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Baseball Swing Analysis for School Level Players in Sri Lanka Using Deep Neural Networks

A dissertation by

Mr. Maleesha Lionel

Supervised by

Mrs. Niwarthana Kariyabaduge

Submitted in partial fulfilment of the requirements for the BSc (Hons) Computer Science degree at the University of Westminster.

May 2023

ABSTRACT

In Sri Lanka, baseball is a recognized sport, and many young players want to play professionally. However, acquiring the technical know-how required to accomplish this goal can be difficult, especially at the school level. By using deep neural networks to examine the baseball swings of Sri Lankan school-level players, this study seeks to solve this problem.

In order to accomplish this, a system was created that makes use of motion capture technologies to create a dataset of baseball swings for the deep neural network's training. The method was created to accurately analyze and give feedback on a player's technical components of their swing, with the goal of enhancing their performance. With the use of various data preprocessing and deep learning techniques, a deep neural network was trained to assess and categorize distinct swing types with accuracy.

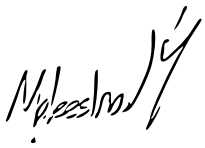
The deep neural network's performance in tests showed how well it could identify and analyze baseball swings. The model performed well, scoring over 90% in both precision and recall. Additionally, the system was able to recognize and offer feedback on particular swing-related technical elements, such as the stance, leg motion, and shot execution. These findings show the potential of deep neural networks for sports analysis and offer important information for the growth of Sri Lankan young baseball players.

Keywords: Machine Learning, Deep Learning , Deep Neural Networks ,Convolutional Neural Networks, Baseball Swing Analyse, Computer Vision, Performance Analysis

DECLARATION

I hereby declare that this dissertation is a result of my own work and it has not been submitted before or is currently being submitted for any degree program or any other academic qualification program offered by another university or institution. Extracted facts obtained from previous works and external sources are appropriately cited.

Name of the Student: Lelwala Guruge Maleesha Diluminda Lionel
Registration No: w1789986 / 2019742

Signature:  **Date**: 10/05/2023

ACKNOWLEDGEMENT

Numerous people in my life have helped and pushed me to go beyond my previous boundaries and succeed in finishing this final research project.

My sincere gratitude is extended to my supervisor, Mrs. Niwarthana Kariyabaduge, who has continuously pushed me to push my boundaries and given me priceless advice throughout the study process. Her guidance has given me the courage to engage in research at any level. I also want to thank the project's reviewers, who included academic and professional experts, as well as top performing IIT seniors and juniors, for devoting their time to reviewing my work and offering helpful criticism at each stage of the research process, from ideation to final evaluation. I would specifically like to mention Mr. Malindu Hewage (National Baseball Coach) for helping to complete this task.

I want to thank the Informatics Institute of Technology's faculty members and administration for their constant support, wisdom, and opportunities throughout my undergraduate studies. I would also like to express my gratitude to my university colleagues, whose ongoing assistance and encouraging influence have greatly aided my development both personally and professionally. My improvement as a researcher and developer has been aided by their encouragement. I also want to thank my brother for helping me financially with my education over the past four years which allowed me to focus on my academic objectives. Finally, I owe my parents and family friends from school my gratitude for their inspiration and support during trying times.

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LIST OF ABBREVIATIONS

Acronym	Description
ML	Machine Learning
DL	Deep Learning
AI	Artificial Intelligence
DNN	Deep Neural Networks
CNN	Convolutional Neural Networks
GUI	Graphical User Interface
GPU	Graphics Processing Unit
TPU	Tensor Processing Units
SSADM	Structured Systems Analysis & Design Method

CHAPTER 1: INTRODUCTION

1.1 Chapter Overview

This chapter evaluates a problem, finds a knowledge gap, sets forward the goals and objectives of the study, and answers the project's final challenge. Additionally, it assesses important prior research and offers evidence supporting the problem. The author provides a thorough summary of the subject, emphasizing the need for more research. The chapter outlines particular objectives and results and addresses the difficulties that must be overcome. To establish the issue's existence and significance, the author evaluates prior research. The chapter defines the groundwork for the analysis and discussion of the research's findings that will come after.

1.2 Problem Domain

1.2.1 Computer Vision

Recently, there has been a lot of interest in the computer vision and robotics research community (Jarvis, 2018). Computer vision is an artificial intelligence area that allows computers and systems to derive meaningful information from digital photos, videos, and other visual inputs and then conduct actions or make suggestions based on that information. Early computer vision experiments were undertaken in the 1950s (Mihajlovic, 2021). Facial recognition programs thrived as the internet evolved, making massive collections of photographs available online for study. These expanding data sets aided computers in recognizing persons in images and movies. Today's technologies are better than humans in detecting and responding to visual inputs. From identifying people to analyzing live sports game activity, computer vision rivals and exceeds human visual ability in many areas. Today's artificial intelligence systems may go a step further and perform actions based on.

1.2.2 Human Pose Estimation

The subject of human posture estimation, often known as the challenge of joint localization in humans, has received significant interest in the computer vision community. (Szegedy and Toshev, 2014). Computer vision functions similarly to human vision, with the exception that humans have an advantage (Szegedy and Toshev, 2014). Human vision has the benefit of lifetimes of context to learn how to discern objects apart, how far away they are, if they are moving, and if there is something incorrect with a picture or footage. To do this, two key technologies are used: DL, a sort of machine learning, and a deep neural network (DNN).

1.2.3 Human Pose in Baseball

By considering the importance of the basic techniques and the importance of training the basics under a pro level trainer along with lack of good trainers and lack of other tools to learn basics and get evaluated, it’s clear that there’s a need of a tool which can teach and analyse the swing of a hitter without the support of a real trainer. So, author recommend platform that substitute a physical trainer, in which a hitter of any level can get the feedback of the swing trained in their training session by giving the video footage.

1.3 Problem Definition

Baseball players at the school level don't have a system in place in Sri Lanka for evaluating their swings. A suggested solution has been put out to address this problem and assist trainers and new players analyze the various phases of a baseball swing. The swing analysis tool is initially intended to concentrate on the hitter's side view, with future expansion to incorporate analysis of the swing's front view. Making use of action recognition technology, the system will examine swing technique images to provide a thorough evaluation of the player's form. The deployment of this technique will offer young baseball players and coaches in Sri Lanka useful insights and chances for improvements.

1.4 Research Motivation

An exciting and helpful research area that appeals to me as a former school-level baseball player with a degree in computer science is the use of deep neural networks to evaluate and enhance baseball swings. Baseball is a well-liked sport in Sri Lanka, and many school-age players are looking for ways to hone their abilities and strategies. To evaluate and analyze a player's swing, however, there are currently few trustworthy and unbiased techniques available. By examining video data and identifying important variables that influence swing success, such as execution, stance, and leg movement deep neural networks can be an effective tool for studying baseball swings. Coaches and players can learn a great deal about their performance and make focused changes to their swing technique by creating a deep neural network model that can reliably predict swing outcomes based on these factors. Additionally, by revealing more about the mechanics underlying effective baseball swings, the research can advance the field of sports analytics. The findings of this study may also be put to use in player scouting, recruitment, and training, improving the standard of baseball in Sri Lanka as a whole. Overall, the advantages of analyzing baseball swings with deep neural networks make this research direction a fascinating and valuable pursuit. As a former baseball player who is currently studying computer science, I am excited to investigate this nexus between sports and technology and help enhance baseball analytics and training.

1.5 Research Gap

Based on previous research done related to baseball swing estimation, there is no literature found to analyze the baseball swing of school-level baseball players considering any height and weight in Sri Lanka using a hitter’s side angle view video footage without any external electronic devices or wearable sensors. This project focuses on solving that problem.

1.6 Contribution to the Body of Knowledge

1.6.1 Technological Contribution

This work targets to analyze baseball swing in the video. While recent methods typically represent actions by statistics of local video features, here author argues for the importance of a

representation derived from the baseball swing. To this end, the author proposed a new Pose-based Convolutional Neural Network descriptor for baseball swing analysis. The descriptor aggregates motion and appearance information along tracks of human body parts. The author investigates different schemes of temporal aggregation and experiments with DNN features obtained both for automatically estimated and manually annotated human poses.

1.6.2 Domain Contribution

The author's research contribution can be summarized as follows:

- Create system to analyze school level baseball player’s bat swings considering any height and weight.
- Analyze baseball bat swing without any external devices or sensors.
- Analyze baseball bat swing using batter’s side angle view.
- Creating an image data set for baseball stance, shot execution and leg movement.

1.7 Research Challenge

Neural networks require a large number of images to generate accurate predictions, but there were no data sets available for matching, so the solution was to create one. Another difficulty to creating the swing data set was that it could not be created by staying indoors because it required playing outside while a professional coach validated the correct strokes. As a solution, author had to create a data set and all the required images for the dataset were photographed by the author, which were then validated by a coach named Mr. Malindu Hewage (National men's baseball coach, National women's baseball coach), who ensured that the system was accurate. Accelerated changes in requirements and a lack of domain experience result in exceeding the task's time limit, which is a risk that any research faces. Baseball swing analysis is a vast and diverse field of study for undergraduate students. To accommodate the undergraduate level research, drafting level and requirement elicitation models were used to break down the task.

1.8 Research Questions

RQ1 – What are the impacts of baseball bat swing analysis on baseball and what solutions are available?

RQ2 – What technologies are available to classify baseball bat swings and estimate them?

RQ3 - what are the most effective techniques for analysing the baseball bat swing?

1.9 Research Aim

The aim of this research project is to design, develop & evaluate a system which analyses the Baseball swing of school level baseball players in Sri Lanka without any profession Intervention The System will focus on Identifying key aspects of the players swing such as leg movement shot execution.

The aim of this research project is to create, develop, and assess a system that uses Deep Neural Networks to examine the baseball swings of players at the school level in Sri Lanka. The technology will be created to automate the labor-intensive process of swing analysis, allowing coaches and players to evaluate important swing characteristics including technique and body posture without the assistance of an expert. The system will be improved over time by employing deep learning techniques, enabling it to adapt to various datasets and increase accuracy. This will give coaches and players a useful and dependable tool to develop their abilities and perform better on the field.

1.10 Research Objectives

The above-mentioned Aims and Research Questions are expected to be met and answered with the successful delivery of the following Objectives. These objectives are expected to be achieved for the research to also be completed successfully.

Objective Objectives	Description	Learning Outcomes

Literature Survey	Perform an in-depth assessment of the research's relevant ways. • R01: To analyze the domain of baseball swing pose estimation. • R02: To analyze baseball swing and, do a critical review on the advantages and disadvantages of those solutions. • R03: To identify research gaps in the domain of baseball swing pose estimations. • R04: To discover potential strategies for increasing the reliability of DL models. • R05: To identify the technical abilities required in the research domain, such as programming languages, development frameworks, and evaluations frameworks/methods.	L01 L04 L05
Requirement Analysis	Collect and thoroughly evaluate users' requirements. • R01: To assess colleagues', industry experts, and academic experts' understanding of the baseball swing pose estimation through meetings and questionnaires. • R02: To collect specifications for a baseball swing pose powerful DL system and examine how consumers expect the research's outcome. • R03: Getting feedback from domain experts and evaluating a reliable strategy to deliver the results	L03 L06 L07

Design	Designing the suggested solution's architecture • R01: To create the preliminary Classification models needed to build and test the proposed framework. • R02: To create a separate component that provides feedback on the swing. • R03: To design a method to analyze the swing pose using the given dataset and optimize them. • R04: To provide a technique that can successfully link the suggested swing pose estimate as a combined solution while maintaining the original model's correctness.	L02 L05 L07
Development	implementing the proposed baseball swing pose estimation framework according to the designed architecture. • R01: To develop initial classification models which will be used to implement and evaluate the baseball swing pose estimation system. • R02: To provide the fundamental functions, sufficient hardware and software needs to be met. • R03: The proposed approach was used to retrain as well as provide robust classification models in baseball swing estimation as a web application.	L01 L05 L06 L07

Testing and Evaluation	To retrain and provide robust classification techniques in swing pose estimation as a web application developed from the proposed strategy. • R01: To develop an effective testing strategy for unit and functionality testing. • R02: To verify the robustness of the models after using the proposed swing pose framework using the appropriate evaluation metrics. • R03: To gather feedback from academic and domain specialists on the research.	L04 L06

Table 1 - Research Objectives

1.11 Chapter Summary

This chapter in this paper includes a detailed overview of the topic and its background, as well as the research gap and challenge. It also defines the issues to be addressed in a research project. Additionally, it outlines the goals of the study and how they relate to those of a University of Westminster BSc (Hons) Computer Science program. The chapter also outlines the research approach that will be taken to solve the issue and fulfill the study's goals.

CHAPTER 2: LITERATURE REVIEW

2.1 Chapter Overview

The application of deep learning techniques for baseball swing analysis, specifically for school-level players in Sri Lanka, is the main emphasis of this literature review. Introduction, deep learning-based baseball swing analysis, earlier field study, and conclusion make up the chapter's four main components. In the introduction, the significance of enhancing a baseball player's technique is briefly discussed, as is the use of deep learning techniques in sports analytics, specifically for swing analysis in baseball. It also draws attention to the vacuum in the body of knowledge about deep learning-based baseball swing analysis for Sri Lankan school-level players. The domain, current comparable products, and potential approaches to achieving them are covered in this chapter.

2.2 Concept Map

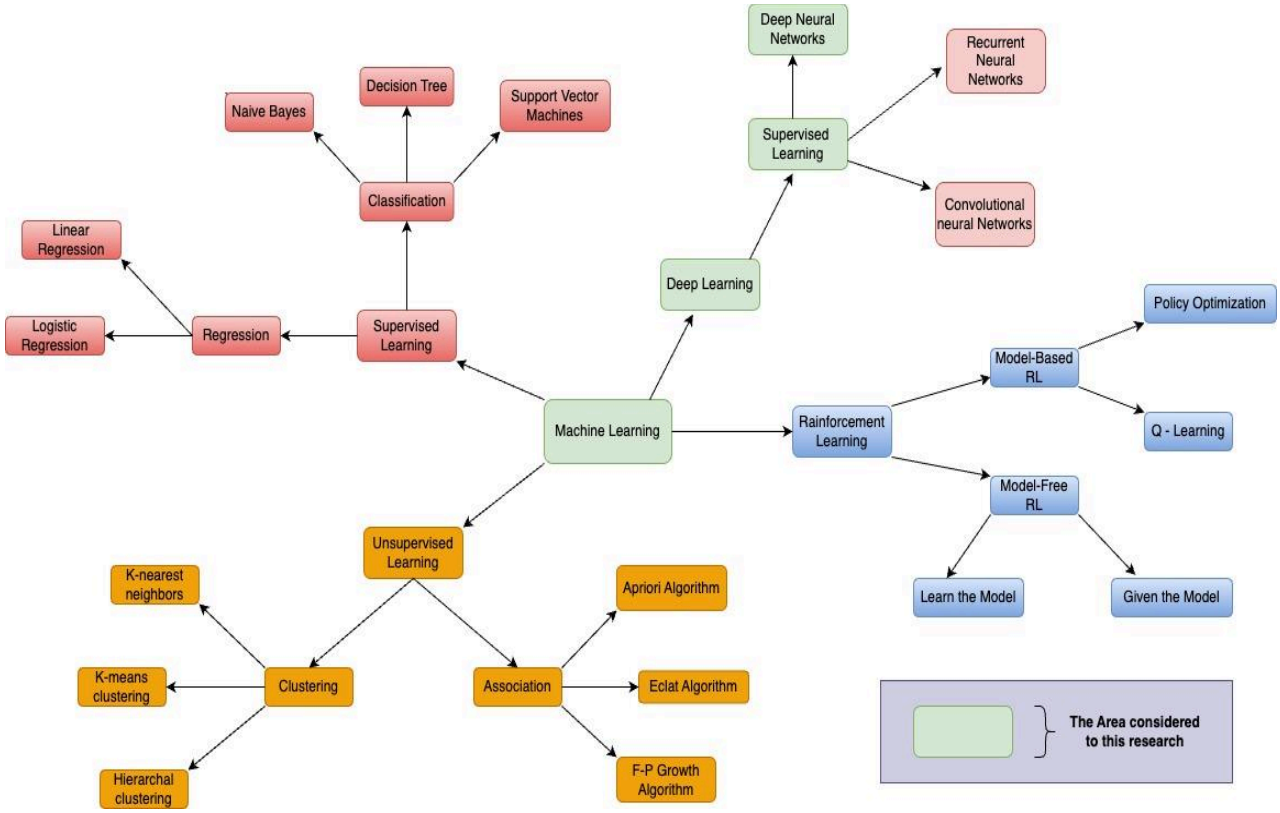


Figure 0-1 - Concept Map

2.3 Literature Review of the Problem Domain

2.3.1 Baseball

Millions of people all over the world are passionate about baseball as a sport. It is one of the most complicated sports because it calls for physical strength and mental agility. Baseball, which got its start in the United States, has since spread over the world and is now extremely popular in places like Japan, Cuba, and the Dominican Republic. The annual World Baseball Classic, a global competition that brings together the top players from all over the world to compete for their countries, showcases the sport's popularity. With millions of viewers turning in to watch the games, this event has grown to be one of the biggest athletic events in the world. Baseball generates shocking amounts of money, and Major League Baseball (MLB), which is played in the United States, is the most valuable sports league globally. The league brings in billions of dollars annually, which demonstrates how well-liked the sport is. Baseball has a long history in numerous nations, even though it is most frequently linked with the United States. For instance, Japan has a strong baseball league that has over the years produced numerous outstanding players. Baseball is a way of life in Cuba and the Dominican Republic, where kids play the game in the streets and have dreams of one day playing in the major leagues. Baseball has a rich history, changing over the years to become the sport we know and love today. Baseball was first played in 1846, according to records, and since then, numerous improvements have been made to the sport, including the usage of gloves and camera equipment to analyze close decisions. In conclusion, baseball is a sport that has endeared itself to fans around. It is a physically demanding sport with complicated regulations that calls for both skill and mental clarity. The World Baseball Classic and the enormous sums of money the MLB makes each year demonstrate how popular baseball is. Even though the sport is most frequently linked to the United States.

2.3.2 Players & How it Plays

There are various player types in baseball, each with specific roles and duties. The catcher, pitcher, and hitter are the three most well-known player types. The catcher is arguably the most important player on the field since they collaborate with the pitcher to call the correct pitches and prevent runs from being scored by the opposition. To stop runners from advancing, catchers need to have lightning-quick reflexes and be able to throw to the bases correctly and fast. The pitcher, on the

other hand, oversees throwing the ball in the direction of home plate to strike out the hitter. The ability to throw a variety of pitches, including fastballs, curveballs, and sliders, each of which has a distinct feature and can be used to outwit the hitter, is a must for pitchers. The player who attempts to hit the pitched ball is known as the batter. He or she can do this by contacting the ball or by letting it pass for a ball or strike. Batters need to be able to make split-second decisions about whether to swing at a pitch or let it pass, which requires exceptional hand-eye coordination. There are more positions on the field, such as first baseman, second baseman, shortstop, and outfielders, in addition to these main player categories. Each of these jobs calls for abilities and physical qualities, like quickness, agility, and hand strength. Baseball is a sophisticated, strategic game that involves cooperation between all players to accomplish a shared objective. To choose the best pitches to throw, catchers must consult with the pitcher, and infielders must be ready to field ground balls and throw with accuracy to put runners out.

