively.

4.1 System Architecture

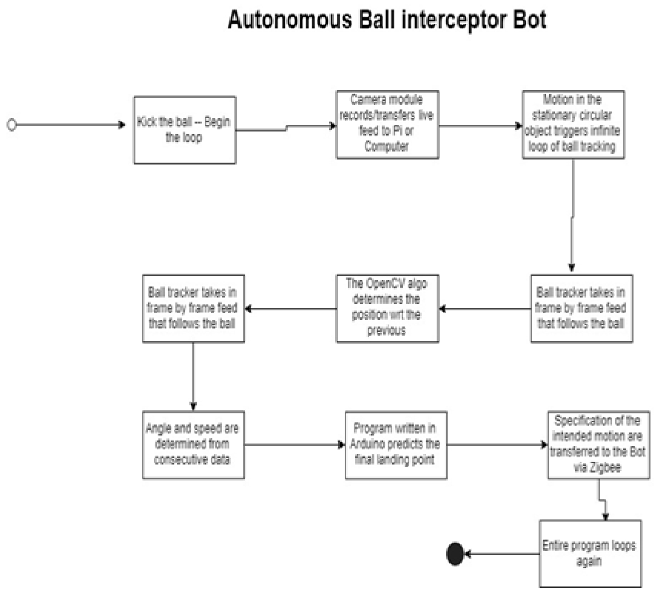

Figure 4: System Architecture

4.2 Design Level Diagrams

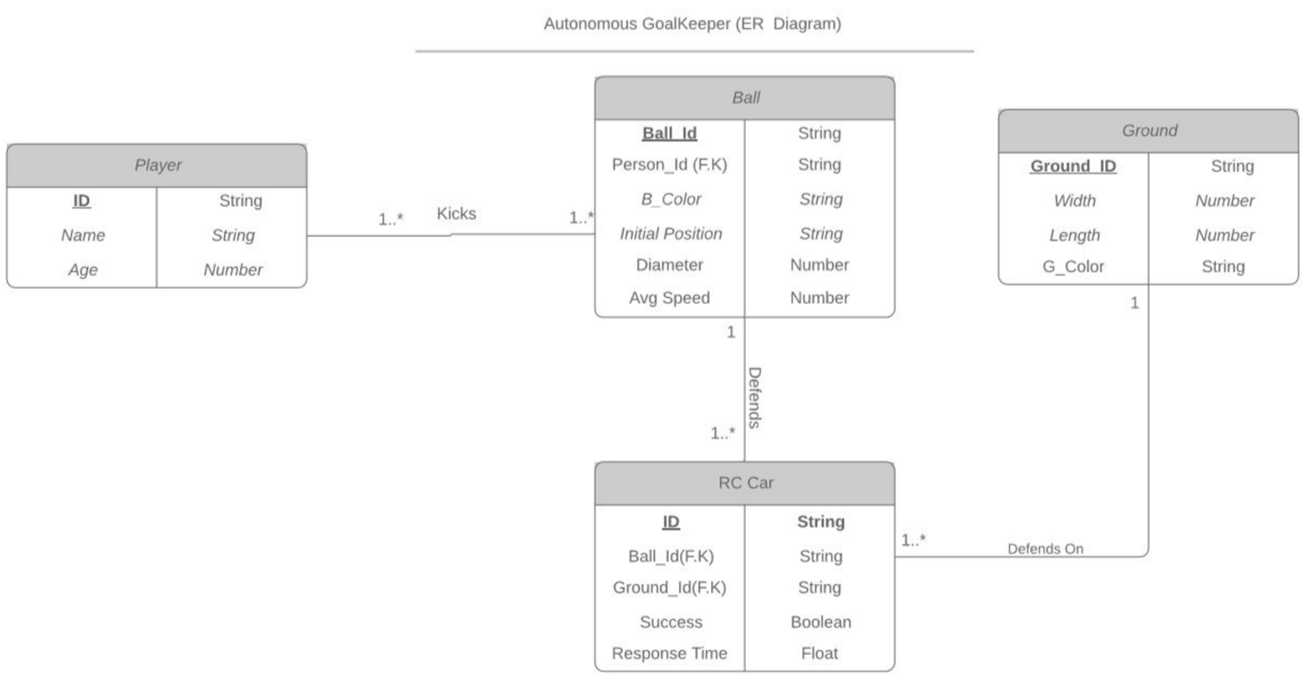

Figure 5: ER Diagram

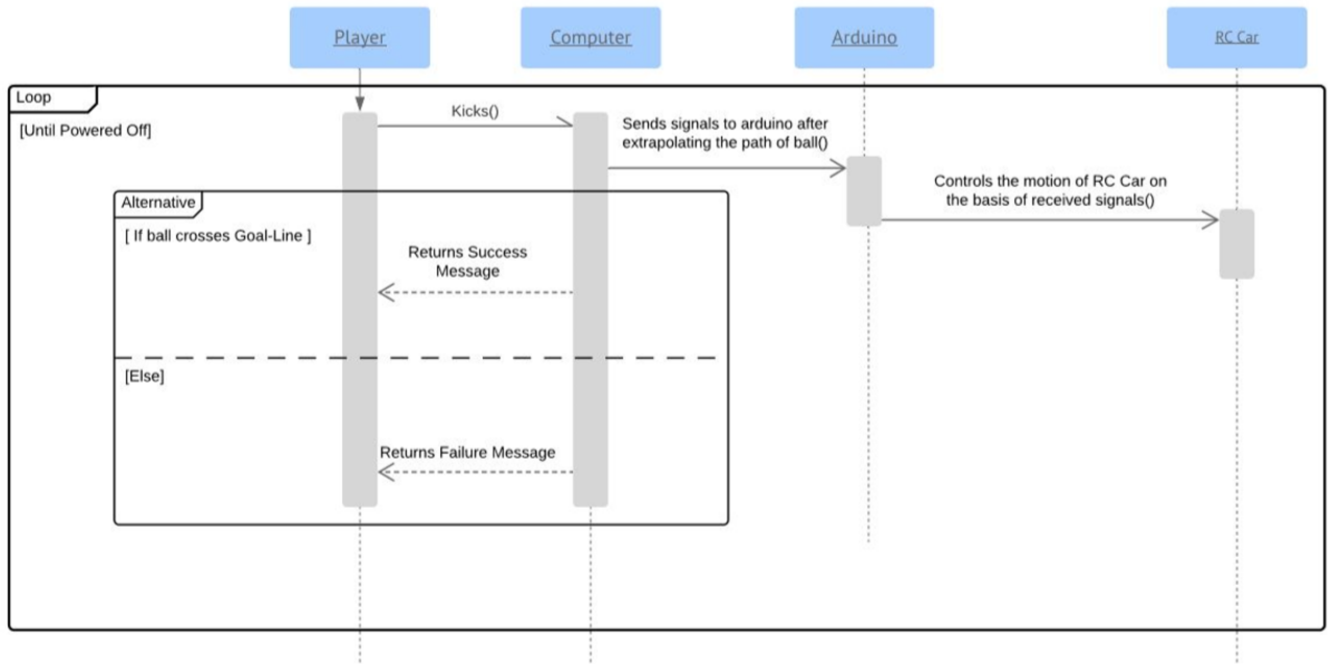

Figure 6: Sequence Diagram

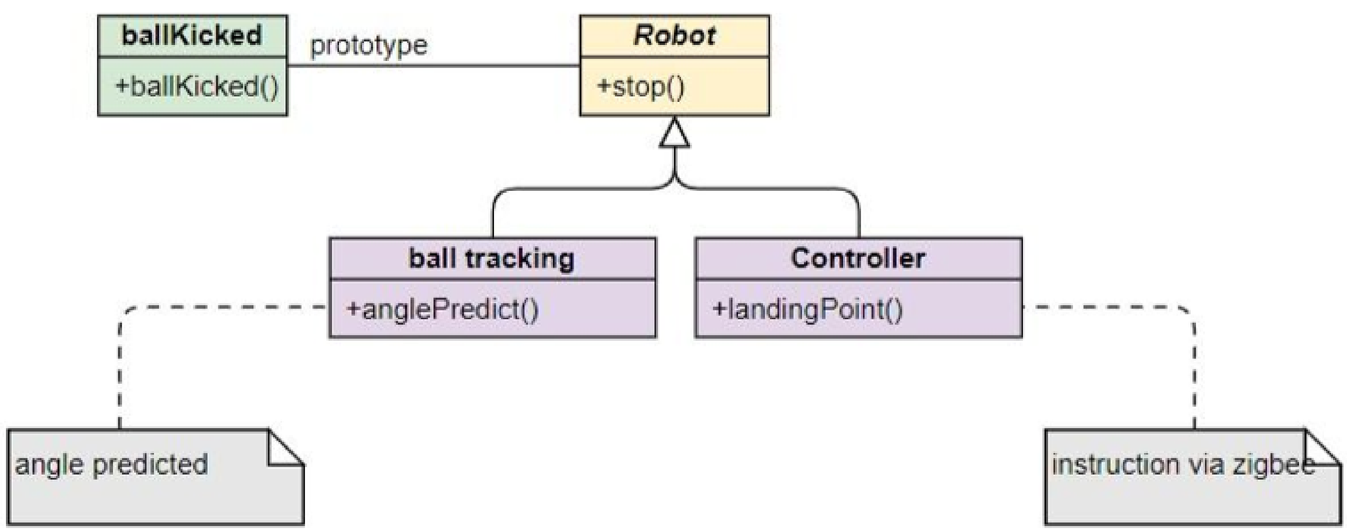

Figure 7: Class Diagram

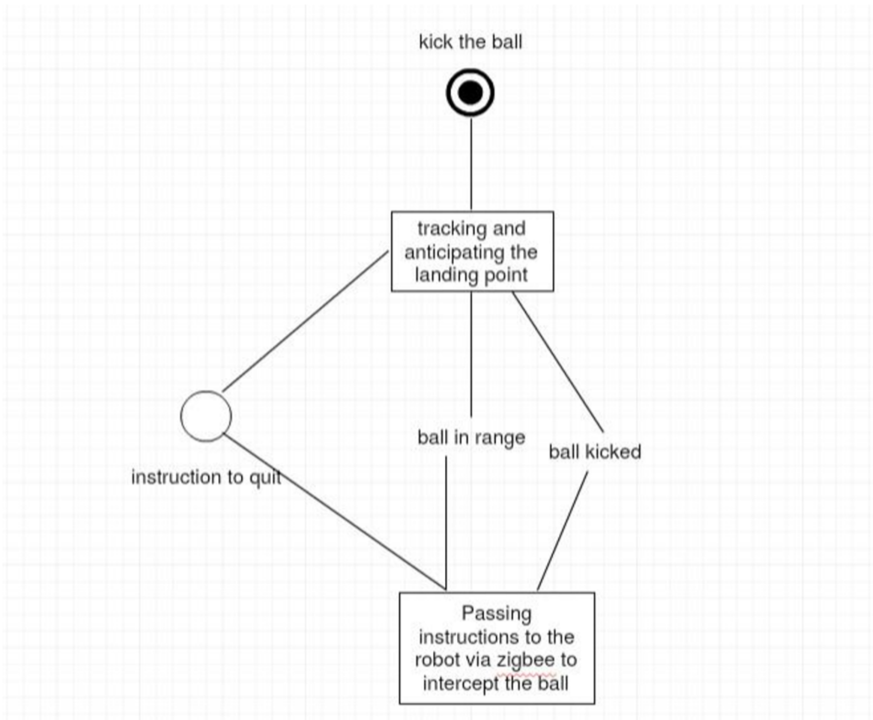

Figure 8: State Chart Diagram

Tracking the ball

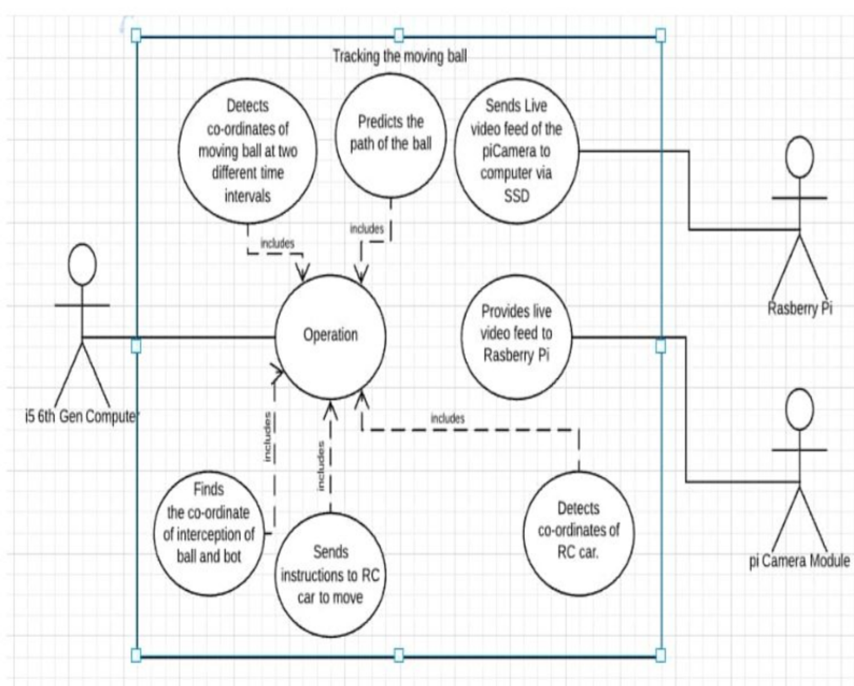

Figure 9: Use Case #1

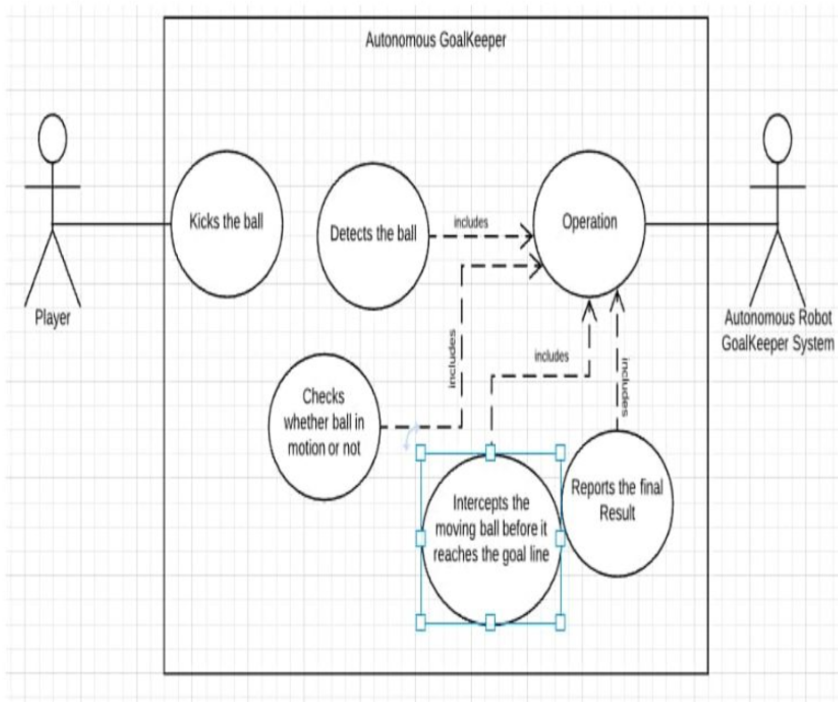

Figure 10: Use Case #2

Intercept the moving ball

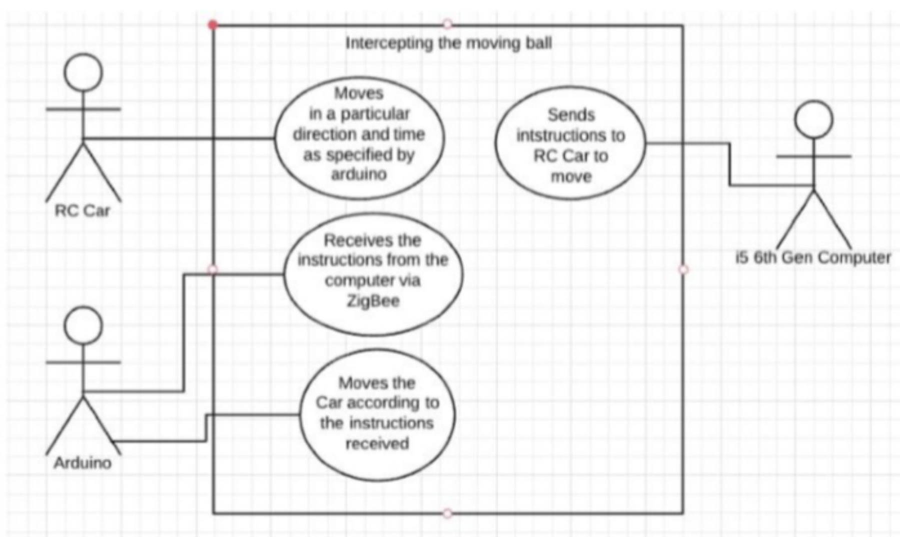

Figure 11: Use Case #3

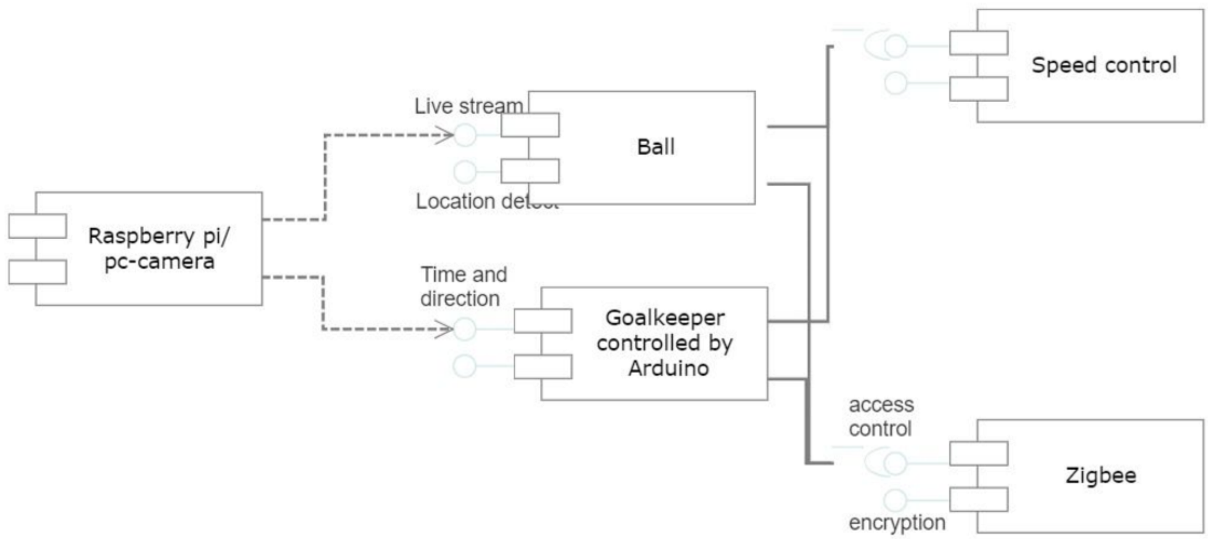

Figure 12: UML Component Diagram

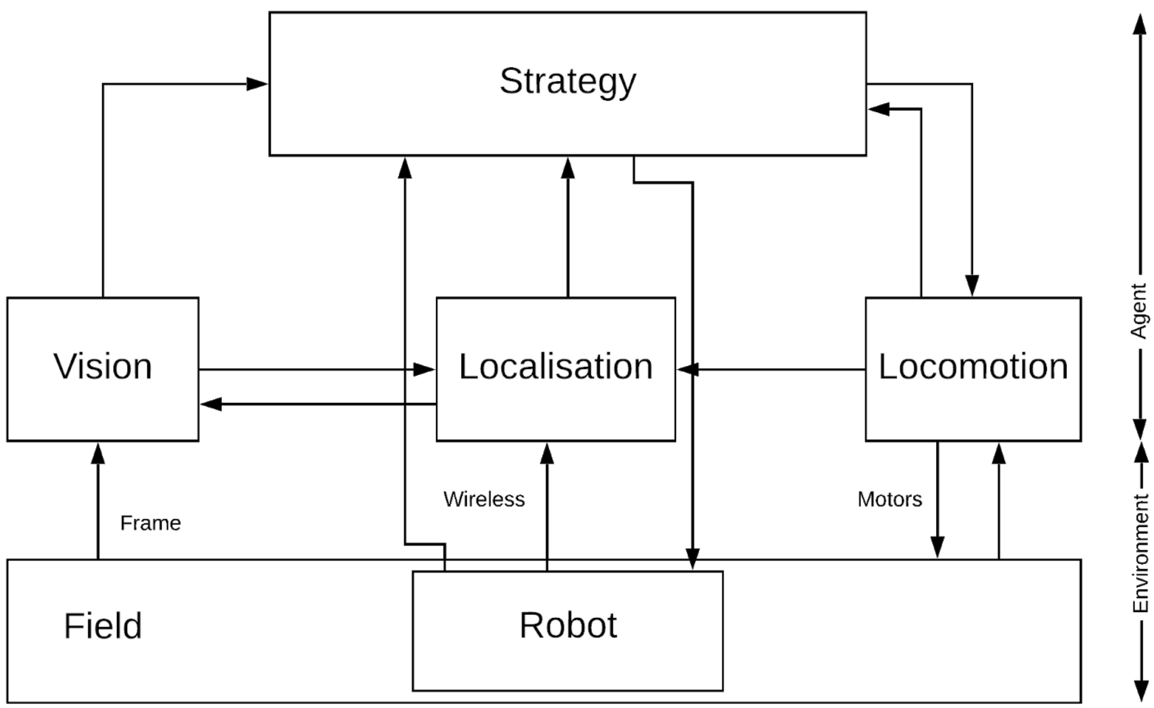

Figure 13: Conceptual Architecture of the system

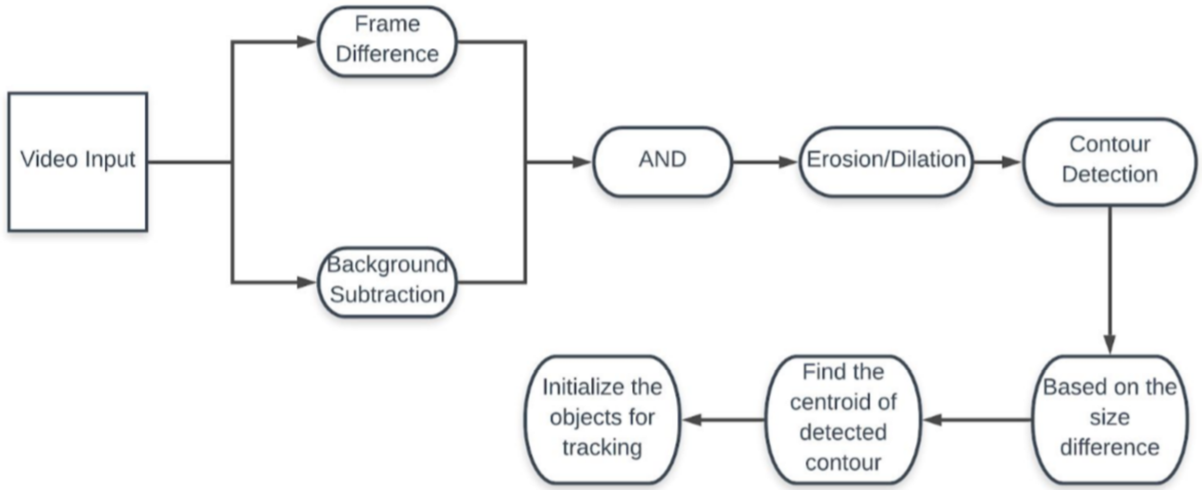

Figure 14: Object Detection Architecture

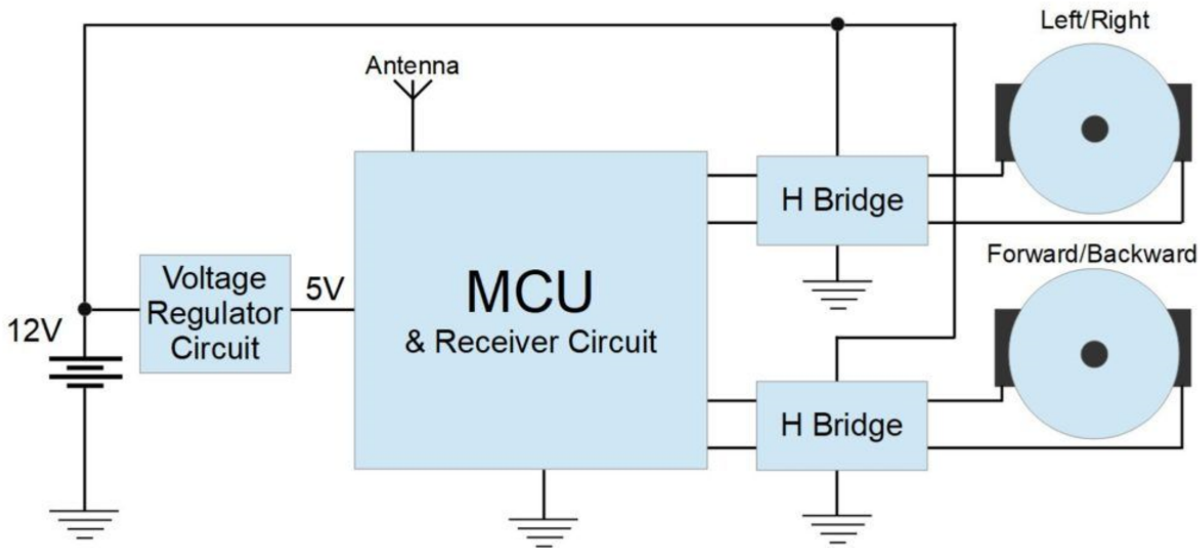

Figure 15: Architecture of Moving Bot

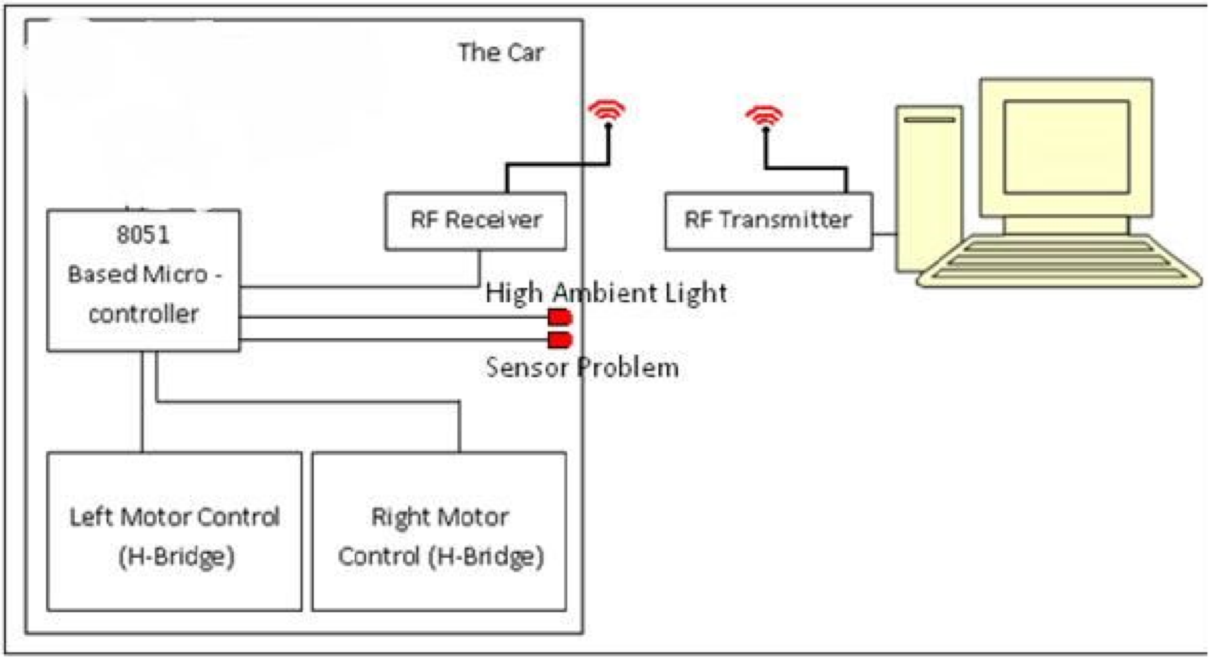

Figure 16: Connection Architecture

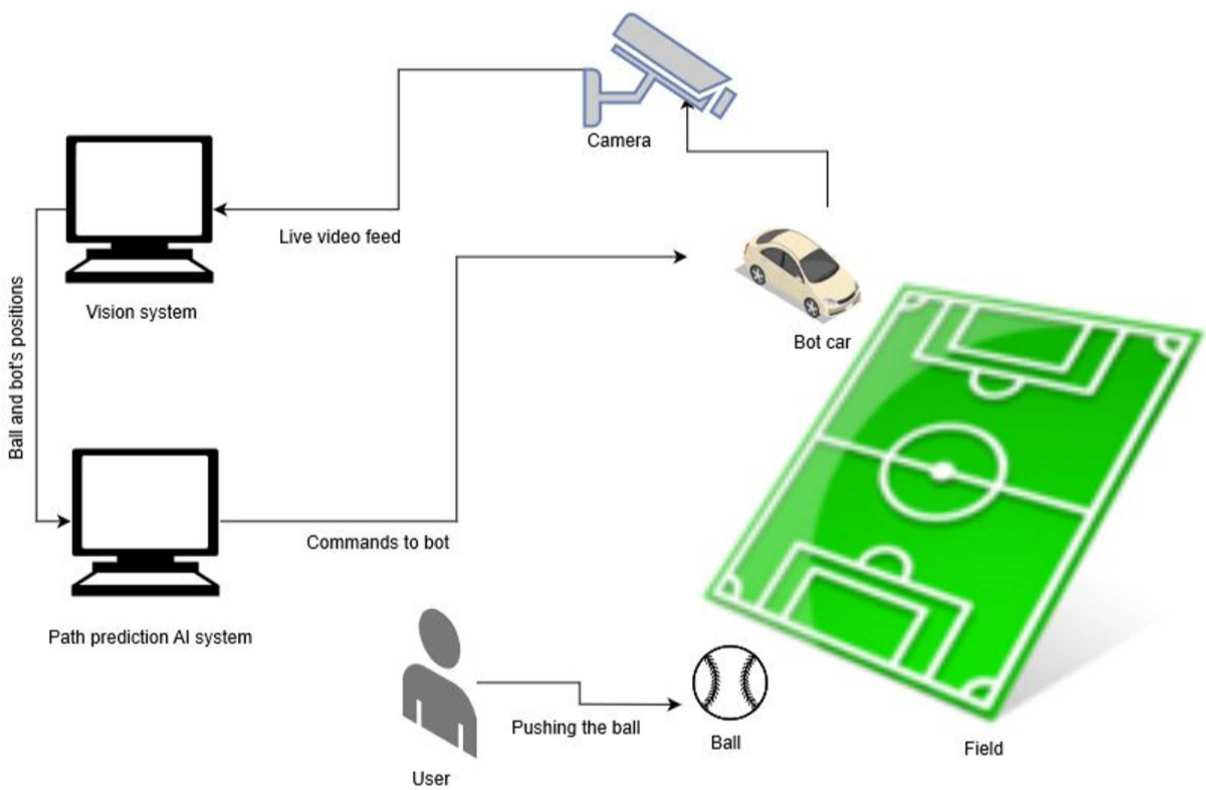

Figure 17: System Architecture

4.3 User Interface Diagrams

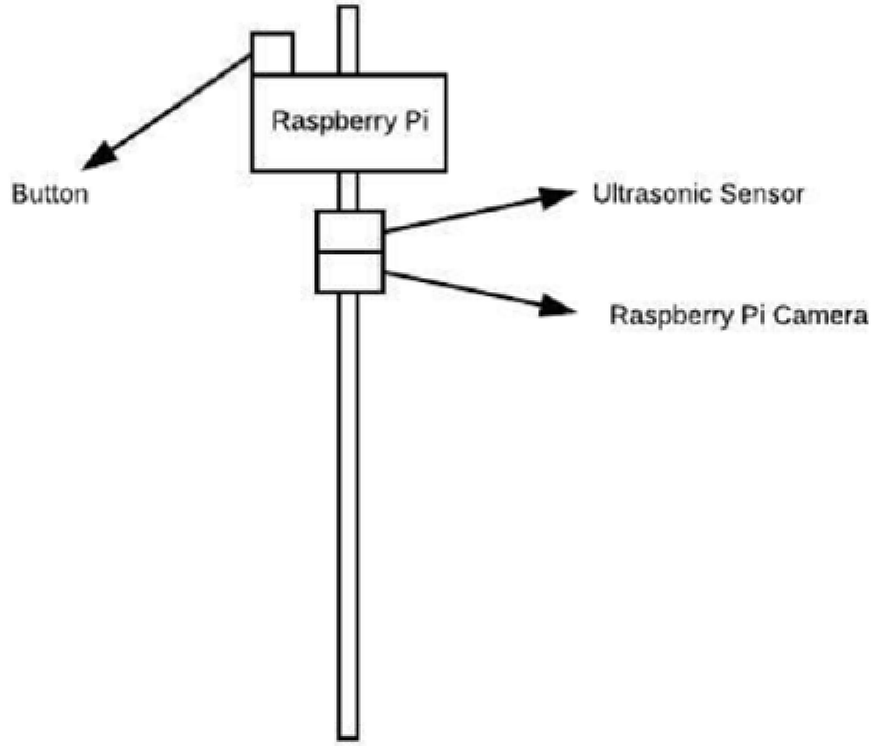

Figure 18: User Interface Diagram

5.1 Experimental Setup

The final setup would be as follows:-

- A goal post of a length suitable to the dimensions of the room(3-5 Metres)
- The uniform ground(color and surface)
- A remotely automated RC car that will behave as the goalkeeper
- Movement of the RC car will be restricted in 1-D only
- A green colored ball with suitable dimensions(4-6 cm radius)
- An overhead camera to observe and detect the events