Overall, each style of baseball player contributes significantly to the game. To succeed on the field, every player—from the catcher, pitcher, and hitter to the infielders and outfielders—must cooperate. Baseball is one of the most adored sports in the world because of its emphasis on teamwork and cooperation.

2.3.3 Sri Lanka Baseball

Baseball is not a sport that is frequently connected to Sri Lanka, although its popularity has been rising recently. Since the establishment of the Sri Lanka Baseball Association in 2002, the game has grown in popularity throughout the nation. The absence of infrastructure and facilities is one of the biggest problems facing baseball in Sri Lanka. Nevertheless, there are several teams and leagues across the nation, with participants ranging in age from kids to adults. The expansion of youth programs has been one of Sri Lankan baseball's most fascinating developments. These initiatives have assisted in introducing the activity to the nation's youth, giving them the chance to pick up essential skills and gaming knowledge. At the national level, the sport is being promoted by the Sri Lanka Baseball Association. Sri Lankan teams have even participated in the Asian Baseball Championships thanks to the organization's involvement in numerous international competitions. The decision to send two players to the 2018 World Children's Baseball Fair in Japan was one of Sri Lankan baseball's greatest triumphs. Through the game of baseball, this event brings

together kids from all over the world to foster friendship and cross-cultural understanding. Even though baseball is still a relatively young activity in Sri Lanka, the passion and effort put forth by those responsible for its promotion can be seen in the sport's rising popularity. There is no question that baseball will continue to develop and flourish in the nation with the assistance of the Sri Lanka Baseball Association and other organizations.

2.3.4 School Level Baseball in Sri Lanka

In Sri Lanka, baseball is not a popular school activity, although there are initiatives to promote the sport and get students interested in it. Schools are encouraged to take part in the young leagues and programs that the Sri Lanka Baseball Association has been attempting to build. The absence of facilities and infrastructure in Sri Lanka is one of the main problems for school baseball. There is a dearth of baseball-savvy instructors and trainers, and many schools lack the required facilities and fields for the sport. Despite these obstacles, baseball programs have been established at about 60 schools in Sri Lanka. These schools have organized teams and take part in regional leagues and competitions, giving students the chance to hone their abilities and face off against rival institutions. To promote the sport, the Sri Lanka Baseball Association has also been striving to plan events and competitions at the high school level. These activities provide students a chance to demonstrate their abilities and pit schools against one another in a fun and engaging setting. Although baseball at the school level in Sri Lanka is still in its early stages, the rising popularity of the sport portends well for the future. More schools are anticipated to start baseball programs and give children the chance to study and play the game with the help of the Sri Lanka Baseball Association and other organizations. For students, playing baseball in school has a lot of advantages. It can aid in the improvement of their physical fitness, teamwork, and sportsmanship. As students cooperate to achieve a common objective, it can also foster a sense of community and belonging. Overall, baseball at the college level in Sri Lanka has the potential to develop and gain popularity among students. More schools can start baseball programs and provide children a chance to study and play the game with the help of the Sri Lanka Baseball Association and other organizations.

2.4 Existing Work

2.4.1 P-CNN: Pose-based CNN Features for Action Recognition

This study focuses on identifying human actions in videos. The authors contend that a representation based on human stance is essential, even if the majority of current techniques employ local video attributes to depict motions. Pose-based Convolutional Neural Network (P-CNN), which they suggest as a novel descriptor, gathers motion and appearance data from tracks of human body components. The authors compare P-CNN features derived from both automatically estimated and manually annotated human poses and evaluate several temporal aggregation strategies. On the difficult datasets JHMDB and MPII Cooking, their method outperforms cutting-edge approaches in terms of performance.

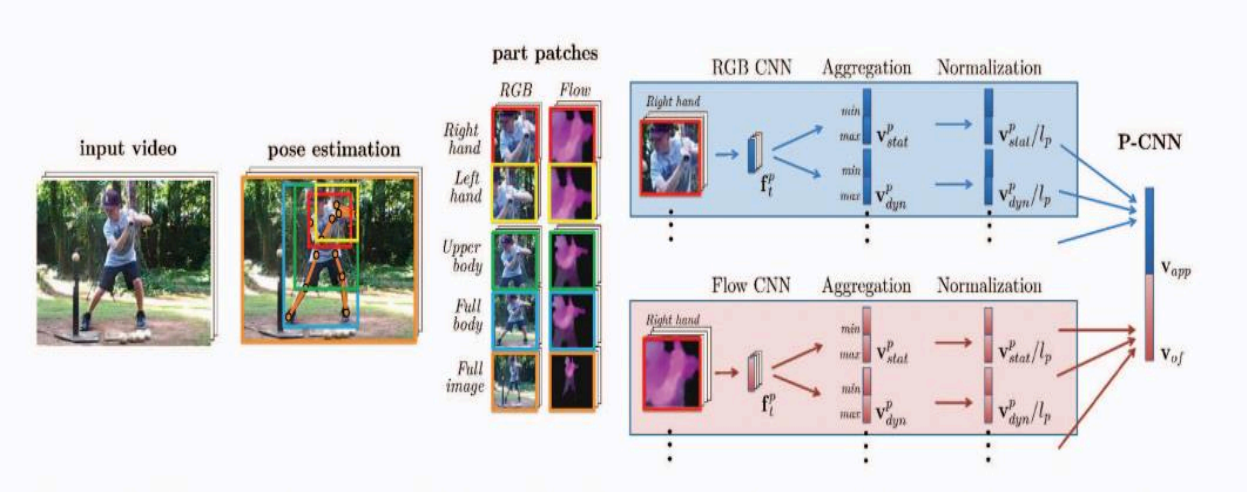


Figure 0-2 - P-CNN Features

2.4.2 STAR-Net: Action Recognition using Spatio-Temporal Activation Reprojection

Although depth cameras and inertial sensors have been used to detect human movement, their use is not always feasible because of their expense or the surrounding environment. Deep convolutional neural networks and low-cost RGB cameras have been the focus of recent research for action recognition, although many of these networks are intricate and computationally expensive. The authors suggest a brand-new framework called spatiotemporal activation reprojection (STAR), which use a stack of 3D convolutions to reproject spatiotemporal activations

produced by human posture estimate layers, in order to overcome these difficulties. The resulting end-to-end architecture, known as STAR-Net, outperforms various approaches that leverage richer data modalities including depth and inertial sensors in small-scale applications. The usefulness of STAR-Net for action recognition is demonstrated by experimental findings on the UTD-MHAD and J-HMDB datasets.

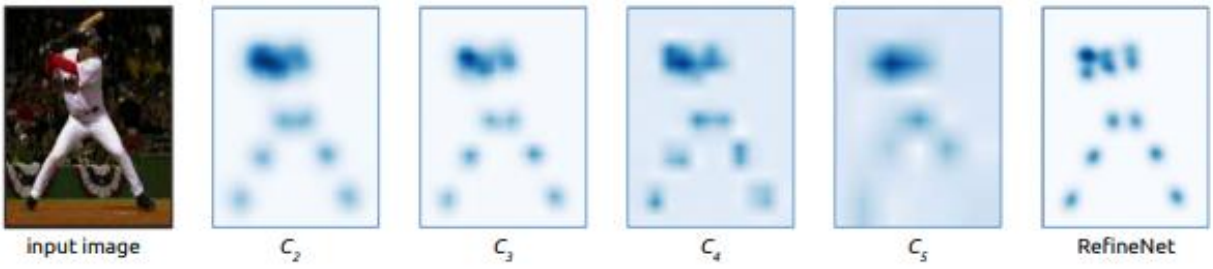


Figure 0-3 - able to identify the correctness of the swing.

2.4.3 Modelling Human Body Pose for Action Recognition Using Deep Neural Networks

Particularly in the context of visual surveillance, human-robot interaction, and sports analysis, the position of the human body is a significant cue that can offer insightful information about human behavior. Pose-based action detection techniques that use traditional techniques have some drawbacks, such as being limited to one person at a time and requiring a fixed input size. Due to these restrictions, it may be challenging to distinguish between activities in real-world scenarios where there are many individuals present or the body is partially obscured. They suggest a novel method based on a deep neural network architecture that may accept a more comprehensive representation of 2D human body joints as input in order to overcome these constraints. This depiction is made to be malleable and versatile in order to accommodate various real-world situations. Using a weighted fusion procedure, we additionally incorporate RGB and optical flow data into our methodology. This enables us to increase the accuracy of action classification by combining data from several sources. Two real-world datasets were used to test our strategy, and the experimental findings show that it outperforms current state-of-the-art techniques. Their method can be used in many situations where it is crucial to recognize human behaviors based on stance, including surveillance systems, human-robot interaction, and sports analysis.

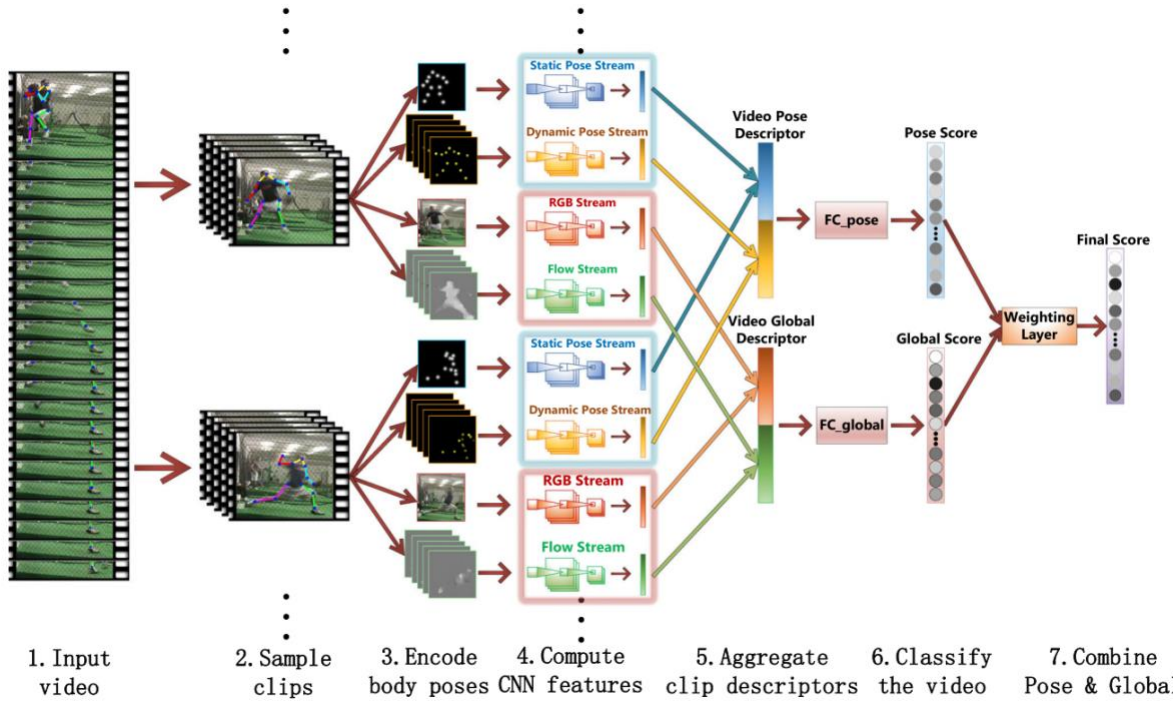


Figure 0-4 - Pipeline of the proposed approach

2.4.4 Center of Mass Trajectory

This study looked into the viability of measuring the human body's center of mass (CoMb) using 2D images and using the trajectory of the CoMb as an event detector for baseball swing action. Three individuals' movement data was gathered utilizing a motion capture equipment and a standard camera. The 2D skeleton and CoMb position from the 2D photos were determined using two posture estimation algorithms and an anthropometry model. For the skeleton and CoMb estimation, the estimated 2D findings had errors of 42.67 mm and 50.69 mm, respectively. A baseball specialist examined 88 baseball swing movies in order to assess the effectiveness of CoMb trajectory as an event detector for baseball swing movement. 90.91% of the expert's observations and the CoMb trajectory agreed. Overall, the study showed that 2D pictures could be used as an efficient event detector for baseball swing movement analysis by estimating CoMb and tracking its trajectory.

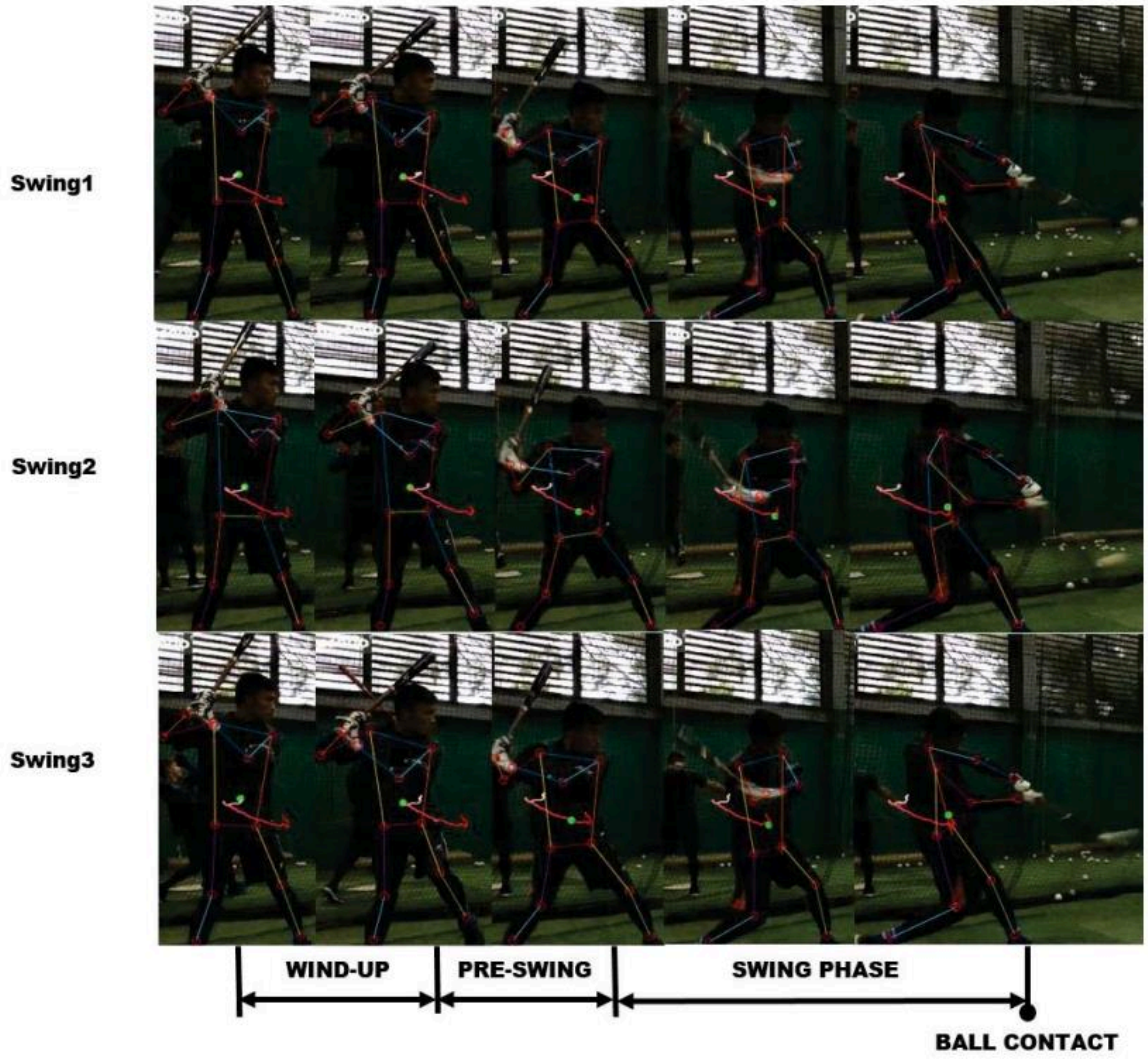


Figure 0-5 - Using the estimated CoMb trajectory as an event detector for baseball swing movement.

2.5 Summary of Existing Work

Citation	Brief Description	Limitations	Contribution
((Li et al., 2021) et al., 2018)	The hitter's limb coordinates are detected by the Open Pose mode. Custom rules are made by research and coaching experience to evaluate the	There was no restriction of the batting stance. If the hitter hit the top or bottom of the ball will	This study endeavored to fabricate a framework to assess baseball swings helping baseball players to address their

	swing of baseball hitters. Each rule is awarded different points.	significantly affect the hit distance. This might cause hit distance was not as far as expected while the hitter got higher score.	swinging postures. The proposed technique chiefly helps baseball hitters to address their body points regardless of whether there are then again different elements.
(Cheron, Laptev and Schmid, 2015)	Focuses on human action recognition in video. Proposed a new Pose-based Convolutional Neural Network descriptor (P-CNN). The descriptor collects motion and appearance data along human body part tracks. Test method using the recent and difficult JHMDB and MPII Cooking datasets. For both datasets, method worked.	The errors of the 2D results are 42.67 mm for the skeleton and 50.69 mm for CoMb estimation.	Helping baseball players to correct their bat swing.
(Fang et al., 2021)	The feasibility of using 2D images to estimate the CoMb and the performance of using the trajectory of the CoMb as an event detector for baseball swing movement were investigated. There are 88 baseball swing movement videos used.	Data deficiency and annotation bias are the main limitations parts in this paper. where supervised learning methods are primarily used. Normally, they need to be manually	In experiments, 80 out of 88 baseball swing videos were agreed by the baseball expert that the trajectory of CoMb can an event detector for baseball swing movement, which is a 90.91% agreement.

		annotated. But there aren't enough annotated data to enable more investigation.	
(McNally, Wong and McPhee, 2019)	Stacks 3D convolutions to reproject the Spatio-temporal activations generated by human pose estimation layers in space and time. UTD-MHAD and J-HMDB show that an end-to-end architecture based on the proposed STAR framework can perform in single-environment and small-scale applications.	Sensors make many applications impossible. Depth cameras' working range is severely limited, and they are not as easily obtainable or financially feasible as RGB cameras.	introduces the concept of spatiotemporal action projection in the context of human action recognition
(Li, Tong and Tang, 2018)	For 2D pose-based action detection tasks, a deep neural network architecture is used. 2D human body joints used as input for CNNs. In addition, to conduct action categorization, provide a weighted fusion approach that integrates RGB and optical flow with human posture data. On two real-world datasets, evaluate the technique and produce better results than state-of-the-art approaches.	The current model is not trained end-to-end	an action detection system that combines human posture information with global RGB and optical flow features

Table 2 - Summary of Existing Work

2.6 Technology Review

2.6.1 Algorithm Analysis

It takes considerable skill and experience to evaluate a baseball player's swing and recognize and correct technique problems. However, swing analysis and other action recognition criteria may now be somewhat predicted thanks to artificial intelligence. These models' primary goal is to assist athletes in self-training without the aid of a physical instructor, hence lowering the possibility of mistakes and injury. For the recognition and categorization of actions, human pose estimation, and image classification, numerous techniques, and neural network topologies have been used. This article will describe a handful of these techniques in this context.