- An arduino combined with the RC car to receive instructions from the computation program and to provide instructions to the RC car
- A machine learning program to detect the ball's movement and predict the final landing point.

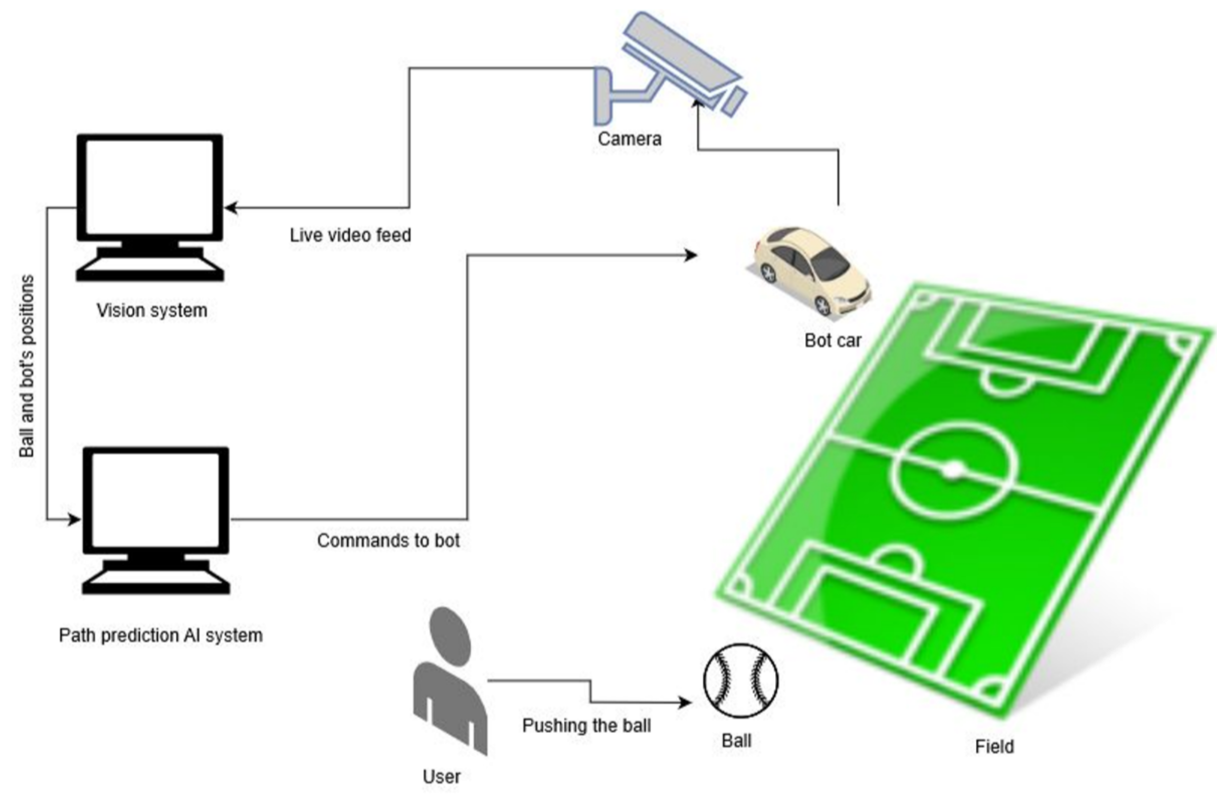

Figure 19: A Simulation model of the Experimental setup

5.2 Experimental Analysis

5.2.1 Data

- The Machine learning program can predict the ball's movement with more than 95% accuracy and it can predict its centre with a whopping 100% accuracy.
- The machine learning program can handle a frame rate of 30 or less
- The ball can have a maximum velocity of 0.7m/sec for accurate prediction. However in some cases this velocity can be 2m/sec as well.
- The RC car can attain a maximum velocity of over 1.5m/sec.

5.2.2 Performance Parameters