2.6.2 Image Processing

Without making any conclusions about the image itself, image processing is the processing of images using mathematical transformations and functions. This indicates that operations like sharpening, smoothing, stretching, and contrasting the image are carried out using algorithms. Rows and columns of pixels are used to represent images as 2D signals. Similar to how MRI transforms magnetic excitations into pictures, these signals can change from one form to another (Russo, 1990). Convolutional neural networks (CNNs) and other machine learning techniques for image processing frequently employ matrix transformations. Images are convolved in CNNs to detect the color intensities and edges of the image using a filter, which is another pixel-valued matrix. This method is essential for finding patterns and features in images and is important for many computer vision applications.

2.6.3 Computer Vision

An essential component of computer vision is image processing, which is modeled using machine learning algorithms. Machine learning makes it possible to create photographs that can be categorized, arranged according to their dimensions, and processed in various ways by finding patterns within the photos. Like human vision, computer vision uses visual reasoning to distinguish between things and classify them according to different attributes like shape, size, and color. A crucial part of computer vision is image processing, which takes images as input and outputs formatted data that contains details about the image's size, color depth, and other properties

(Zaleski, 2010). A video camera placed close to a baseball player must recognize the batter within the frame and identify them from other objects or characteristics in the background as one example of applying image processing methods in computer vision. By learning and making choices based on visual inputs, computer vision ultimately aims to mimic human vision. To make decisions and take action in this situation, sophisticated algorithms that can evaluate and interpret visual input are needed.

2.6.4 Artificial Neural Networks

Artificial neurons, which are conceptually comparable to the real neurons present in the brain, are interconnected units or nodes that make up an artificial neural network (ANN). Similar to synapses in the brain, these artificial neurons receive messages from other neurons through connections. An artificial neuron process signals after receiving them in accordance with a set of guidelines or algorithms. The main goal of the ANN technique was to solve contemporary issues in a manner similar to how the human brain would. ANNs have been used for a variety of applications, including speech recognition and computer vision (Gatys et al, 2015). When taking into account an image categorization issue. Manual feature extraction from an image calls for a profound knowledge of both the subject and the field. It is a procedure that takes longer. Therefore, feature engineering is automated using deep learning.

2.6.5 Deep learning neural networks utilized in computer vision

In computer vision applications, deep learning neural networks are being employed to provide robots the ability to interpret, evaluate, and comprehend visual data much like the human brain. These networks let robots to pick up on patterns, forms, objects, and even emotions in pictures and movies. Numerous opportunities for applications in fields including self-driving cars, facial recognition, medical imaging, and more have been made possible by this.

- ANN - Artificial Neural Networks
- CNN - Convolutional Neural Networks
- RNN - Recurrent Neural Networks

CNN models have become more and more popular across a range of fields and applications, with a focus on video and image processing tasks. These models are commonly employed because they

are excellent at tasks like object detection, segmentation, and recognition since they can automatically learn and extract pertinent information from photos and videos.

2.6.6 Convolutional Neural Networks

Using filters, CNN is a potent neural network architecture that keeps the spatial relationships between pixels while extracting characteristics from images. These features are extracted from the image using the convolution procedure, which is simply a mathematical formula applied to a matrix. The network learns to recognize patterns and features that are helpful for the specified task by doing this operation on the image. CNNs have been quite successful in working with visual data because of their capacity to extract pertinent elements from images (Krizhevsky, 2012).
The number of trainable parameters dramatically rises with image size when an artificial neural network (ANN) is used to solve an image classification task. Due of this, handling spatial features, which are essential for image identification tasks, may be challenging for ANNs. Convolutional neural networks (CNNs) are superior to ANNs for image classification tasks because they are built to extract spatial characteristics from images.

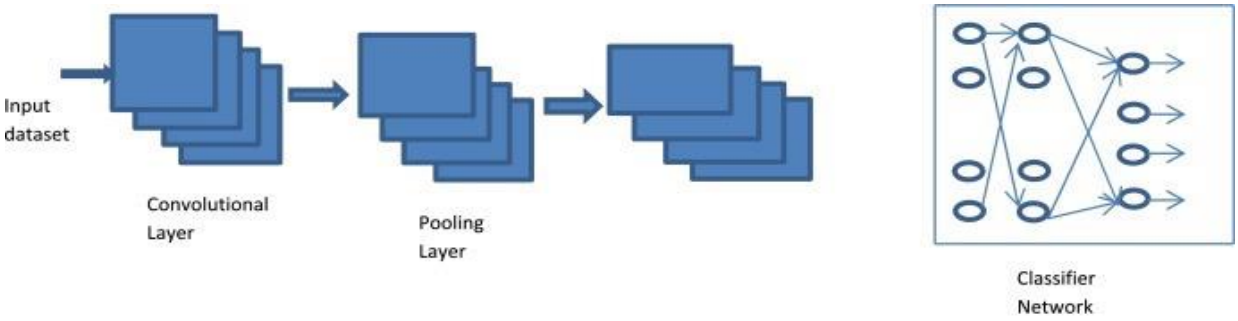


Figure 0-6 - Convolutional Neural Networks

2.6.7 Pose Estimation

In other words, the anatomical key points or "joints" localizing have primarily focused on detecting key body parts of a human (Cao et al, 2017). Human pose estimation is one of the fundamental computer vision problems with the objective of detecting the spatial location of joints of a human body in unconstrained pictures (Lecun et al, 1998). It is a significant play because, in addition to having to distinguish between the smooth coordinates of the joints, the display of body key points changes dramatically as a result of different clothing trends, arbitrary obstructions, and unrestricted

background contexts. Convolutional neural networks are more effective at this task as powerful image processing approaches (Zhang et al, 2019).

(Cao, Siemen, Wei, Sheikh, 2017) proposed a setup for a human's pose estimation in 2D. Part Affinity Fields is a non-parametric design that has been used to research how to link body parts with persons in the image. The benchmark of "MPII Multi-Person" and the "inaugural COCO 2016 key points" challenge showed encouraging results for the suggested system. The principal advantages of the system,

- Pose estimation capabilities for a large number of characters in a single image.
- the capacity to work effectively and precisely independent of the presence or absence of humans in the image.

A technique for human pose estimation was suggested in a paper by (Carreira, Agrawal, Fragkiadaki, and Malik, 2016), where the system receives repeated error feedback to improve the pose estimation process. The key benefit of this approach is that the system has a self-correcting capability that enables it to advance gradually rather than foretelling the output pose for a specific input image right away.

2.7 Chapter Summary

The techniques, procedures, strategies, and ideas used to successfully address the issue area are described in this chapter. The strategy began with the creation of a concept graph that graphically represented the information that had to be obtained. The review of the literature was then undertaken, and it was broken down into parts related to the problem domain, previous research, technologies, and approaches. The research results and comparisons were then thoroughly examined in light of the problem domain, comparable systems, appropriate technology, and methodologies. The research approaches and procedures used to develop a practical solution to the issue area are thoroughly reviewed in this chapter.

CHAPTER 3: METHODOLOGY

3.1 Chapter Overview

The approaches used for the research, project management, and project development are covered in detail in this chapter. The analysis of many possibilities and the choice of approaches are covered, along with comparisons between them. Also discussed is the viability of the methodologies picked. The chapter also contains a number of diagrams that illustrate the suggested plan for carrying out the project.

3.2 Research Methodology

The quality of research is determined by four major factors. Methodological quality, strategy appropriateness, policy and practice relevance and reporting quality (Boaz and Ashby, 2003). The table below shows the scientifically designed to represent research methodology that was chosen for this project.

Research Philosophy	What is the philosophy you have Among the positivism, pragmatism, realism, and interpretivism approaches, pragmatism was chosen. Because the researchers will explore and evaluate numerous approaches in order to discover which works best for reaching the research aim.
Research Approach	This research aims to investigate and evaluate a theory that might ncrease the general robustness of deep learning techniques on a baseball swing. The deductive technique was chosen above the inductive and deductive since the study heavily relies on a combination of current hypotheses. Both qualitative and quantitative methodologies were implemented as data analysis approaches.
Research Strategy	The proposed study outlines how will execute the methodology to address the research questions. Surveys, interviews, and experiments based on assessment measures will be used to evaluate prospective candidates.
Choice	Because both qualitative and quantitative data, such as performance values, and replies from interviews, would be utilised for the research, the mixed method

	was chosen among the multiple approaches of mono, mixed, and multi-methods.
Time horizon	Data collection must proceed at some point throughout the evaluation process of the researchers' research. Among the longitudinal & cross-sectional approaches, a cross-sectional approach was selected.
Techniques & Procedures	Interviews, observations, dialogues, reports, organizational, statistics, surveys, records, papers, and tabular data will be used for data gathering and analysis.

Table 3 - Research Methodology

3.3 Development Methodology

Among the many available software lifecycle approaches. Since there will be various assessments at different phases, the author will use the prototype technique to build and test the system frequently. The author chose the prototype model because must make adjustments and test frequently till an achievable outcome is gathered and a favorable outcome is achieved.

3.4 Project Management Methodology

Because this study is simulation-based from the alternative ways of Agile, waterfall, Kanban, and PRINCE2.etc., the Agile Prince-2 method will be used for project management.

3.4.1 Gantt Chart

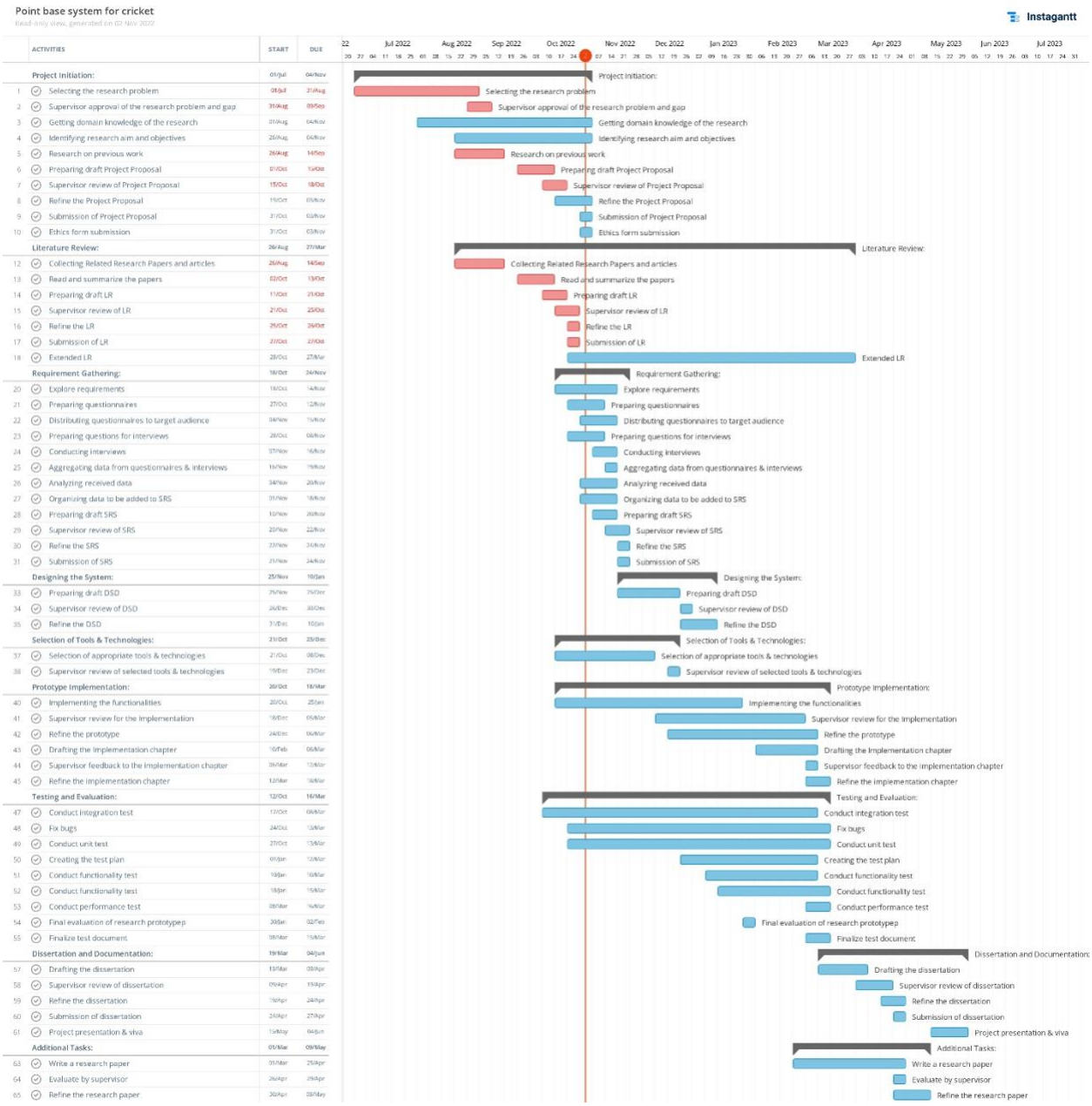


Figure 0-7 -Gantt Chart

3.4.2 Deliverables

Deliverable	Date
Project Proposal Document The initial proposal of the project	3rd November 2022

Literature Review Document The Critical review of existing work and solutions	11th December 2022
Software Requirement Specification The document specifying requirements to be satisfied and developed as the final prototype and means of collecting data	15th December 2022
System Design Document The document specifying the design developed for the Recommendations System and overviews of the algorithms to be developed.	1st December 2022
Prototype The prototype with main core features functional	1st February 2023
Thesis The final report documenting the project and research process and decisions	15th March 2023
Review Paper A review paper reviewing existing related Recommendation Systems	1st March 2023
Final Research Paper A research paper introducing the Recommendations System developed at the end of this project	2nd May 2023
Public project library A publicly accessible project library/ repository to set up, test and use the developed Recommendations System	2nd May 2023

Table 4 - Project Deliverables

3.5 Resources

3.5.1 Hardware Requirements

- Core i5 processor or above or M1 chip or above – A minimum quad-core CPU is capable of handling high-resource-consumption computer vision operations.
- 40GB Space or More – To store the DL models & datasets.
- 8GB RAM or above – A RAM that can handle big datasets of 1GB – 4 GB in capacity and trained DL models.

3.5.2 Software Requirements

- Operating System – An operating system that can handle large computational tasks and operating needed DL-related technologies without any compatibility problems.
- Python – python is the main programming language used to develop the DL models.
- TensorFlow – Google developed a deep learning framework to deep learning development.
- Google Collab - To explore and try out various available models with GPU power in the cloud.
- MS Office - To documentations
- Zotero – To manage references and citations
- Google Drive – To store backups and the dataset

3.5.3 Skill Requirements

- Knowledge in human pose estimation
- Knowledge in baseball swing and the batting methods

3.5.4 Data Requirements

- Must create new dataset for baseball swing analysis

3.6 Risk and Mitigation

Risk	Probability of Occurrence	Magnitude of the loss	Mitigation Plan
The project's needs are continually changing. This research, like any	5	5	Following the prototype, methodology will assist.

other, will be subject to changing requirements as the prototype is replicated. Such adjustments must be addressed.			in managing the frequent requirement changes.
Deep knowledge in computer vision and baseball	3	3	There are some online platforms provide a restricted number of tutorials for gaining fundamental info.
Lack of experts who have worked with baseball – In Sri Lanka there is only few experts working on this sport	3	3	Find out some professional coaches
Limited hardware resources are on hand since the prototype system may requires advanced computing capacity and processing speed.	5	5	To address this issue Google collab and other cloud services can be used.
When comparing to the project, losing previously and existing related work might be a significant risk.	4	4	The author must stay current on the domain and techniques. If such unexpected contributions are made, they should be assessed, and the project adjusted accordingly.

Table 5 - Risk & Mitigation

3.7 Chapter Summary

The methods and tactics utilized in carrying out research, creating services, and managing projects were covered in this part. Along with the selection criteria and specifications for each requirement, it also explains why those criteria were chosen. Additionally, it describes any potential risks that might occur throughout the procedure and suggests a mitigation strategy to deal with them.

CHAPTER 4: Software Requirement Specification

4.1 Chapter Overview

This chapter's goal is to identify the project's stakeholders by exploring all of the potential ways in which the system may interact with them. This is accomplished by developing a rich picture diagram, consolidating their viewpoints, and assessing and developing anticipated use cases and prototype requirements (both functional and non-functional).

4.2 Rich Picture Diagram

The figure is intended to make clear the numerous ways that different groups, or stakeholders, might engage with the system.

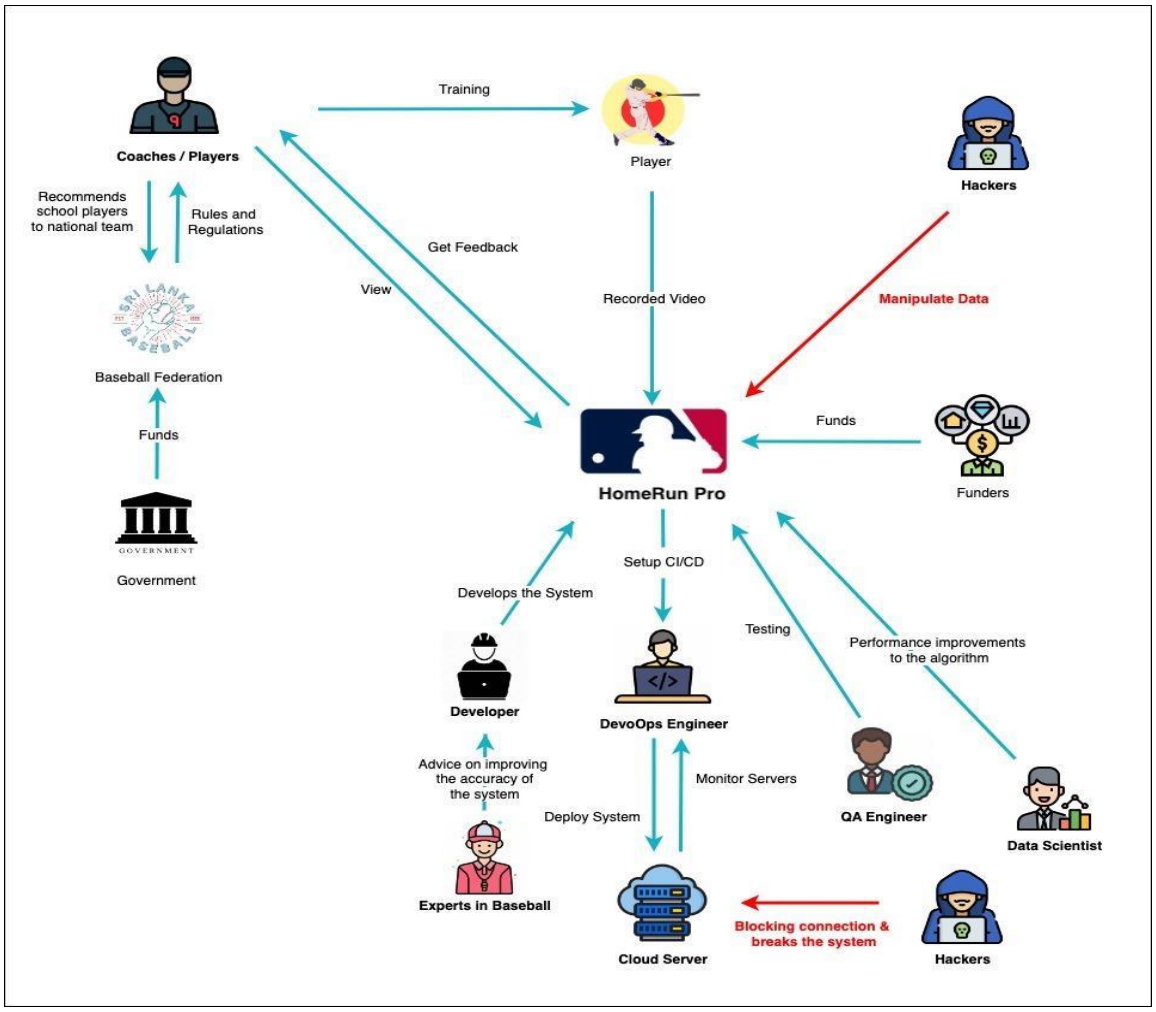


Figure 0-8 - Rich Picture Diagram

4.3 Stakeholder Analysis

In Stakeholder Viewpoints, the Stakeholder Onion Model depicts acknowledged stakeholders connected to the system and provides an explanation of each stakeholder's engagement in the system.

4.3.1 Stake Holder onion model

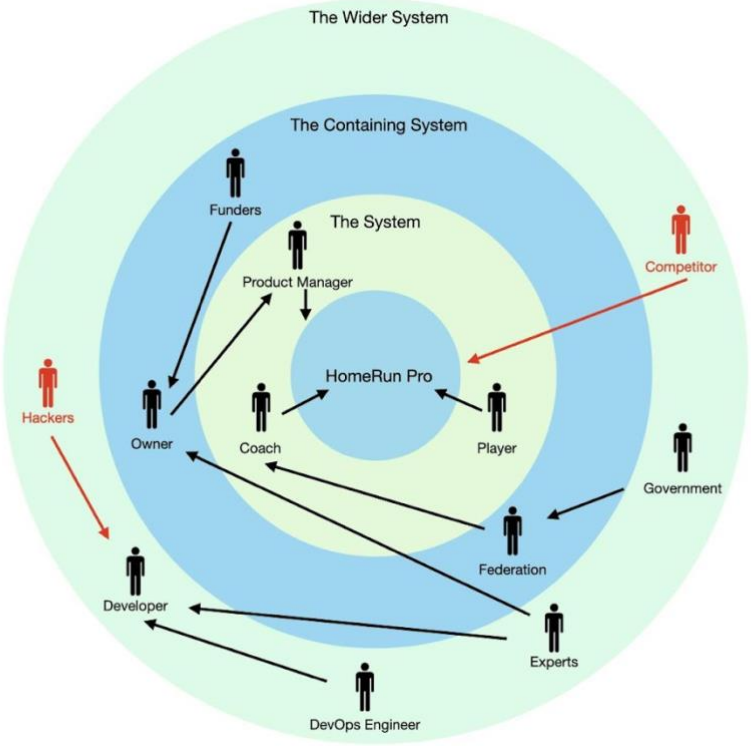


Figure 0-9 - Stake Holder onion model

4.3.1 Stake Holder Viewpoints

Stakeholder	Role	Benefits/Drawback
Developer	Developer	The person in charge of creating the suggested system makes forecasts using a platform with a user interface.

DevOps Engineer	Product Maintenance & Deployment	Makes sure the system is operating properly and responds to any requests or issues that users may have.
Domain Experts	Expert	provide information on the subject and the sector. Review the system and provide helpful criticism
Hackers	Negative Stakeholder	Try to break into the system, steal crucial information, and disable it.
Competitor	Negative Stakeholder	There could be competing services developed with pricing higher than or lower than those offered for sale.
Government	Functional Beneficiary	Provides funds and rules and regulations
Federation	Quality Regulator	Provides rules and regulations to the sport
Product Owner	Financial Beneficiary	Owner of the product
Funders	Financial Beneficiary	To benefit from the system, investors will contribute to its growth and upkeep.
Coach	Normal Operator	Will be able to use the product and analyse player swing
Player	Normal Operator	Will be able to use the product and analyse player swing
Product Manager	Advisory	It is wise to advise the usage of various tools and technologies to maintain the project inside its allotted time limit and to offer feedback.

Table 6 - Stake Holder Viewpoints

4.4 Selection of Requirement Elicitation Methodologies

The information needed to build the research study was gathered through a variety of ways. These techniques included surveying, interviewing, literature analyses, and prototyping. The explanations for selecting these particular requirement elicitation techniques are given below.

Method 01 - Literature Review
Before beginning the assignment, the author conducted a thorough examination of the existing literature to see whether there were any research gaps in the chosen field and the intended area of investigation. Researching existing systems and assessing comparable technologies that may be used with the systems discussed in the literature were part of the review process. This was done in order to find any technological gaps that may be the subject of future study.
Method 02 - Interview
To identify the most effective method of solving the issue and add to the body of knowledge via research, interviews were conducted to gain expert insights on the particular requirements of the area. Because the subject was new and needed specialist technical knowledge, this approach was thought to be the most successful. Qualitative input on the proposed system was acquired through the interviews, enabling for the identification of any potential flaws or problems that could need to be fixed during the prototype stage.
Method 03 - Survey
To learn more about the preferences and requirements of possible users of the suggested system, a survey questionnaire was used. This approach helped the author better comprehend the viewpoints and expectations of the prototype's users. It also enabled the author to establish whether the suggested solution would be beneficial to the intended users

Method 04 - Prototyping
The prototype was tested, evaluated, and opportunities for improvement were found using prototyping as a tool. The project was using an Agile Software Development Lifecycle, hence this strategy was chosen.

Table 7 - Requirement Elicitation Methodologies

4.5 Discussion of Findings

4.5.1 Literature review

Finding	Citation
The hitter's limb coordinates are detected by the Open Pose mode. Custom rules are made by research and coaching experience to evaluate the swing of baseball hitters. Each rule is awarded different points.	((Li et al., 2021)
Focuses on human action recognition in video. Proposed a new Pose based Convolutional Neural Network descriptor (P-CNN). The descriptor collects motion and appearance data along human body part. tracks. Test method using the recent and difficult JHMDB and MPII Cooking datasets. For both datasets, method worked.	(Cheron, Laptev and Schmid, 2015)
Stacks 3D convolutions to reproject the Spatio-temporal activations generated by human pose estimation layers in space and time. UTD-MHAD and J-HMDB show that an end-to-end architecture based on the proposed STAR framework can perform in single- environment and small-scale applications.	(McNally, Wong and McPhee, 2019)
For 2D pose-based action detection tasks, a deep neural network architecture is used. 2D human body joints used as input for CNNs. In addition, to conduct action categorization, provide a weighted fusion approach that integrates RGB and optical flow with human posture data. On two real world datasets, evaluate the technique and produce better results than state of the-art approaches.	(Li, Tong and Tang, 2018)

Table 8 - Literature review

4.5.2 Interview

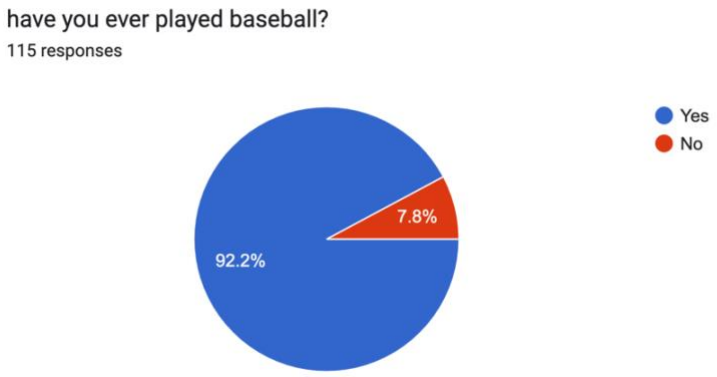
To acquire data on technical skills, interviews with specialists from related domains were conducted. Specialists and researchers in computer vision and video analysis were chosen for interviews to evaluate the project's needs. Interviews with software engineers, computer science graduates, and lecturers were conducted in addition to those with data science engineers. The following topics were used as the foundation for a thematic analysis of the interview.

Theme	**Analysis**
Collection & preprocessing of available data	The main issue mentioned was the accessibility of the data because this initiative is meant to be a learning experience. The author was advised to collect a dataset of Sri Lankan school-level baseball players and to use computer vision techniques to improve the model's precision. To make sure that the data obtained appropriately represents the target population and to consider any obstacles or constraints that may occur specifically in the Sri Lankan context, it was also advised to extensively investigate and experiment with alternative methodologies. The author was also urged to think about adding synthetic data to the dataset to boost its volume and diversity while preserving its applicability to the intended audience.
Research gap & scope	The experts have questioned agreed that the shortcomings in the current literature had been correctly identified, and the author had clearly laid out their strategy for filling these gaps. The experts agreed that a novel, cutting-edge strategy that has never before been used in baseball would be especially helpful in a nation like Sri Lanka. Given the time restrictions, the interview subjects thought the research's scope was appropriate and practicable.
Baseball swing pose estimation existing approaches and techniques	The majority of those analyses to improve the project idea was worthwhile and the author's suggested strategy for analyzing baseball swings was a good one. Experts suggested testing several computer vision models to identify which one is best for swing analysis and looking into other options. In order to pinpoint areas for development

	in the project proposal, the experts also advised analyzing previous work done for other sports.
Features of Prototype and Suggestions	The experts recommended that the prototype be kept straightforward and that further modifications may be introduced once its validity had been demonstrated because it is primarily focused on a user interface (UI).

4.5.3 Questionnaire

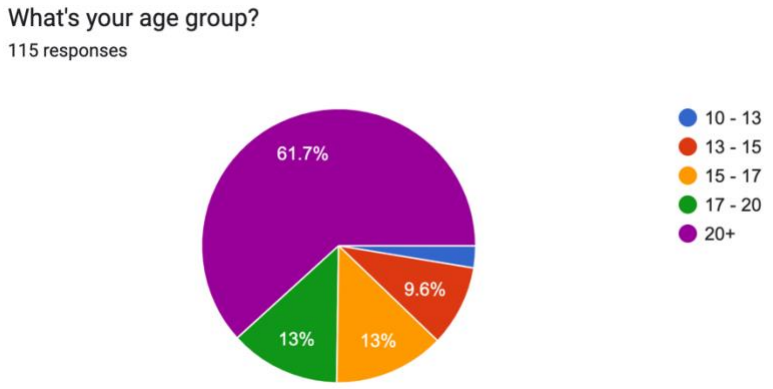
Question	Have you ever played baseball?
Aim of the Question	To determine whether the domain of baseball is shared with the right audiences.
Findings & Conclusions	



To ensure the most accurate results, the questionnaire was only made available to people who were familiar with baseball and relevant specialists in the field. The legitimacy of the replies may be verified by this method.

Question	What's your age group?
Aim of the Question	To determine whether the survey is shared with the right audiences.

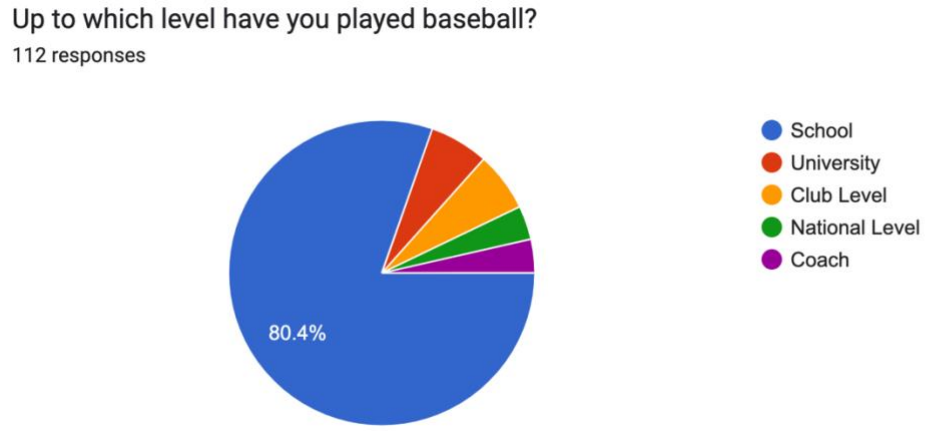
Findings & Conclusions



This question is asked to identify the age groups of the participants who have participated in this survey.

Question	Up to which level have you played baseball?
Aim of the Question	To determine whether the survey is shared with the right audiences.

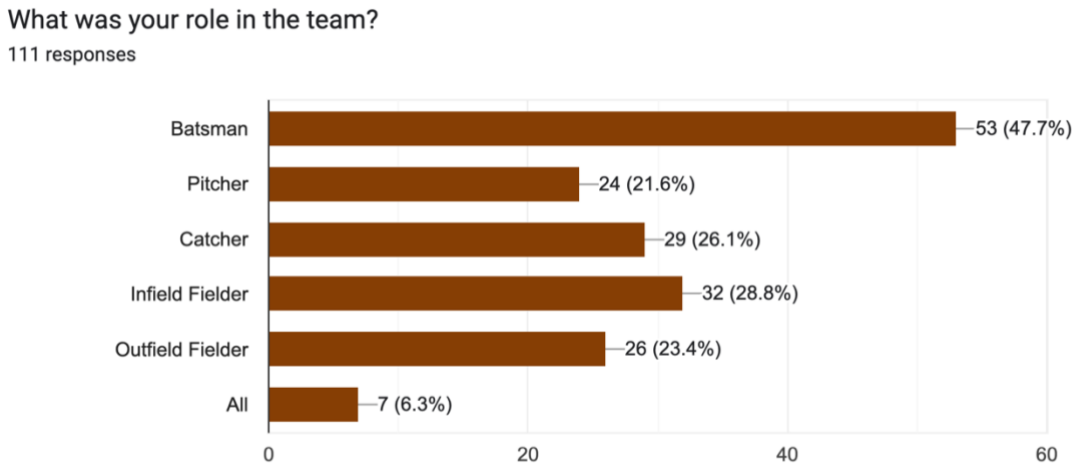
Findings & Conclusions



This question is asked to identify the experience level of the participants who have participated in this survey.

Question	What was your role in the team?
Aim of the Question	To identify the kind of experiences the participants have.

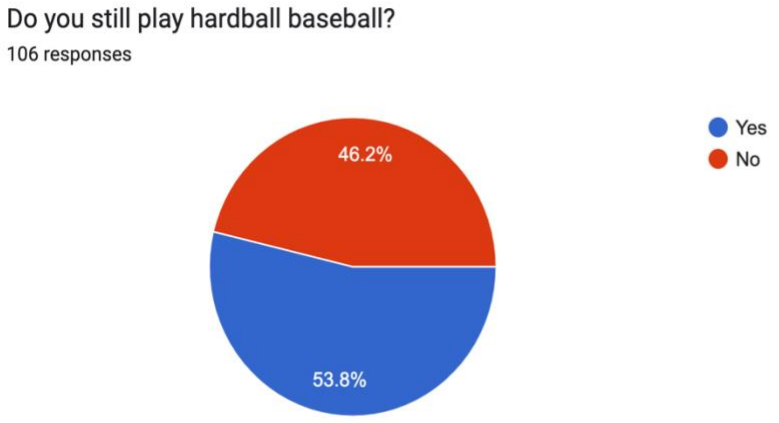
Findings & Conclusions



This question is asked to identify the type of experience of the participants who have participated in this survey.

Question	Do you still play hardball baseball?
Aim of the Question	To identify the participants who still playing baseball.

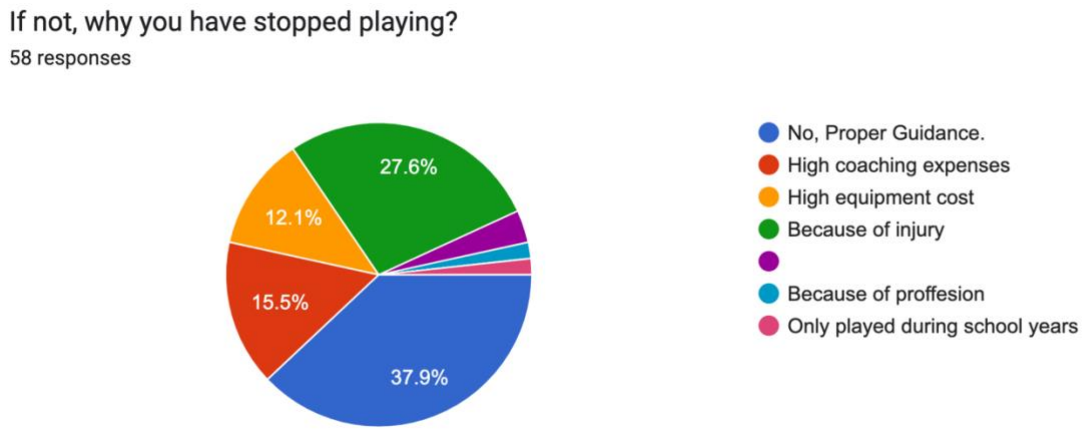
Findings & Conclusions



This question is asked to find the participants who still playing baseball.

Question	If not, why you have stopped playing?
Aim of the Question	To identify the participants who still playing baseball and find the reasons why others don't play.

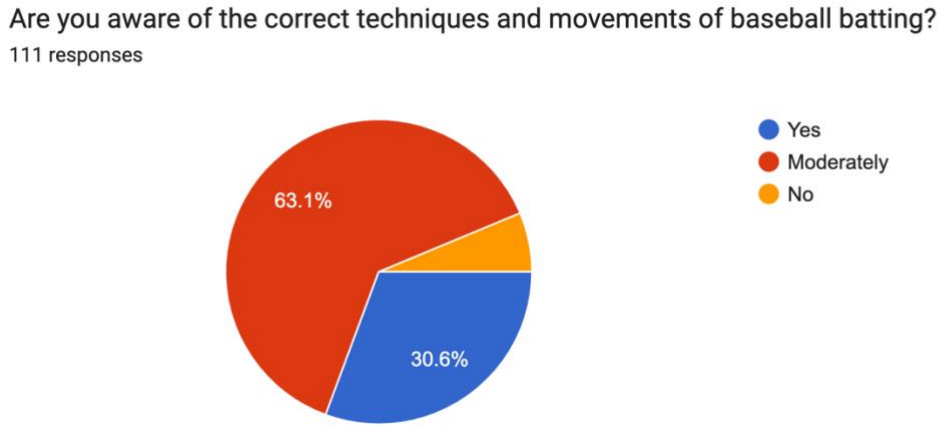
Findings & Conclusions



This question is asked to find the participants who still playing baseball and if they are not playing baseball to find the reason for that.

Question	Are you aware of the correct techniques and movements of baseball batting?
Aim of the Question	To identify the participants in this survey who has the proper understanding of correct baseball batting techniques.