The software was executed in different environments before final accuracy was derived. The software's accuracy is 100% when background is of uniform color and surface and less than 70% when background is non uniform and lighting is non uniform. Thus giving us an average accuracy of over 95%.

Ball's of different colors were used before finally landing on the color green because of the advantage that the color does not interfere with the background.
More than 1000 test cases different starting coordinated were run to identify the suitable speed of the ball.
Different frame rates were chosen before landing on the suitable number 15 that balances accuracy and execution speed.

5.3 Working of the project

5.3.1 Procedural Workflow

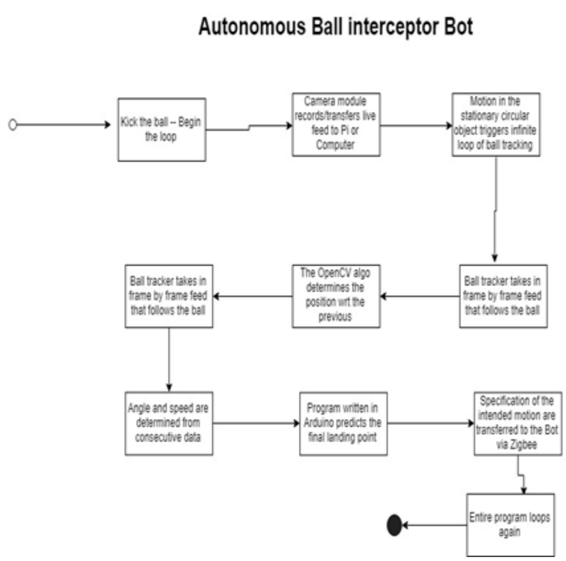

Figure 20: Procedural Workflow Diagram

5.3.2 Algorithmic Approaches Used

The Viola-Jones Object Detection Framework is the first voice detection framework, which provides a real-time competitive object detection rate, proposed in 2001 by Paul Viola and Michael Jones. Although it can be trained to detect different types of object classes, it was mainly inspired by the problem of facial recognition.

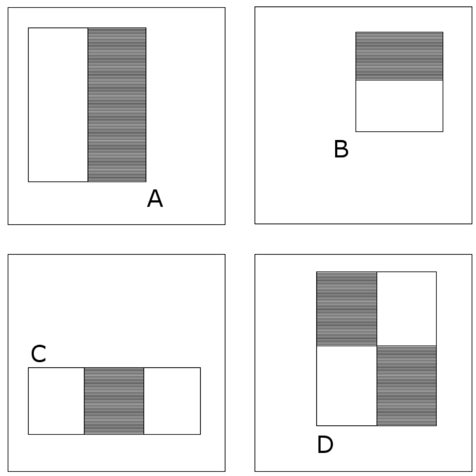

Figure 21: Example rectangle features shown relative to the enclosing detection window

The characteristics of Viola–Jones algorithm which make it a good detection algorithm are:

❑ Robust – very high detection rate (true-positive rate) & very low false-positive rate always.
❑ Real time – For practical applications at least 2 frames per second must be processed.
❑ Face detection only (not recognition) - The goal is to distinguish faces from non-faces (detection is the first step in the recognition process).