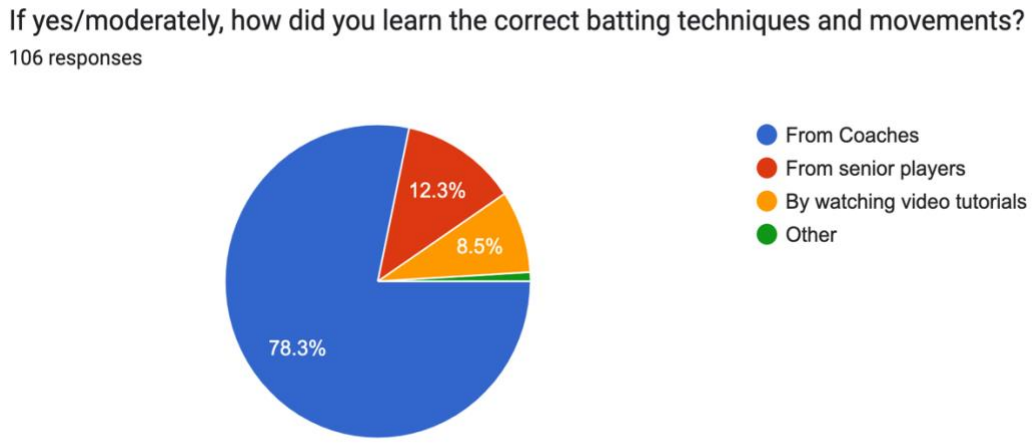
Findings & Conclusions



This question is asked to find the participants in this survey who has the proper understanding of correct baseball batting techniques and to understand their awareness of correct techniques.

Question	If yes/moderately, how did you learn the correct batting techniques and movements?
Aim of the Question	To identify the participants in this survey how they know proper understanding of correct baseball batting techniques.

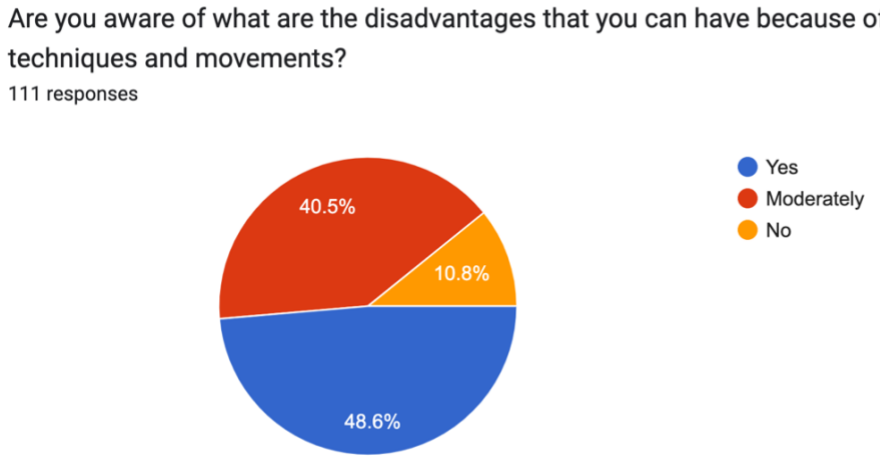
Findings & Conclusions



This question is asked to find how the participants in this survey got awareness of correct techniques.

Question	Are you aware of what are the disadvantages that you can have because of incorrect batting techniques and movements?
Aim of the Question	To identify the participants in this survey who has the proper understanding of disadvantages of incorrect baseball batting techniques.

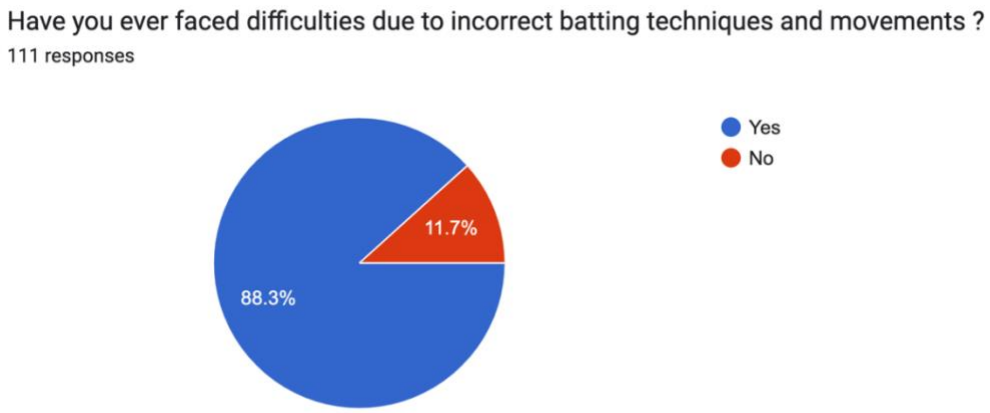
Findings & Conclusions



This question is asked to find the participants in this survey who has the proper understanding of disadvantages of incorrect baseball batting techniques and movements.

Question	Have you ever faced difficulties due to incorrect batting techniques and movements?
Aim of the Question	To identify the participants in this survey who has faced difficulties because of incorrect baseball batting techniques.

Findings & Conclusions

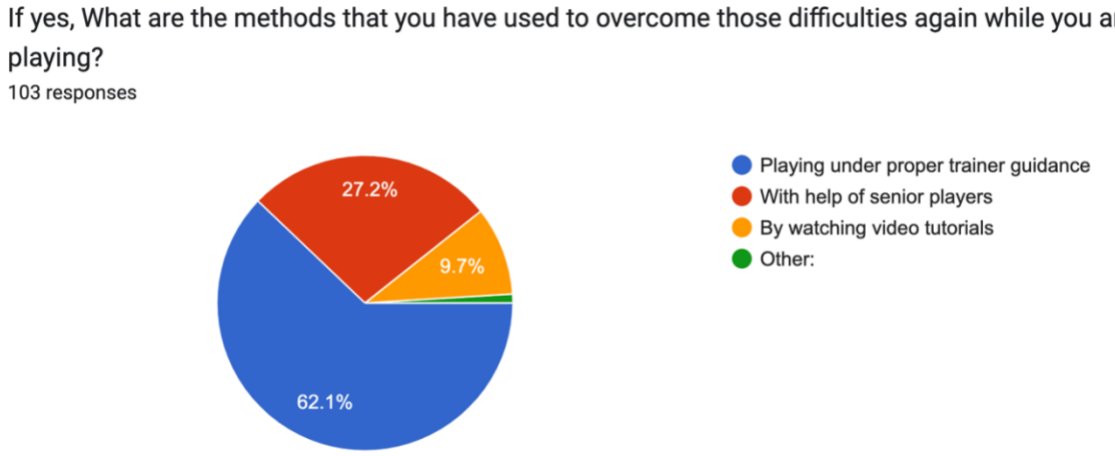


This question is asked to find out how the participants in this survey have awareness of the difficulties due to incorrect techniques.

Question	If yes, What are the methods that you have used to overcome those difficulties again while you are playing?

Aim of the Question	To identify the participants in this survey who has faced difficulties because of incorrect baseball batting techniques and what they have done to overcome those difficulties.

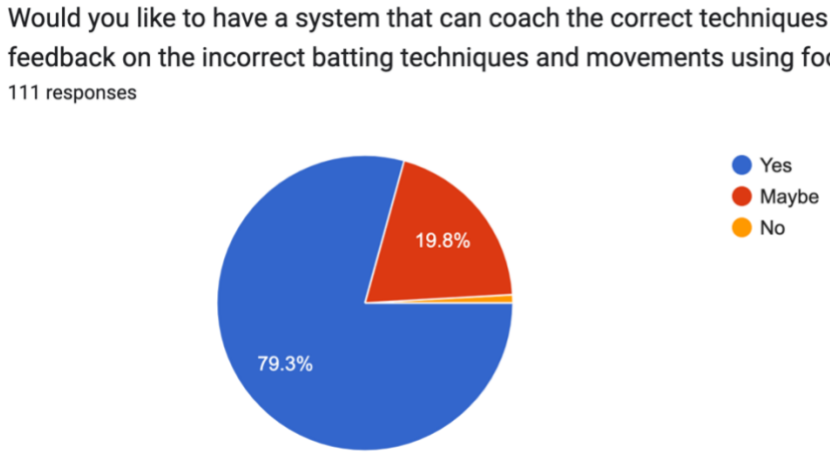
Findings & Conclusions



This question is asked to identify the participants in this survey who has faced difficulties because of incorrect baseball batting techniques and what they have done to overcome those difficulties.

Question	Would you like to have a system that can coach the correct techniques and movements and give feedback on the incorrect batting techniques and movements using footages of batting?
Aim of the Question	To identify how valuable the system is to the end users

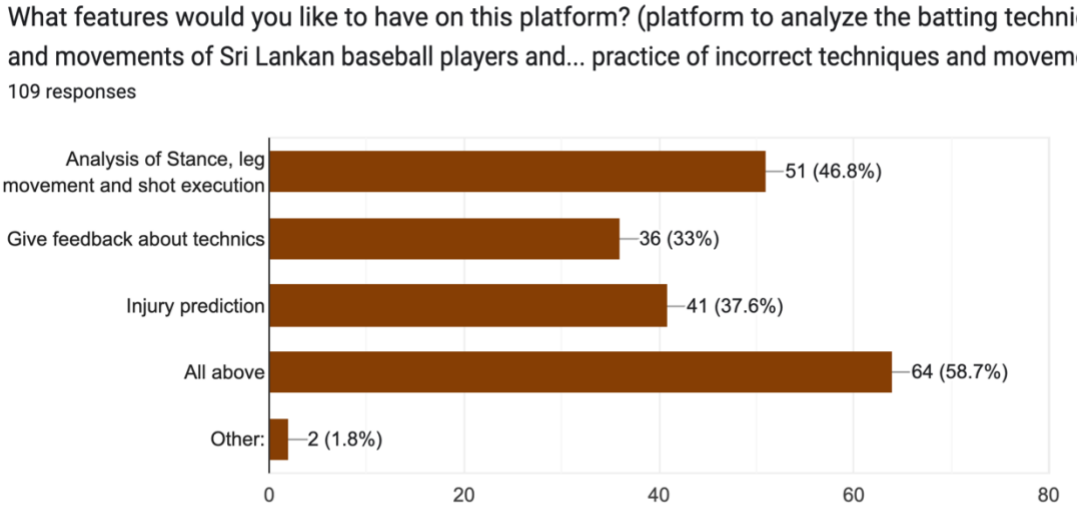
Findings & Conclusions



This question is asked to identify how valuable the system is to the end users.

Question	What features would you like to have on this platform? (Platform to analyze the batting techniques and movements of Sri Lankan baseball players and to give feedback, based on their prolonged practice of incorrect techniques and movements)
Aim of the Question	To identify what kind of features end users are expect from this kind of system.

Findings & Conclusions



This question is asked to identify what kind of features end users are expect from this kind of system.

Table 9 - Questionnaire

4.5.4 Summary of Findings

ID	Finding	Literature Review	Interviews	Survey	Prototyping
01	In Sri Lanka, there is no system to analyse to baseball bat swing and give feedback.		✓		
02	The project's idea is sound, and it deals with a problem that the Sri Lankan baseball community runs across regularly.		✓	✓	
03	To precisely determine the ideal baseball swing techniques, it would be helpful to have a system that estimates baseball swing postures using videos.	✓	✓	✓	✓
04	It is advised to create reports and write code to accelerate the analyzing process.	✓	✓		
05	The system would need a large volume of well-cleaned and pre-processed data to function properly.	✓	✓		✓
06	The domain gap that has been found may be a major factor in the expansion of Sri Lanka's baseball industry.	✓	✓	✓	
07	When compared to other models, the LSTM model has the ability to reach a greater accuracy level.	✓	✓		✓
08	The detection procedure is expected to be improved even further by upgrading the model and training it to evaluate the most recent swing approaches.	✓	✓	✓	

Table 10 - Summary of Findings

4.6 Context Diagram

To illustrate the connections and communication between the suggested system and various external components, the author has prepared a context diagram. The interaction between the system and these components is shown in the diagram.

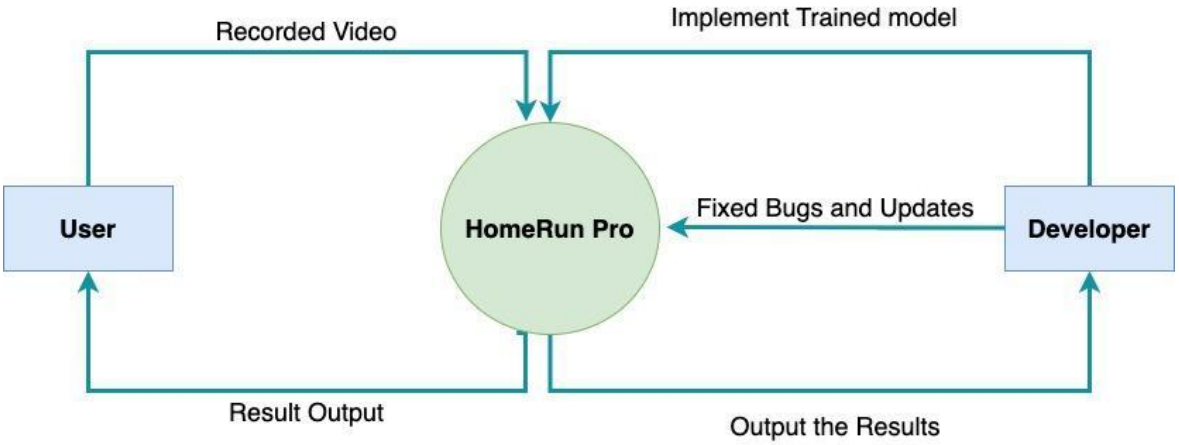


Figure 0-10 - Context Diagram

4.7 Use case Diagram

The use-case diagram show interactions between the system and its actors as well as an overview of the system's features and scope. To depict the suggested system, the author has developed a use-case diagram that shows these components.

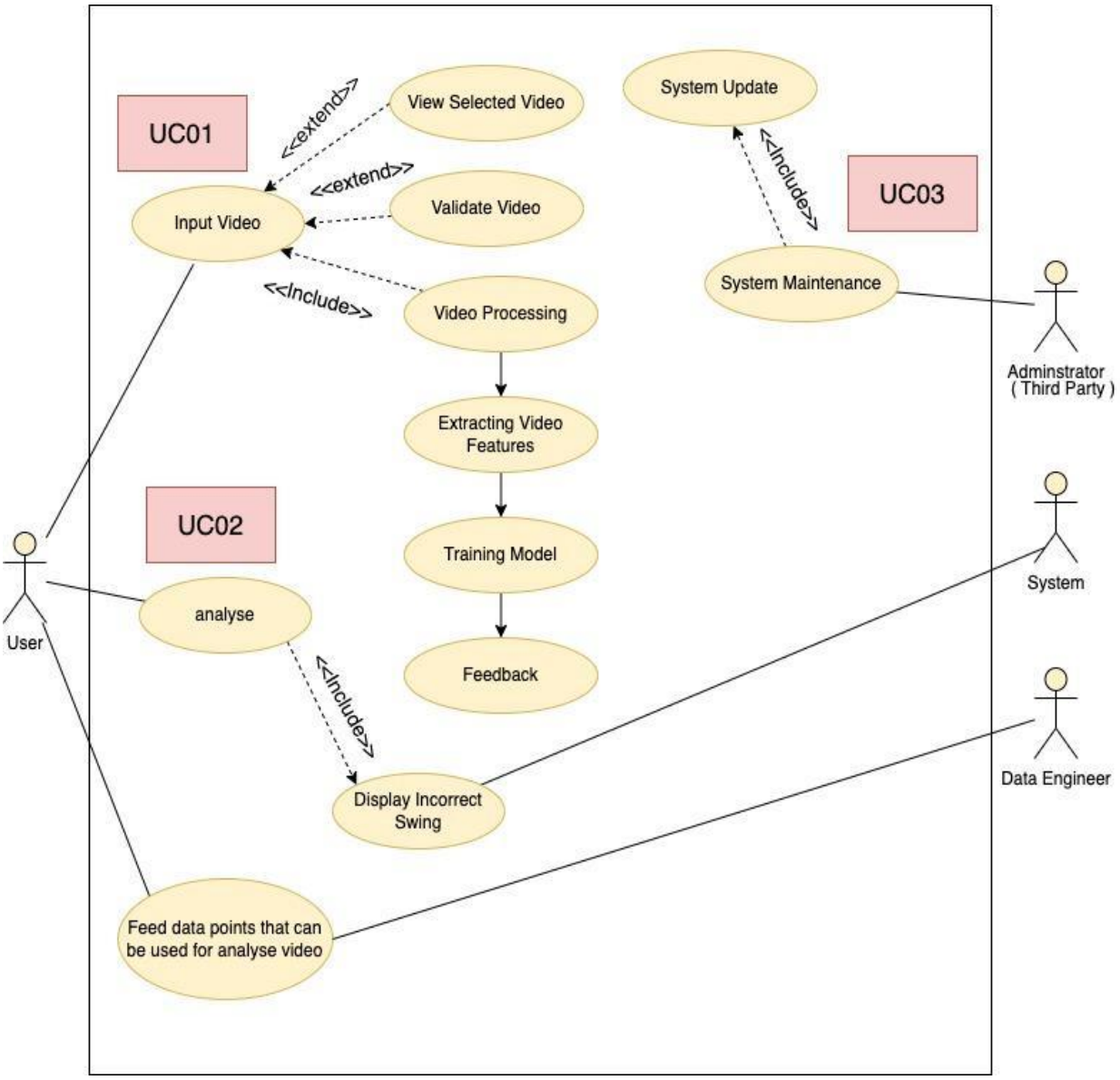


Figure 0-11 - Use case Diagram

4.8 Use case Descriptions

Use case	Uploading Video Selected Video
ID	UC01
Brief Description	Uploading the recorded baseball bat swing video in to the application

Primary Actor	User
Pre-condition	Uploaded video must be an baseball bat swing video and it should be .mp4 format.
Main Scenario	1. User should upload video to the application. 2. If the uploaded video is in an incorrect format the system will show an error message. 3. The analyzing process will start once the user uploads the correct format of a video and clicks the analyze button.
Alternative Flow	None

Table 11 - Use Case Description 1 - Transliterate Content (self-composed)

Use case	Display analyzed bat swing result
ID	UC02
Brief Description	The application should be able to analyze stance, leg movement, and shot execution after a user uploaded the video in the correct format.
Primary Actor	User
Pre-condition	The video user uploaded should be a mp4 format.
Post Condition	User will have to go to the main page manually to analyse another video by clicking home icon.

Main Scenario	1. Analyzing the uploaded video format and video content. 2. Displaying the feedback.
Alternative Flows	None

Table 12 - Use Case Description 1 - Transliterate Content (self-composed)

4.9 Requirements

Functional and non-functional criteria represent the two categories of the system specifications. To describe how the requirements for the system were identified, the author provided tables for each category. These tables enable readers to comprehend how the author arrived at their conclusions on what the system requires.

4.9.1 Functional Requirements

The author applied the MoSCoW approach to identify the functional needs of the system and their priority level. The outcomes of this procedure are shown in the tables below, together with the priority level, use case IDs, and functional requirements considered suitable for the system.

Priority Level	Description
Must have (M)	The fulfillment of this degree of priority is essential for the system's fundamental operation.
Should have (S)	Although these needs are not as crucial as the fundamental requirements of the system, they are nonetheless necessary since they greatly improve the outcome.