The algorithm has four stages:

(1)Haar Feature Selection

(2)Creating an Integral Image

(3)Adaboost Training

(4)Cascading Classifiers

Features sought by the detection framework include the amount of image pixels within rectangular regions. As such, they bear some resemblance to Haar basis functions, which have already been used in the realm of image-based object detection. However, since the facilities used by Viola and Jones all rely on more than one rectangular area, they are generally more complex. The figure on the right shows the characteristics used in four different types of structures. The value of any feature is the sum of pixels within explicit rectangles subtracted from the sum of pixels within the shaded rectangles. This type of rectangular features are primitive when compared to alternatives such as steerable filters. Although they are sensitive to vertical and horizontal characteristics, their response is quite coarse.

Using Viola-Jones for object tracking:

In videos of moving objects, one does not need to apply object detection to each frame. Instead, one can use tracking algorithms such as the KLT algorithm to detect the main features within the detection bounding box and track their movements between frames. This not only improves tracking speed by removing the need to re-locate objects in each frame, but it also improves robustness as well as more features than the rotation and photometric changes from the main features Viola-Jones detection framework Is flexible.

Kanade–Lucas–Tomasi feature tracker:

Kanade-Lucas - Tomasi (KLT) feature tracker is an approach to feature extraction. It is proposed primarily to tackle this problem that traditional image registration techniques are generally expensive. KLT uses spatial intensity information to direct location search that gives the best match. This is faster than traditional techniques for investigating less potential matches between images.

5.3.3 Project Deployment

The Following is the way the project is deployed:

Figure 22: Robo car which will stop the ball

Figure 23: Wireless Camera system with stand

Figure 24: Both ball and car are placed for testing to begin

5.3.4 System Screenshots

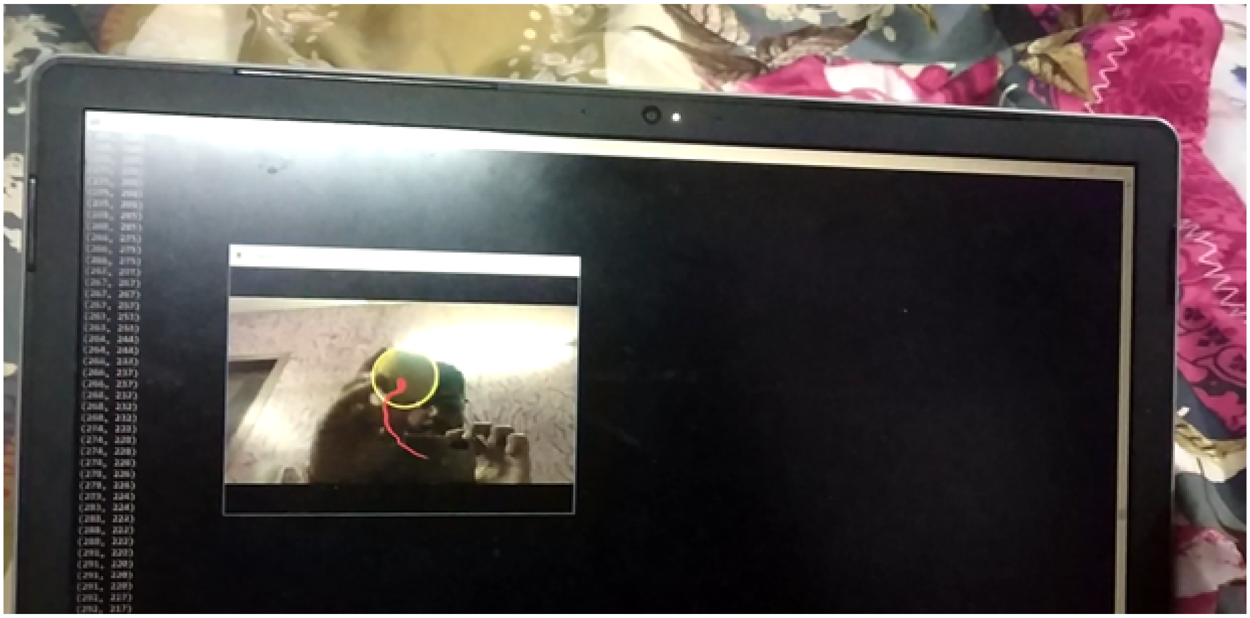

Figure 25: System screenshot of Object detection

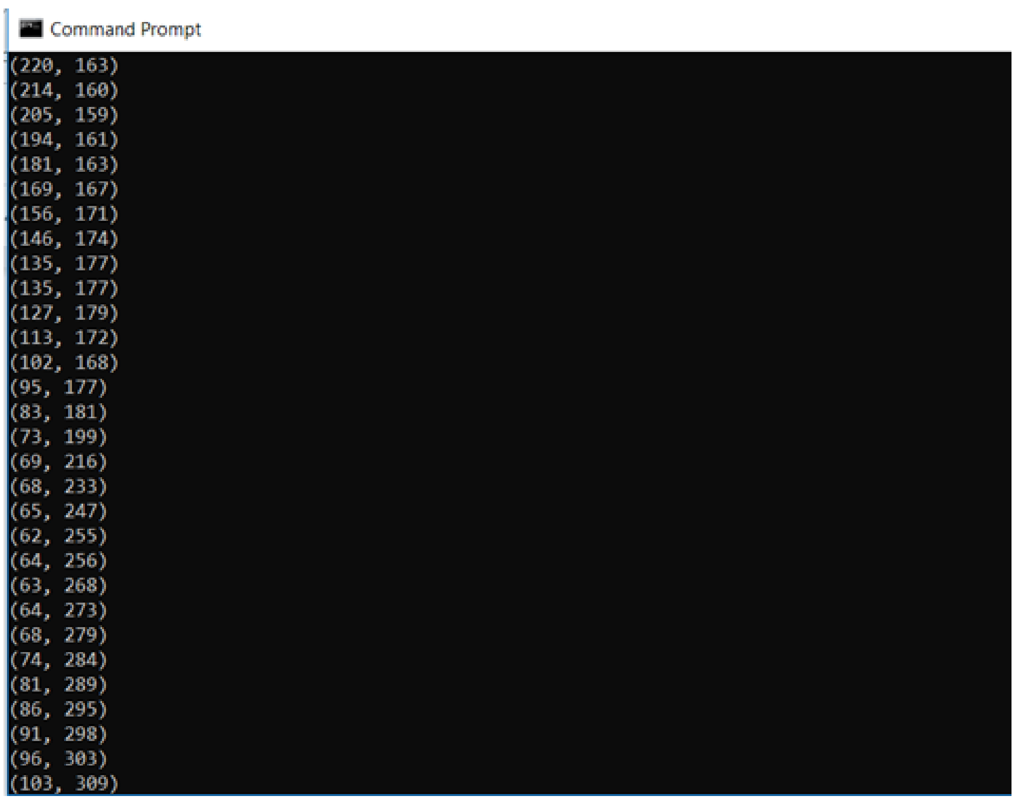

Figure 26: Console Screenshot of the object's instantaneous location

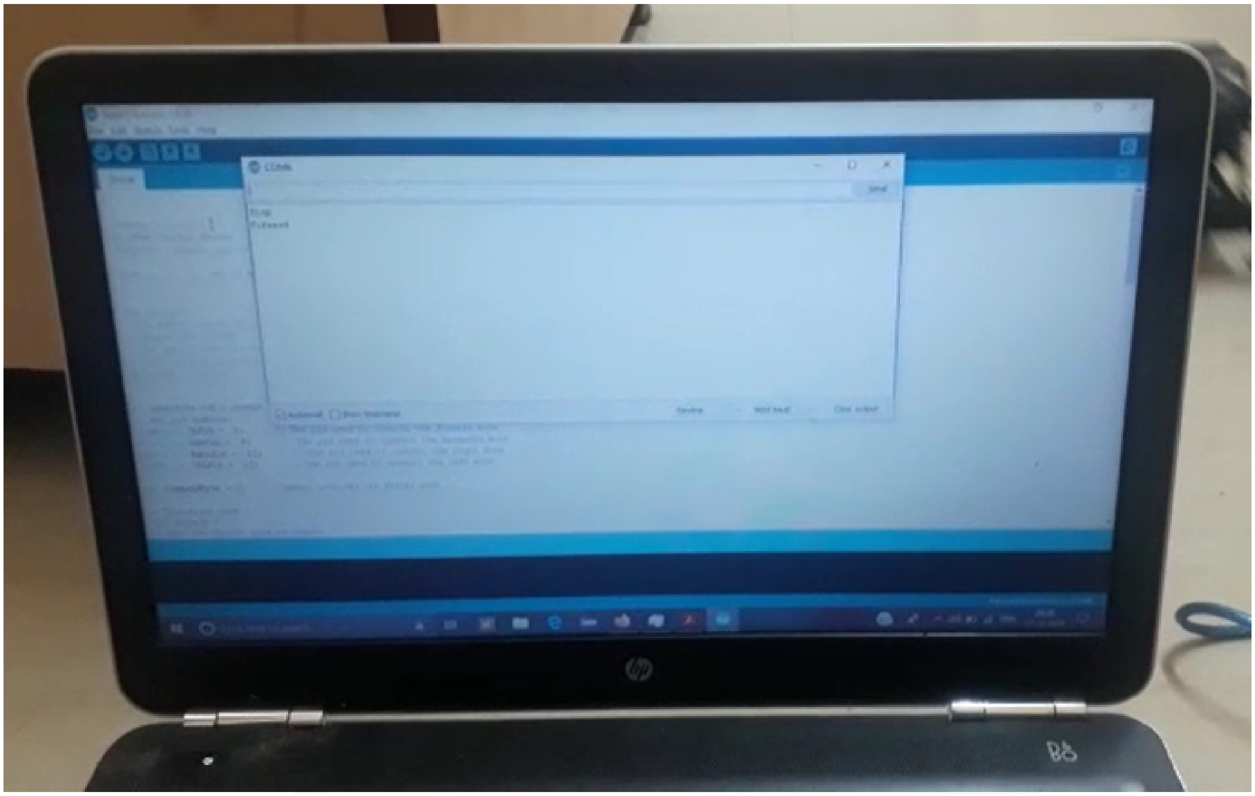

Figure 27: System screenshot of arduino IDE

5.4 Testing Process

5.4.1 Test Plan

The plan is to test for both normal and critical cases. That way we can measure the system's limit in doing its task.

5.4.1.1 Features to be tested

- The system's ability to successfully detect the presence of the ball in live camera feed.
- The system's ability to accurately predict the future location of the ball.
- The system's ability to control the bot properly with commands.
- The goalkeeper bot's ability to intercept the football before it hits the goal post.
- The camera-computer combination's ability to track the ball's position accurately and predict its route.
- The bot's high speed will be tested.

5.4.1.2 Test Strategy

The strategy is to behave normally as any user would do while interacting with the system and give unconditioned input so that the system's reliability can be tested under random circumstances.

The Ball will be placed under the stand on which the camera is placed and car will be at some distance away straight from there. Then the user is going to push the ball and system will do its work to stop the ball.

5.4.1.3 Test Techniques

The Ball can be pushed slowly or fast-ly or at a moderate speed. The car needs to validate itself in both left and right directions. The ball's movement will be tested through the frame of live video stream coming from wireless camera which is sometimes unreliable due to latency to broadcast or frame stuttering.

5.4.2 Test Cases

Figure 28: Car is stationary as the ball has not moved

Figure 29: The ball and car both move

Figure 30: Car successfully catches the ball

5.4.3 Test Results

In all the test cases shown above the car and the system passed the test and it is working.

5.5 Results and Discussions

Following results can be observed:

i. Using a local camera gives a 95% accuracy while using a remove camera wirelessly transferring frames via Bluetooth or Wifi gives 92% accuracy

ii. Using a local camera allows the program to have a frame rate less than or equal to 30 while using a remote camera shifts the frame rate to a mere 15.

iii. A 12 MP camera is the optimal choice since it establishes an optimal balance between accuracy, quality of frame and computational time

iv. The program can successfully detect the moving object trace its centre and predict its final landing point under 0.2 sec of response time. And remote camera can transfer high quality feed with a successfully frame rate of 15 under 0.1sec (estimate).

5.6 Inferences Drawn

Semantic segmentation is a long-studied problem in computer vision and is one of the grand challenges to solve when it comes to automatically understanding the world we live in. Essentially, semantic segmentation allows us to assign a hierarchical tag (also called a label). Each pixel in an image. This is relatively easy for humans, as we can usually understand the content of an image in terms of the objects it contains. For example, most of us can identify cars, pedestrians, houses etc. and are not meant to think twice about it.

However, teaching machines to see (and, moreover, understand) what is happening in an image for a completely different story. These days, we take it for granted that 10 megapixels say an image will have a resolution, which means a machine essentially has 2 million points to settle on a 2 million grid. But how can we help orient ourselves computer to such a vast pool of data and actually provide us with meaning annotations for each pixel in an image.

5.7 Validation of Objectives

TABLE 6: Validation of Objectives

S. No.	Objectives	Status
1	The system will be able to successfully detect the presence of the ball in live camera feed.	Successful
2	The system should be able to accurately predict the future location of the ball.	Successful
3	The system should be able to control the bot properly with commands	Successful
4	The goalkeeper bot shall be able to intercept the football before it hits the goal post	Successful
5	The camera-computer combination will be able to track the ball's position accurately and predict its route.	Successful
6	The bot will have high speed motor to ensure quick movement.	Successful

CONCLUSIONS AND FUTURE DIRECTIONS

6.1 Conclusions

The final project included a camera module optimised to a frame rate that will be transferred to the computer immediately and a machine learning algorithm drafted in Python 3 that will take in frame recorded from the camera and will determine its locations and angle, speed with respect to the previous location. The angle and speed calculated will be stored in a database that will be used to predict the final landing point of the ball. The Python program will trigger the Arduino program that will calculate the distance, speed and direction of the bot required to stop the ball from hitting the target. The instructions will be transferred to the bot via a zigbee and the bot will execute the instructions with the help of an Arduino attached to it.The bot will be made by reverse engineering a wireless remote controlled car or will be designed from scratch with a high speed motor at the very base.

6.2 Environmental, Economic and Societal Benefits

The project will benefit the society in a very positive manner, athletes can train on this bot for goalshoot practicing. Children can play with it indoors without need of a companion. It can be developed in 3d to train cricketers -- batsmen -- to a level that wasn't thought of before. There are hundreds ,if not a thousand, benefits of this project. It can be used wherever an autonomous target interception has to be used.

6.3 Reflections

The target of developing an autonomous bot has been achieved with a camera module that sends live footage to the computer which in turn processes the footage frame by frame and trains the ML algo using it. The algo in turn predicts the landing point and instructs the bot to intercept it. In General, the project can be defined as an autonomous high speed target interceptor in real time.

6.4 Future Work

This technique can be further developed to manufacture a missile interceptor for Indian Defense. A weapon that no country posses, not even USA. This weapon can give any country massive advantage over its enemies. Anti- missile weapon is the ultimate protection any country can hope for. The techniques involved in autonomous goalkeeper are very similar to techniques that will one be used to develop the ultimate anti missile project.

7.1 Challenges Faced

- Keeping Team on The Same Page
- Poorly Defining the Goals And Objectives
- Unrealistic Deadlines
- Insufficient Team Skills
- Miscommunication Causing Conflicts
- Risk Management
- Challenges of Teamwork
- Lack of Accountability

7.2 Relevant Subjects

Relevant Subjects related to the project:

Artificial intelligence: Areas of artificial intelligence for robotic systems to navigate through the environment deal with autonomous planning or deliberation. A detailed understanding of these environments is necessary to navigate through these mediums. Information about the environment can be provided by a computer vision system, acting as a vision sensor and providing high-level information about the environment and robots.

Artificial intelligence and computer vision share other disciplines such as pattern recognition and learning techniques. As a result, computer vision is sometimes viewed as a part of the field of artificial intelligence or, in general, the computer science field.

Solid-state physics: Solid-state physics is another field closely related to computer vision. Most computer vision systems rely on image sensors that detect electromagnetic radiation, usually in the form of visible or infra-red light. The sensors are designed using quantum physics. The process by which light interacts with surfaces is explained using physics. Physics explains the behavior of optics which is a core part of most imaging systems. Sophisticated image sensors also require quantum mechanics to provide a complete understanding of the image formation process. In addition, various measurement problems in physics can be addressed using computer vision, for example motion in liquids.

Neurobiology: A third area that plays an important role is neurobiology, specifically the study of biological vision systems. Over the last century, a comprehensive study of eyes, neurons, and brain structures devoted to the processing of visual stimuli has been performed in both humans and various animals. It turns out to be a rough, yet complex, description of how a "real" vision system operates to solve certain vision functions. These results have led to a subfield within computer vision where artificial systems are designed to mimic the processing and behavior of biological systems at different levels of complexity. Also, he has a background in biology for some of the methods of learning developed within computer vision (such as neural nets and deep learning based on image and feature analysis and classification).