Could have (C)	These are the desirable specs that are optional and not necessary for the system to function.
Will not have (W)	These are the requirements that the system may not meet, but which are not now thought to be of vital concern.

Table 13 - MoSCoW Priority Levels (self-composed)

FR ID	Requirement	Priority Level	Use Case
FR1	The option for people to select and submit recorded footage of their baseball bat swings for analysis should be provided.	M	UC1
FR2	The system must be able to precisely recognize the swing of a baseball bat using video inputs.	M	UC2
FR3	Even in the event of equipment failures or other interruptions, the system must continue to operate properly.	S	UC4
FR4	The software system should be able to identify key elements in the videos, such as posture, leg motion, and swing execution, that may be used to assess a baseball bat swing.	M	UC1
FR5	A large collection of labeled images, including photographs showing both correct and incorrect baseball bat swing patterns, will be used to train the model.	M	UC1
FR6	Users must be able to view feedbacks after the baseball bat swing analyzing	M	UC4
FR7	Audio, text, and picture inputs won't be analyzed.	W	N/A

Table 114 – Functional Requirement

4.9.2 Non- Functional Requirements

NFR ID	Requirement Type	Description	Priority Level

NFR1	Usability	Even non-techies should be able to quickly use the application's user-friendly and intuitive design. The design should reduce the time and effort needed to train new users on how to utilize it effectively.	Desirable
NFR2	Accuracy	It is recommended that the provided algorithms and models have a high degree of accuracy.	Important
NFR3	Security	To protect privacy, precautions should be made to stop unauthorized users from tampering with test findings or accessing user inputs.	Important
NFR4	Availability	Everyone has free access to and may simply use this program, which is available to all users.	Desirable
NFR5	Scalability	The system must be able to grow and accommodate several simultaneous user visits while maintaining excellent performance.	Desirable
NFR6	Compatibility	The system should work properly on any web browser and be compatible with all sorts of operating systems and their corresponding versions.	Important
NFR8	Maintainability	The system should be designed with focus on simplicity when adding or deleting functionality, and it should adhere to accepted coding conventions to simplify future development.	Desirable

Table 15 - Non-Functional Requirements

4.10 Chapter Summary

This chapter provides an in-depth analysis of the many components that make up the system to provide a full perspective of the system. The author begins with a Rich Picture Diagram, which offers a bird's-eye view of the entire system and serves as a high-level depiction of it. The Onion Model then describes the interactions between the system's important participants and the outside environment. The perspective table provides a clear explanation of how the system works and who it helps by outlining each player's position and the advantages they gain from utilizing it. A context diagram of the system's major functions and interactions with the outside environment is also

included in the chapter. The author offers a use case diagram and use case descriptions that describe how the system functions to further highlight the functionalities of the system. The chapter ends with an analysis of the functional and non-functional needs acquired using the author's approach of requirement elicitation. To give a clear understanding of the criteria and how they were established, a summary of the results from each technique is presented.

CHAPTER 5: SOCIAL, ETHICAL AND PROFESSIONAL ISSUES

5.1 Chapter Overview

This section's purpose is to discuss potential difficulties that might occur throughout the project in terms of social, legal, ethical, and professional issues. It also describes the steps that will be taken to lessen or resolve these problems.

5.2 SLEP Issues and Mitigations

Social	**Legal**
• The questionnaire answers were incorporated into the thesis in a way that covered the participants' individual viewpoints. Instead, only an overview of the replies was recorded. • The interviewees were requested for their permission to have their names and jobs listed in the thesis after being notified that their answers would be used in it.	• The project's programming frameworks, tools, and languages were all subject to an open-source license. • The GPL3 license will apply to the research's source code, which includes the data gathering and preparation. • The system was created in a way that it wouldn't require any personal information to provide the desired results.
Ethical	**Professional**
• The people who responded to the questionnaires were informed of the	• The equipment and software used to create the prototype were all legal and legitimate purchases. Throughout the

initiative and how they may participate in it. • There are no instances of fabrication, falsification, or plagiarism in the thesis. Every piece of data and information presented is accurate, and any expertise or information from outside sources was dutifully noted and referenced.	entire procedure, only open-source options or licenses intended for educational use were applied. • The project's outcomes were precise and correctly conveyed. The results' documentation has not been changed in any way.

Table 16 - SLEP Issues and Mitigations

5.3 Chapter Summary

This chapter identified and explored a variety of social, legal, ethical, and professional issues that can potentially come up throughout the research. For each category, the mitigation techniques used to deal with these problems were also provided.

CHAPTER 6: DESIGN

6.1 Chapter Overview

An overview of the system architecture and design based on the obtained requirements is presented in this chapter. It discusses the choices in design and architecture that were taken to produce the best architecture possible for execution. The chapter comprises low-fidelity UI wireframes, class diagrams, activity diagrams, sequence diagrams, and high-level architectural diagrams. The chapter also explains in detail the many design and architectural decisions that were taken so that the reader may comprehend the arguments behind them.

6.2 Design Goals

Design Goal	**Description**
Usability	Designing the system in a way that is intuitive and simple to use, especially for people with minimal technical experience and understanding of baseball techniques, is essential to making it accessible to the end user. The prototype must be simple and uncomplicated, stressing effectiveness and simplicity in its design, in order to accomplish this. This will provide a fluid and user-friendly user experience, allowing users to efficiently use the system without difficulty.
Scalability	The system is expected to manage several concurrent user requests in a production setting. It is crucial that the backend infrastructure be strong enough to handle this large volume of traffic and give consumers a smooth experience. Additionally, it should be simple and quick to add new data to the database without needing a lot of technical know-how or effort. As a result, the system will be able to scale and modify to meet the users' expanding demands while retaining its high performance and dependability.
Performance	The system should be able to reliably recognize and assess baseball swing stances. Additionally, it's critical that the system function computationally well, processing enormous amounts of video data fast without degrading speed or

	performance. The system must meet this need for computational effectiveness in order to efficiently carry out its function and offer insightful information to users.
Adaptability	The system must be adaptable enough to enable simple replacement of the existing model with new ones while guaranteeing that the upgrading procedure is error-free. Since the DL model utilized in the system may need to be adjusted in response to changing data availability and user needs over time, it is crucial to maintain stability and minimize the impact of changes during the model upgrading process. By doing this, the system will be kept reliable and stable while also being current and relevant.
Correctness	The system needs to be able to precisely assess baseball swing poses using the information learned from the trained model. When given a video that does include a baseball swing, the algorithm will be deemed incorrect if it cannot accurately identify the postures that a baseball swing takes or if it produces an inaccurate result. The system must meet this accuracy criteria in order to successfully offer users insightful analyses and judgments.

Table 17 - Design Goals

6.3 High Level Design

6.3.1 Architecture Diagram

The picture shows a three-tiered design with distinct layers for data, logic, and display. The data preparation in the data tier, the application of reinforcement learning models, and the client tier make up most of the the system's contribution to research.

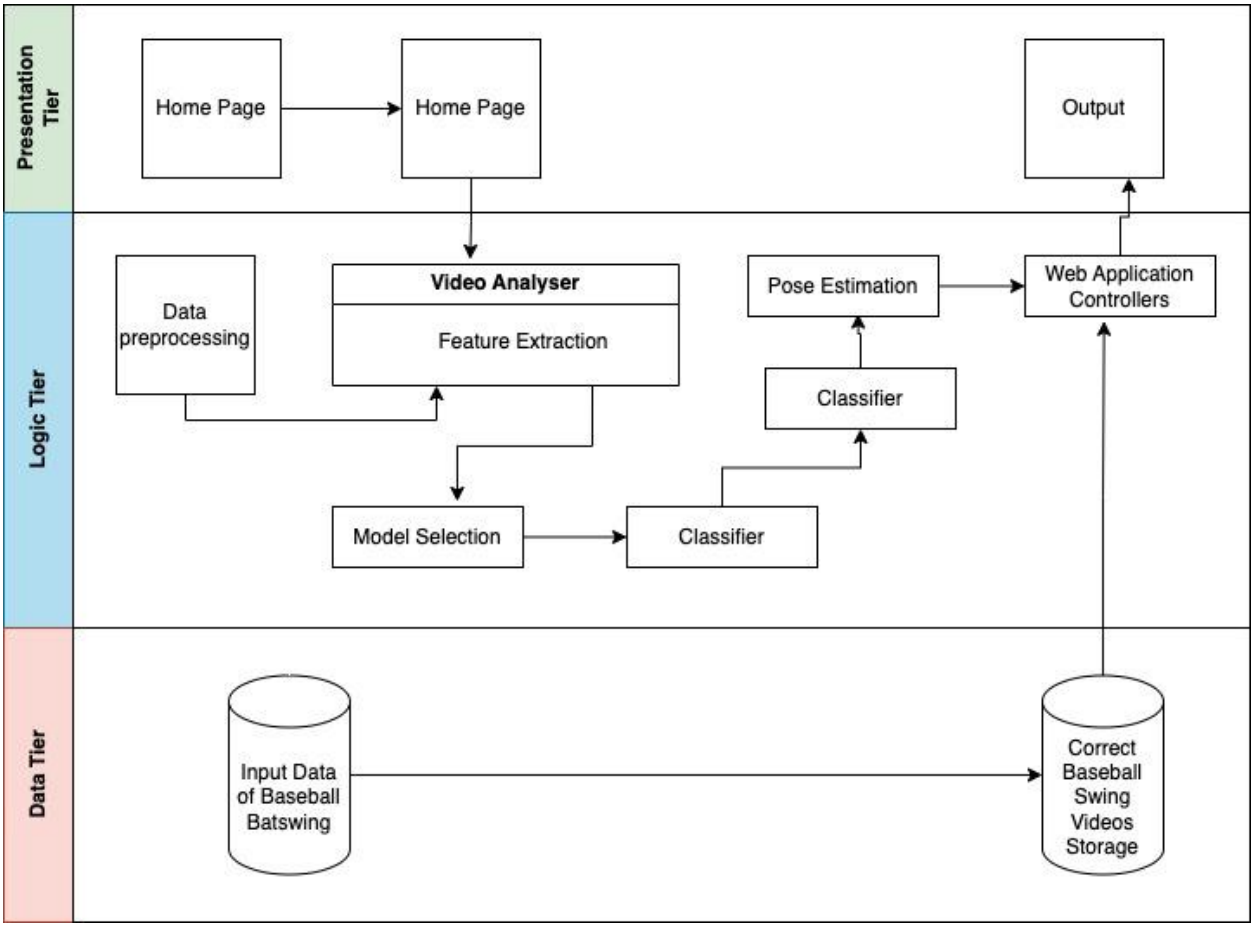


Figure 13 – Architecture Diagram

6.3.2 Discussion of tiers / layers of the Architecture

6.3.2.1 Presentation Tier

The user interacts with the presentation tier of the system, which functions as the interface between them and the program. The graphical user interface (GUI) of the system is basically represented by this layer, which is in charge of gathering input from the user and delivering the output to them.

- **Landing Page -** The user will be given an overview of the system and a quick introduction when they first visit the application. This will contain a thorough manual on how to use and navigate the system correctly, guaranteeing an easy and productive user experience.
- **Input Video -** The user should first upload a video of their baseball bat swing using the program to obtain an analysis of their swing from the model. Through the system

controllers, the assigned bat swing analyzing model will receive this video input and analyze it.

- **Output Result -** After the start screen, the user will be taken to a new page that shows both their actual video input as well as the model's response. The user will be given access to the analysis findings in an intuitive style that is simple to understand thanks to the model.

6.3.2.2 Logic Tier

The logic tier is regarded as the foundation of the system and is essential to guaranteeing its proper operation. Most of the operations and tasks that keep the system operating efficiently are carried out by this layer.

- **Pre-Processing -** The images in this system go through preprocessing procedures including data augmentation, normalizing, and scaling before being used for training the model.
- **Video Analyzer -** The first processing stage is performed on user-submitted videos of baseball bat swings to improve their quality and get rid of any superfluous data. The video is then subjected to a posture estimation technique to remove the backdrop. This algorithm is used to identify the backdrop from the remainder of the vids content with accuracy.
- **Model Selection -** After preprocessing the data, an LSTM model would be chosen.
- **Processing & Analyzing -** The approach uses a DL model that has already been trained to classify the data that was gathered and to evaluate a video of a baseball bat swing.
- **Web API Controllers -** Users can upload a video of a baseball bat swing using the API with the help of the API controllers for the web.
- **Feedback -** The system will review this video, and it will respond with feedback in the form of a JSON answer.

Error handling - To handle any issues that can arise during the processing and analysis of videos, such as wrong video format, the API contains built-in error-handling capabilities.

6.3.2.3 Data Tier

- **Input data of Baseball bat swing -** Input baseball bat swing data - This data set is created by the author by visiting baseball fields and players.
- **Storage -** A video input had to be used to evaluate a baseball bat swing, and the findings were to be shown on the presentation layer. The output movies were saved using a temporary storage module to do this. This made it possible to temporarily store the data before displaying it on the presentation layer. The storage module would be emptied once the data has been examined.

6.4 Detailed Design

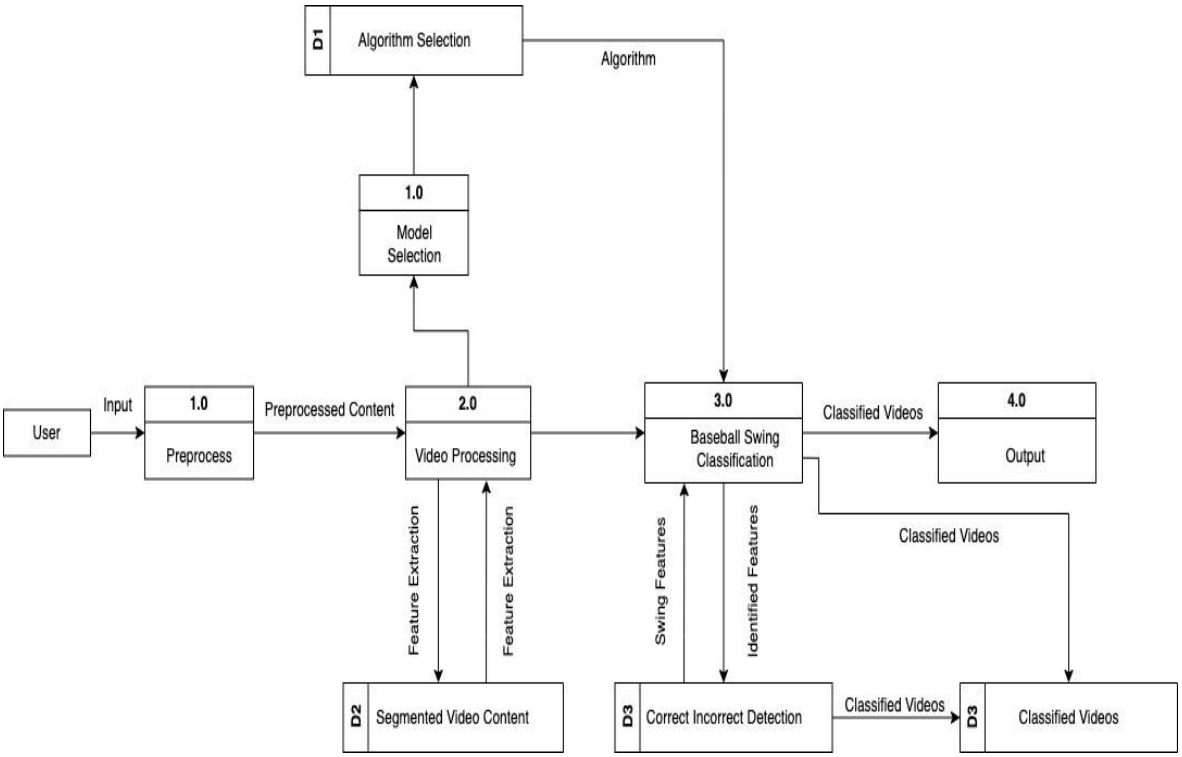
6.4.1 Choice of design paradigm

Due to the necessity for high accuracy and precision, the author chose the Structured Systems Analysis and Design Technique (SSADM) as the design methodology for the baseball swing position estimate application. A well-designed system that satisfies all criteria is ensured by SSADM, which uses tools like entity-relationship diagrams, data flow diagrams, and other modeling approaches to precisely specify the system components and their interactions. Given that this system can be used to make significant decisions, SSADM's emphasis on thorough and accurate system specifications may be useful.

6.5 Design Diagrams

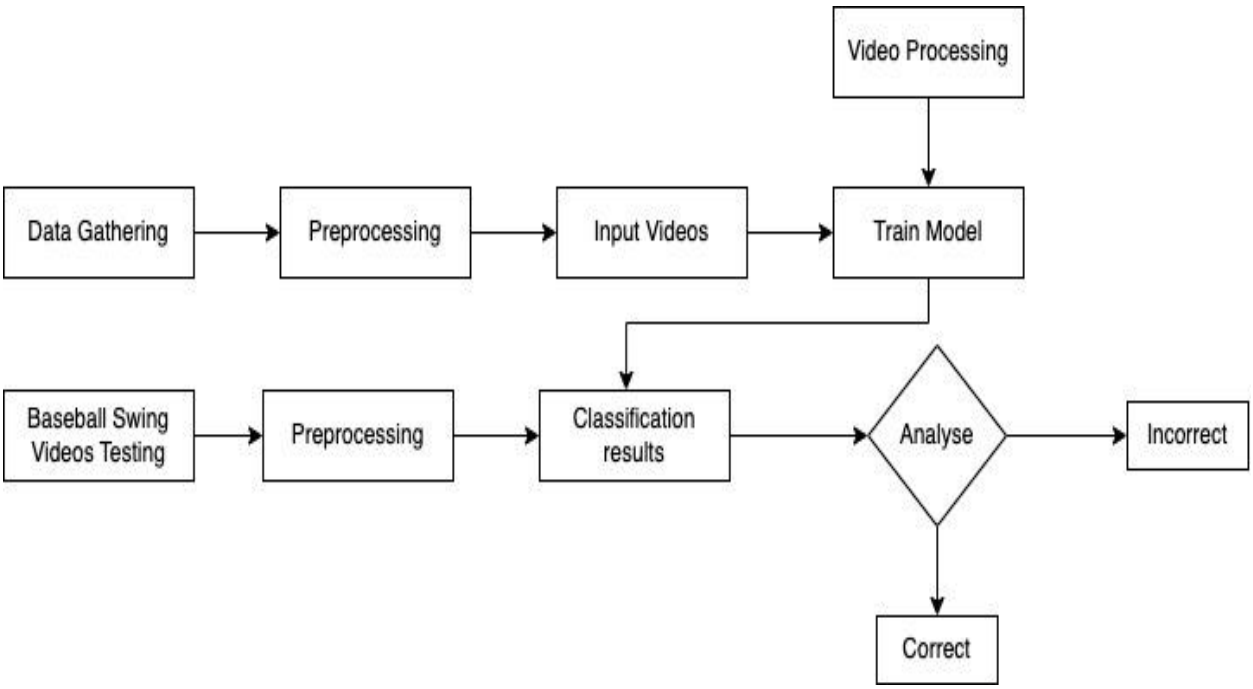
6.5.1 Component Diagram

The many system components that have been identified and require implementation are shown in the data flow diagram. The graphic also shows the direction of data flow among the system's various sections of components.



6.5.2 System Process Flow Chart

The provided flowchart illustrates the algorithm's operational steps and decision-making techniques. The flowchart covers a sizable percentage of the system's functionality because the anticipated implementation is mostly procedural.



6.6 Chapter Summary

We describe the procedure for starting and carrying out the research project's prototype in this chapter. Based on the non-functional requirements acquired in the previous chapter, the design goals for the system were created. Data flow diagrams and process flow charts were used to depict the high-level design using the three-tier architectural technique. In addition, interface UI designs were developed to provide a greater understanding of the prototype's low-level architecture. We hope to offer a thorough knowledge of the architecture and design of the research prototype by adding these components.

CHAPTER 7: Implementation

7.1 Chapter Overview

The author goes into the practical aspects of building the recommended system's prototype. Along with a concise and persuasive argument for each decision, they describe the precise technologies, frameworks, programming languages, and supporting external libraries and tools that have been used. The author also describes how the frontend and backend components were combined to achieve the system's goal.

7.2 Technology Selection

7.2.1 Technological Stack

stack selected for each tier as shown in the previously stated High-level architectural diagram.

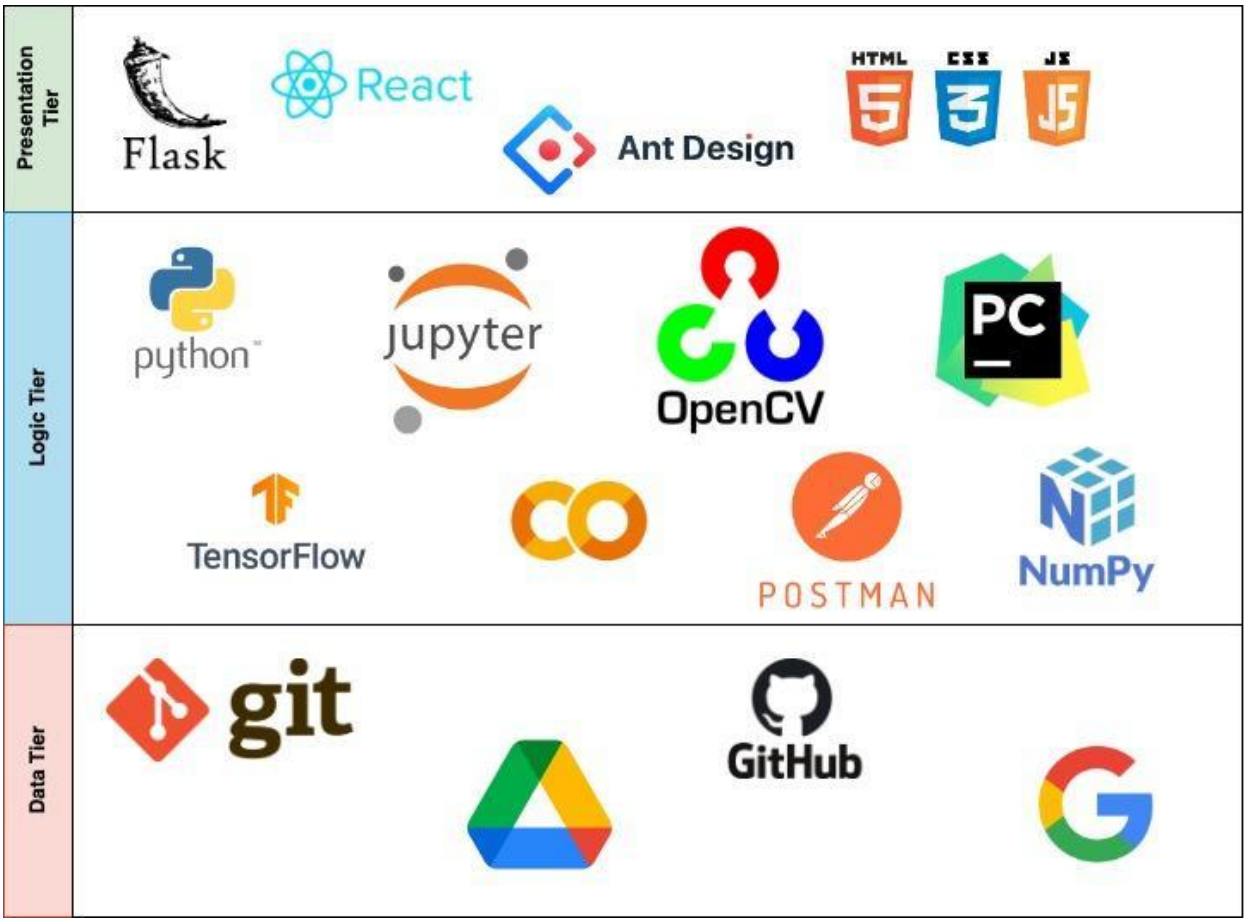


Figure 0-14 - Technological Stack

7.2.2 Data-set Selection

Images of baseball swings that were recorded in various lighting and side views are included in the collection. Players of all skill levels, including both professionals and amateurs, executed the swings. The dataset offers a wide range of swing types for examination and includes both successful and unsuccessful swings. The author has divided the images into many categories, such as "stance," "leg movement," and "shot execution," to guarantee that each swing in the dataset is accurately tagged. The author has created a solid basis for training a DL model to evaluate baseball swings by producing this dataset. The dataset has a wide variety of swings and is big enough to be a trustworthy training set for DL.

7.2.3 Development Frameworks

TensorFlow - TensorFlow is intended to offer a versatile and effective method for developing, configuring, and training machine learning models. It enables programmers to specify complicated calculations as data flow graphs, where the graph's nodes stand in for mathematical processes and the edges signify the data flow that occurs between them. This method enables TensorFlow to manage massive volumes of data effectively and optimize the calculations to benefit from cutting-edge technology, such as GPUs and TPUs.

React - React may be combined with a DL model to develop a web-based user interface for a baseball bat swing analyzer that uses video as input. Users would be able to upload videos and examine the outcomes of the model's analysis of the swings through this interface. Because it makes it simple for developers to create interactive user interfaces that can be changed in real-time depending on the model's predictions, react is an excellent tool for this purpose. Additionally, it makes it easier to integrate new functionality, such as video processing and upload, into online or mobile apps.

Flask - The Flask Microframework, which is renowned for its simplicity and usability, was used to construct the web application. Flask provides less boilerplate code than other web frameworks, enabling developers to easily create a simple application with little effort. Because of this, Flask is a well-liked option for developers that value simplicity and want to quickly launch a web application. Additionally, Flask's simplicity of use makes it easy for developers to learn and

comprehend the framework, making it a viable alternative for newcomers or those with little prior web programming expertise.

7.2.4 Programming Languages

In this study endeavor, the author decided to use Python as the main programming language for the logic tier. It was decided to do this for several reasons. First off, there are several libraries for Python, like NumPy, SciPy, and pandas, that provide strong data manipulation and analysis capabilities. Second, there are several machine learning libraries available in Python, including well-known choices like Scikit-learn, TensorFlow, and Keras, which are frequently employed in this sort of study. Finally, the decision to pick Python as the main language for this study endeavor was influenced by the author's past expertise with and familiarity with the programming language.

7.2.5 Libraries

Pandas - Pandas may be used to modify and evaluate data in baseball swing video estimates. In particular, the Python module pandas offers strong capabilities for working with structured data, such as tabular data. Pandas may be used to read and organize the data from video footage of baseball swings, including details on the player's position and movement, the angles and trajectory of the bat, and other pertinent elements, in the domain of baseball swing video estimate.

OpenCV - Key aspects of baseball swings may be extracted from video recordings using a variety of video processing methods offered by OpenCV. It may be used, for instance, to identify and follow the player and bat's movements in a video, calculate the bat's angle and trajectory, and assess the swing's speed and acceleration.

7.2.6 IDE

PyCharm - The Python computer languages integrated development environment (IDE), PyCharm, is not frequently employed for baseball swing video estimates. Nevertheless, PyCharm may be used to create applications or scripts for handling and analyzing video data, including baseball swing films. In these situations, PyCharm may offer a productive and practical

environment for creating, testing, and debugging code as well as for interfacing with other images- and video-processing tools and libraries.

Anaconda - Access to powerful computer capabilities that might not be accessible on their local PC's is made possible by anaconda for developers and academics. This is crucial for projects involving vast volumes of data and computationally demanding tasks like DL, such as baseball swing video estimates.

7.2.7 Summary of Technology Selection

Component	Tools
Programming Languages	JavaScript, Python
Development Framework	Flask
UI Framework	Ant Design, ReactJS, Material UI
Libraries	React, Tensorflow, OpenCV, Pandas, Keras
IDE – Research	Jupyter Notebook, Google Colab
IDE – Product	PyCharm, VS Code
Version Control	GIT Hub, Git
Application hosting	Heroku

Table 18 – Technology Selection

7.3 Implementation of the Core Functionality

Each code sample relating to a certain functionality is connected to the appropriate topic in this section, which discusses the essential components of the system.

Remove dodgy images

```
In [7]: import cv2
        import imghdr
        from matplotlib import pyplot as plt

In [8]: if os.path.isfile("Stance_Data/.DS_Store"):
            os.remove("Stance_Data/.DS_Store")

In [9]: data_dir = 'Stance_Data'

In [10]: image_exts = ['jpeg','jpg','bmp','png']

In [11]: for image_class in os.listdir(data_dir):
             for image in os.listdir(os.path.join(data_dir, image_class)):
                 image_path = os.path.join(data_dir, image_class, image)
                 try:
                     img = cv2.imread(image_path)
                     tip = imghdr.what(image_path)
                     if tip not in image_exts:
                         print('Image not in ext list {}'.format(image_path))
                         os.remove(image_path)
                 except Exception as e:
                     print('Issue with image {}'.format(image_path))
                     # os.remove(image_path)

Issue with image Stance_Data/Correct/.ipynb_checkpoints
```

Figure 15 – Removing dodgy images

Load Data

```
In [12]: import numpy as np
         from matplotlib import pyplot as plt

In [13]: Stance_Data = tf.keras.utils.image_dataset_from_directory('Stance_Data')

Found 116 files belonging to 2 classes.

2023-05-01 01:17:36.344875: I tensorflow/core/platform/cpu_feature_guard.cc:193] This TensorFlow binary is optimized
with oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-critical operat
ions:  AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.

In [14]: data_iterator = Stance_Data.as_numpy_iterator()

In [15]: batch = data_iterator.next()

In [16]: batch[0].shape

Out[16]: (32, 256, 256, 3)

In [17]: batch[1]

Out[17]: array([0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1,
                0, 0, 1, 0, 1, 0, 0, 1, 1, 1], dtype=int32)

In [18]: batch
```

Figure 16 - Loading images to train and evaluate deep learning model.

Preprocess Data

```
In [20]: scaled = batch[0] / 255

In [21]: scaled.max()
Out[21]: 1.0

In [22]: Stance_Data = Stance_Data.map(lambda x,y: (x/255, y))

         WARNING:tensorflow:From /opt/anaconda3/lib/python3.9/site-packages/tensorflow/python/autograph/pyct/static_analysis/liveness.py:83: Analyzer.lamba_check (from tensorflow.python.autograph.pyct.static_analysis.liveness) is deprecated and will be removed after 2023-09-23.
         Instructions for updating:
         Lambda fuctions will be no more assumed to be used in the statement where they are used, or at least in the same block. https://github.com/tensorflow/tensorflow/issues/56089

In [23]: scaled_iterator = Stance_Data.as_numpy_iterator()

In [24]: batch = scaled_iterator.next()

In [25]: batch[0].max()
```

Figure 17 - Preprocessing the data set

Split Data

```
In [27]: len(Stance_Data)
Out[27]: 4

In [28]: train_size = int(len(Stance_Data)*.7)
         val_size = int(len(Stance_Data)*.2)+1
         test_size = int(len(Stance_Data)*.1)

In [29]: train_size+val_size+test_size
Out[29]: 3

In [30]: train = Stance_Data.take(train_size)
         val = Stance_Data.skip(train_size).take(val_size)
         test = Stance_Data.skip(train_size + val_size). take(test_size)

In [31]: len(train)
Out[31]: 2
```

Figure 18 - Splitting the data set

Build Deep Learning Model

```
In [32]: from tensorflow.keras.models import Sequential
         from tensorflow.keras.layers import Conv2D, MaxPooling2D, Dense, Flatten, Dropout

In [33]: model = Sequential()

In [34]: model.add(Conv2D(16, (3,3), 1, activation='relu', input_shape=(256,256,3)))
         model.add(MaxPooling2D())

         model.add(Conv2D(32, (3,3), 1, activation='relu'))
         model.add(MaxPooling2D())

         model.add(Conv2D(16, (3,3), 1, activation='relu'))
         model.add(MaxPooling2D())

         model.add(Flatten())

         model.add(Dense(256, activation='relu'))
         model.add(Dense(1, activation='sigmoid'))

In [35]: model.compile('adam', loss=tf.losses.BinaryCrossentropy(), metrics=['accuracy'])

In [36]: model.summary()
```

Figure 19 - Building deep learning model

Train

```
In [37]: logdir='logs'

In [38]: tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=logdir)

In [39]: hist = model.fit(train, epochs=20, validation_data=val, callbacks=[tensorboard_callback])
```

Figure 20 - Training the model

7.4 User Interface

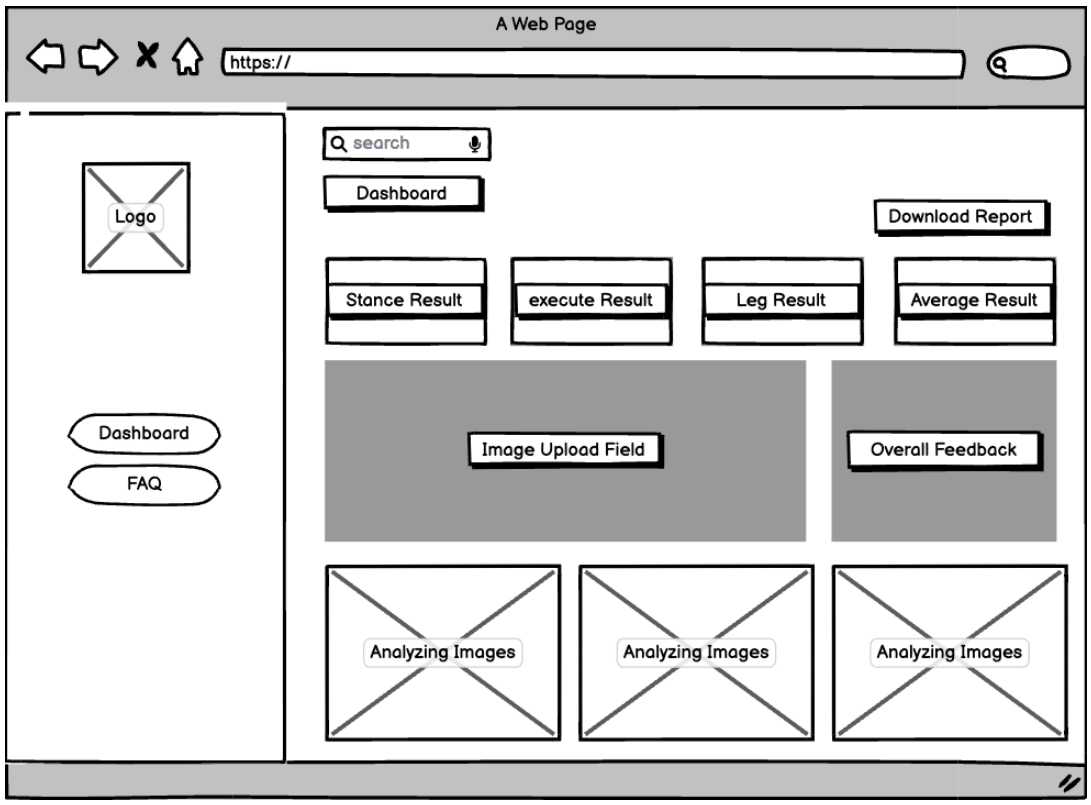


Figure 21 - Wireframe

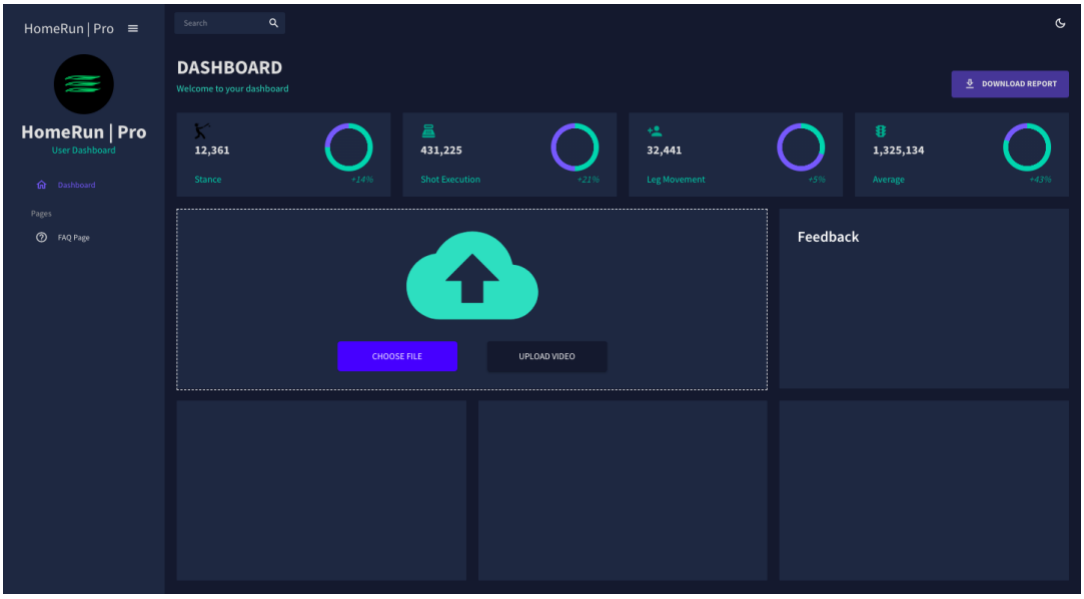


Figure 22 - UI Design

7.5 Chapter Summary

This chapter explains the rationale for the selection of specific languages, tools, and technology. Along with the important implementation decisions and their justifications, the presentation also includes code samples and explanations for the key features. This chapter also contains an explanation of the code and screenshots of the GUI tool.

CHAPTER 08: TESTING

8.1 Chapter Overview

This chapter focuses on the various testing techniques that were used for the study. The testing goals and objectives are introduced at the outset, along with the numerous testing criteria that were considered. The chapter also covers the various testing approaches that were used in various scenarios. It also discusses the techniques used for functional and non-functional testing. Overall, this chapter offers a thorough review of the testing techniques that were applied throughout the study.

8.2 Objectives and Goals of Testing

There are two major groups into which the objectives of a testing phase can be separated. The first is to determine whether the system that was created complies with the requirements as intended, and the second is to look at and review the outcomes that the system generated. The following research goals were set up to improve the testing procedure.