Some varieties of computer vision research are closely related to the study of biological vision - in fact, many varieties of AI research are closely associated with research in human consciousness, and stored knowledge to interpret, integrate, and use visual information. use of. Biological vision models the physiological processes behind the field of study and visual perception in humans and other animals. Computer vision, on the other hand, studies and describes the processes applied in software and hardware behind artificial vision systems. Interdisciplinary exchange between biological and computer vision has proved fruitful for both fields.

Signal processing: Yet another area related to computer vision is signal processing. Several methods for processing one-variable signals, typically temporal signals, can be extended to computer vision for processing two-variable signals or multi-variable signals from a natural point of view. However, due to the specific nature of the images, several methods have evolved within computer vision, with no counterpart in the processing of one-variable signals. Along with the multi-dimensionality of the signal, it defines a subfield in signal processing as a part of computer vision.

Other fields: Apart from the above mentioned views on computer vision, many of the related research topics can also be studied from a purely mathematical point of view. For example, many methods in computer vision are based on statistics, optimization, or geometry. Finally, an important part of the field is devoted to the implementation aspect of computer vision; How existing methods can be realized in various combinations of software and hardware, or how these methods can be modified to achieve processing speed without losing too much performance. Computer vision is also used in the fashion ecommerce, inventory management, patent search, furniture and beauty industries.

7.3 Interdisciplinary Knowledge Sharing

The ultimate goal of computer vision is to make possible systems that can autonomously interpret the visual environment under almost any operating condition. That is, to reproduce the amazing performance of the human visual perception. The elusiveness of this goal can be seen from attempting to define robustness in the context of computer based image understanding. Different definitions emerge at different levels of the hierarchy of techniques often associated with solutions to computer vision problems. On the top level, a robust vision system should be able to recognize new objects based exclusively on previous examples from the same class of functionality. Thus, a piece of furniture should be identified independent of its style, a car independent of its maker, etc. Such cognitive components however are yet to be developed for general purpose vision systems. Changes in the visual environment due to nonrigid motion of the objects or alteration of viewpoint, or both, are a primary concern when building object descriptions at the intermediate level of the vision hierarchy. Complex visual events arise for which robust interpretation requires separating the external causes from the intrinsic properties in the appearance of each object. This task, roughly equivalent to perceptual constancies in human visual perception, is currently an active research area in computer vision.

7.4 Peer Assessment Matrix

The following is a Matrix on 1 (min) to 5 (max) rating of contribution of group members by each member.

TABLE 4: Peer Assessment Matrix

		Evaluation	Of:		
		Taranjeet Singh	Vaibhav Sood	Utkarsh Chugh	Tushar Mahajan
Evaluated	Taranjeet Singh	5	5	5	5
By:	Vaibhav Sood	5	5	5	5
	Utkarsh Chugh	5	5	5	5
	Tushar Mahajan	5	5	5	5

7.5 Role Playing and Work Schedule

Team members played different roles at different times according to the need, members also usually shifted from their role to the others if for some reason the other wasn't able to do their work. Members usually worked during day however they also worked on night time some days.

7.6 Student Outcomes Description and Performance Indicators

TABLE 5: SO & PI(A-K Mapping)

SO	Description	Outcome
A1	Applying mathematical concepts to obtain analytical and numerical solutions.	Used mathematical concepts like Trigonometry for accurate direction predicting in image processing. These concepts were also used to calculate the results..
A2	Applying basic principles of science towards solving engineering problems	Applied basic principles of physics like speed, momentum and acceleration.
A3	Applying engineering techniques for solving computing problems	Chose a fast kind of remotely controlled car for high catch rates.
B1	Identify the constraints, assumptions and models for the problems.	Understood the physical and computational limits to the project
B2	Use appropriate methods, tools and techniques for data collection.	used emerging technologies like Computer vision, ML for the solution
B3	Analyze and interpret results with respect to assumptions, constraints and theory.	Analyzed the results which seem to follow the established constraints and assumptions.
C1	Design software system to address desired needs in different problem domains.	wrote appropriate Arduino and python scripts
C2	Can understand scope and constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	the scope of this project is well beyond traditional limits, it has high economic, environmental and safety potential
D1	Fulfill assigned responsibility in multidisciplinary teams.	Fulfilled the assigned responsibility
D2	Can play different roles as a team player.	Members played several different roles at different times
E1	Identify engineering problems.	identified the engineering

		problems while making the architecture of the system
E2	Develop appropriate models to formulate solutions.	Appropriate architecture models were formulated to find solutions
E3	Use analytical and computational methods to obtain solutions.	Used basic trigonometry to solve the prediction problem
F1	Showcase professional responsibility while interacting with peers and professional communities	Gave well and good presentation to the capstone panel and were professional with mentor
F2	Able to evaluate the ethical dimensions of a problem.	Understand that this technology can be used as both offensive and defensive
G1	Produce a variety of documents such as laboratory or project reports using appropriate formats.	Used the official formats for reports
G2	Deliver well-organized and effective oral presentation.	A well understood presentation was given to the panel
H1	Aware of environmental and societal impact of engineering solutions.	Engineering solutions can have great and good impact on environment
H2	Examine economic tradeoffs in computing systems.	Everything has a price so does electronics and computers
I1	Able to explore and utilize resources to enhance self-learning.	Explored different resources like library, internet, etc for self learning
I2	Recognize the importance of life-long learning.	any skills learned can be useful in future life
J1	Comprehend the importance of contemporary issues.	We live in a society, it has specific sociological structure and it has to stay stable or our lives are at stake
K1	Write code in different programming languages.	Written code in python and arduino IDE
K2	Apply different data structures and algorithmic	Different data structures were

	techniques.	used for various operations
K3	Use software tools necessary for computer engineering domain	used software such as jupyter, spyder, visual studio, arduino uno, etc.

7.7 Brief Analytical Assessment

Q1. What sources of information did your team explored to arrive at the list of possible Project Problems?

Ans: Our team explored sources including but not limited to library, internet, mentors, professors, etc.

Q2. What analytical, computational and/or experimental methods did your project team use to obtain solutions to the problems in the project?

Ans: Our team used team used KLT Feature tracker algorithm to compute feature extraction of the moving ball.

Q3. Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? If yes, how did you apply?

Ans: Yes the project demanded demonstration of knowledge of fundamentals, scientific principles. We consulted our professors for the help.

Q4. How did your team shares responsibility and communicate the information of schedule with others in team to coordinate design and manufacturing dependencies?

Ans: Our team shared responsibilities and communicated the information of schedule with others in team using whatsapp, mobile calling, in person meetings, etc.

Q5. What resources did you use to learn new materials not taught in class for the course of the project?

Ans: Our team used resources like internet, library, mentors to learn new materials and technologies.

Q6. Does the project make you appreciate the need to solve problems in real life using engineering and could the project development make you proficient with software development tools and environments?

Ans: Yes the project made us appreciate the need to solve problems in real life using engineering and the project made us proficient with Software development as a whole.

APPENDIX A: REFERENCES

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APPENDIX B: PLAGIARISM REPORT

Plagiarism Checker X Originality Report

Plagiarism Quantity: 14% Duplicate

Date	Saturday, December 21, 2019
Words	2108 Plagiarized Words / Total 14654 Words
Sources	More than 175 Sources Identified.
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R E A L T I M E B A L L T R A C K E R A N D G O A L K E E P E R C a p s t o n e P r o j e c t R e p o r t E n d - S e m e s t e r E v a l u a t i o n Submitted by: (101610091)Taranjeet Singh (101610093)Vaibhav Sood (101603364)Utkarsh Chugh (101611057)Tushar Mahajan BE Final Year, COE CPG No: 27 U n d e r t h e M e n t o r s h i p o f D r . R a m a n G o y a l A s s i s t a n t P r o f e s s o r C o m p u t e r S c i e n c e a n d E n g i n e e r i n g D e p a r t m e n t T I E T , P a t i a l a D e c e m b e r 2 0 1 9 A B S T R A C T In this report we will discuss our project of autonomous goalkeeper in detail.

All the diagrams and every little detail needed to understand the concept of autonomous moving target tracker and interceptor. Our basic approach to dealing with this problem would be to use OpenCV to track the ball and use a bot that would stop the ball in turn. The blocking commands will be transferred from the PC to the bot via a zigbee. The Python script we developed was able to detect the presence of a colored ball, followed by the track and the position of the ball as it moved around the screen.

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