- Check to see if the system satisfies the functional specifications listed in the specs.
- Check to see if the system complies with the non-functional specifications as stated in the specifications.
- Verify that the code complies with the accepted best practices and consistency criteria.
- Identify any mistakes or flaws that slipped through during the development process.

8.3 Testing Criteria

To evaluate the testing process in software applications, two methods can be used.

Functional Testing - aims to make sure that the software fulfils the tasks it was intended to achieve and behaves as predicted.

Code Structural Testing - Software is tested and evaluated to make sure it complies with accepted coding guidelines and consistency criteria.

8.4 Model Testing

8.4.1 Stance Model Evaluation

```
In [86]: print(f'Precision:{pre.result().numpy()}, Recall:{re.result().numpy()}, Accuracy:{acc.result().numpy()}')

         Precision:1.0, Recall:0.7058823704719543, Accuracy:0.84375
```

Figure 23 - Accuracy 1 (Self Composed)

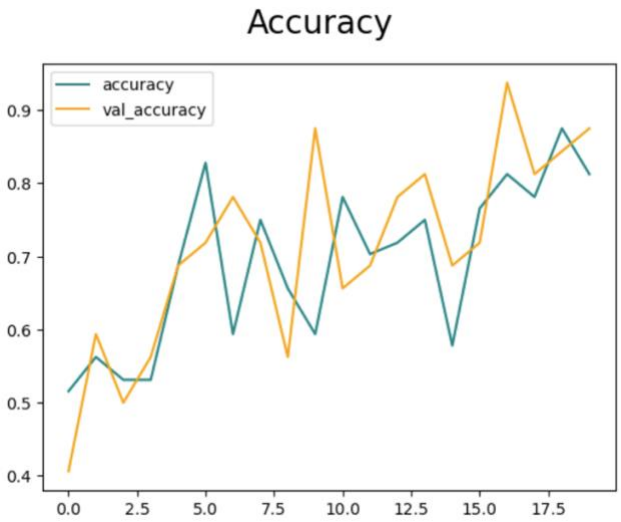


Figure 0-14 - Accuracy Graph (Self Composed)

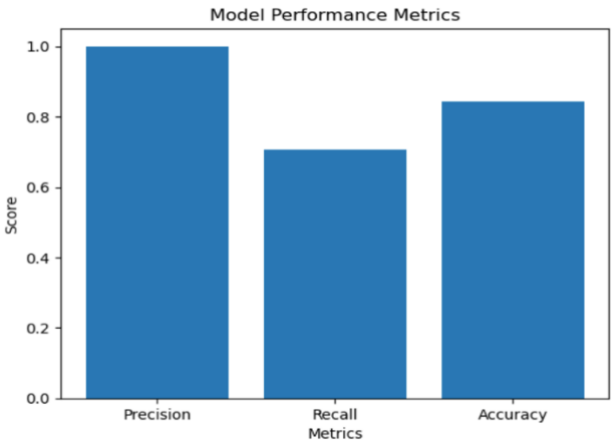


Figure 25 - Model Performance Metrics

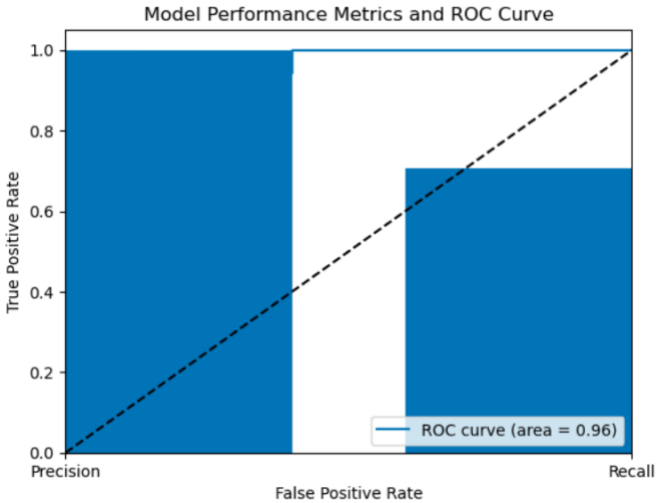


Figure 26 - ROC Curve

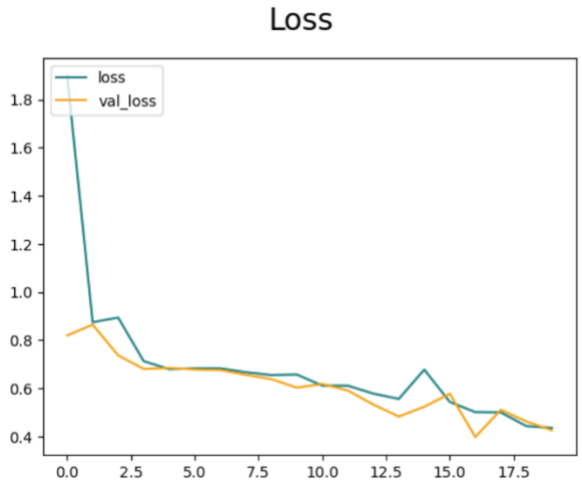


Figure 27 - Loss Function Graph

8.4.2 Leg Classification Model

```
print(f'Precision:{pre.result().numpy()}, Recall:{re.result().numpy()}, Accuracy:{acc.result().numpy()}')
## Results should be in between 0 - 1
```

```
Precision:0.692307710647583, Recall:0.8999999761581421, Accuracy:0.8214285969734192
```

Figure 23 - Accuracy 1 (Self Composed)

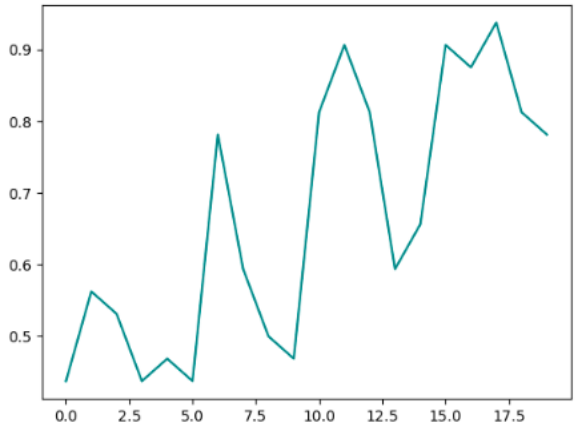


Figure 0-3 - Model Accuracy.

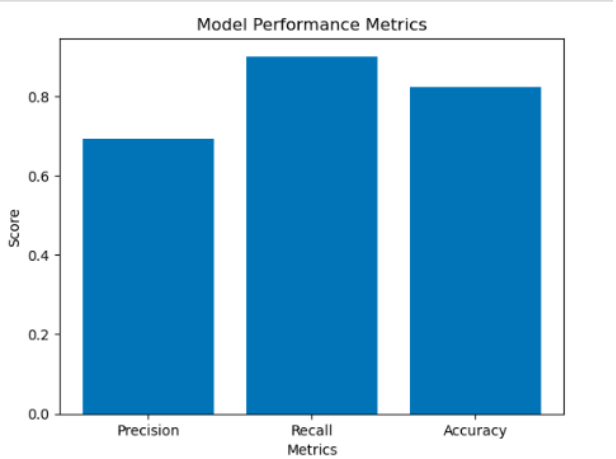


Figure 0-2 - Model Performance Metrics

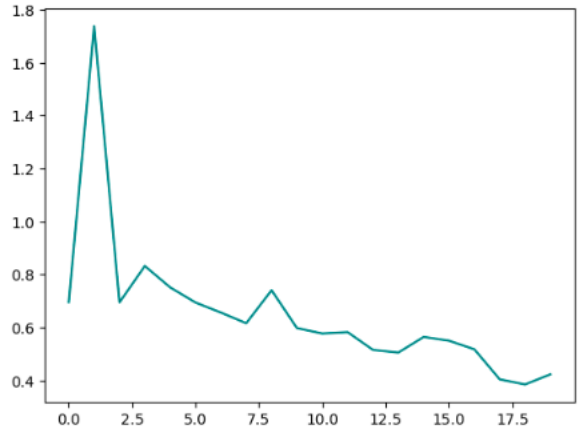


Figure 0-5 - Loss Function Graph

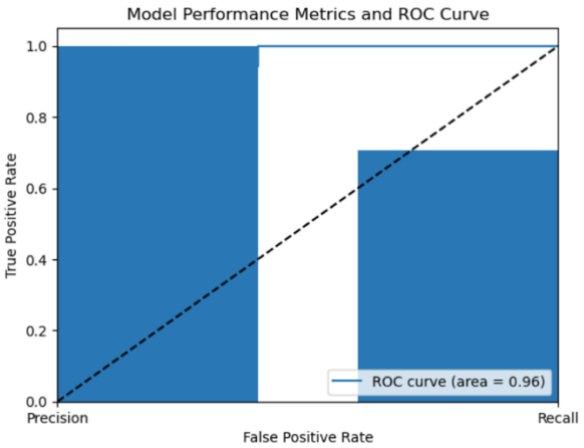


Figure 0-4 - ROC Curve

8.5 Benchmarking

A standardized dataset is required for the testing methods' results to be regarded as reliable. However, the author is unable to conduct a comparative analysis of the suggested system because no prior research has been done on analysing the baseball bat swings of school level players in Sri Lanka. The author therefore intends to use a Baseline Benchmarking approach to evaluate the system. Future researchers will be able to evaluate new systems in this field by using the

benchmark evaluation results, which will be made available to the public together with the datasets utilized.

8.6 Functional Testing

Developers can conduct testing according to the user stage by using the spiral approach. Together with the application, the functional requirements were tested using the discovery testing methodology. The results from testing the functional requirements are summarized in the table that follows.

Functional Requirement	Expected Outcome	Actual Outcome	Status
Video Upload	User should be able to upload video	User can upload video	Pass
Recognize the swing	Should be able to identify the correctness of the swing	able to identify the correctness of the swing	Pass
Able to identify key elements in the videos	Able to identify key elements	Can identify the key elements	Pass
Able to view feedbacks after the analyzing	Feedback should display after the process	Feedback is displaying after the process	Pass
Audio, text, and picture inputs won't be analyzed.	Only analyze videos	Only analyze videos	Pass

Table 18 – Functional Testing

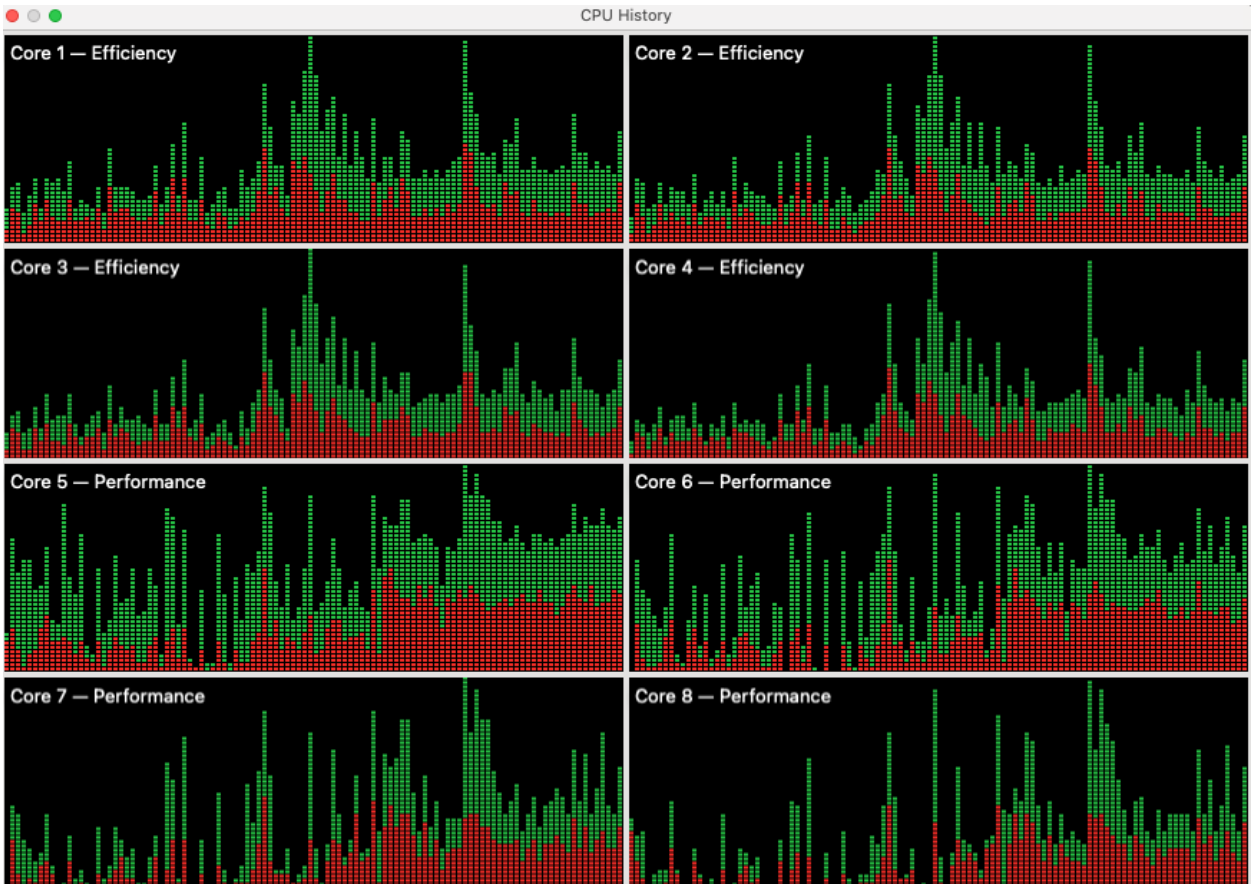
8.7 Module and Integration Testing

Module	Input	Expected Output	Actual Output	Status
Pose Extraction	Retrieved frames from the uploaded video	coordinates for each frame's key body points for the batter.	coordinates for each frame's key body points for the batter.	Passed

Pre-process	Coordinates of body key points	Identify the body key points	Identify the body keypoints	Passed
Image Classification	Set of Images	Saving 3 stages of images to unique folders	Saving 3 stages of images to unique folders	Passed
Analysis	Selected image from each folder	Analysis of the swing technique of each step	Analysis of the swing technique of each step	Passed
Web Application	Uploading Video	Generate Results	Generate Results	Passed

Table 19 - Module and Integration Testing

8.8 Non-Functional Testing



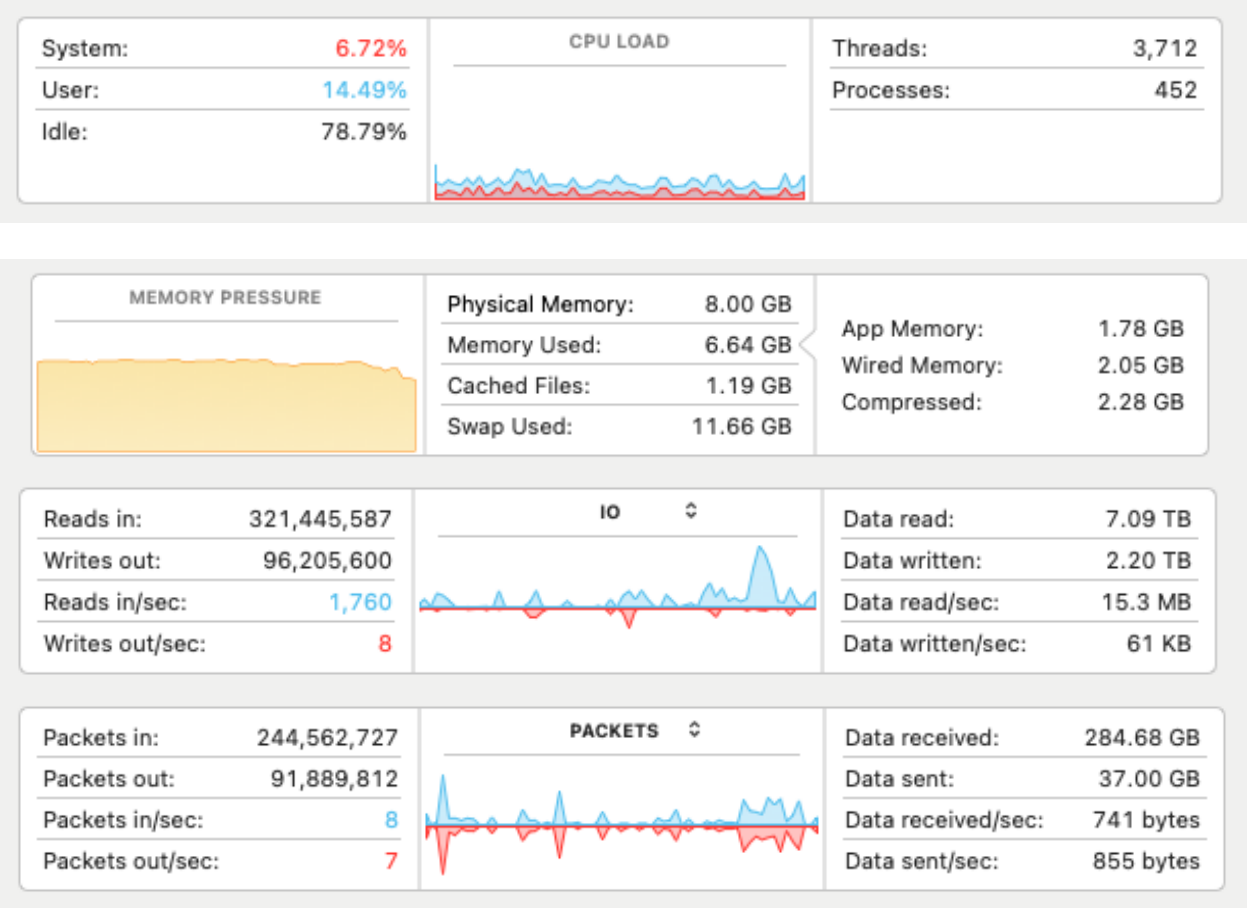


Figure 28 - Non-Functional Testing

8.9 Limitations of the Testing process

The testing procedure in the context of baseball swing analysis utilizing deep neural networks has several restrictions. First off, the calibre of the data utilized to train the neural network determines how accurate the testing results will be. Incomplete or biased training data can produce erroneous and unreliable outcomes. Additionally, because it may not consider each player's particular physical traits and playing style, the testing procedure might not always fully capture the complexity of the swing. Additionally, there is a chance of overfitting the model, which occurs when it becomes too tailored to the training set of data and struggles to generalize to fresh data. The testing procedure could also take a lot of time and computer power, making it challenging to scale up for bigger datasets or real-time analysis.

8.10 Chapter Summary

An overview of the procedures and approaches used to test the created system is provided in this chapter. Along with the criteria and different testing methodologies that are appropriate for the system, the testing goals and objectives were defined and listed. The application of model testing to the project, including the confusion matrix and its elements, is also covered in this chapter. Additionally, as necessary, functional, and non-functional testing methodologies were used.

CHAPTER 09: EVALUATION

9.1 Chapter Overview

To improve its performance, the prototype was thoroughly implemented and tested. The system was then assessed in accordance with the criteria listed in the SRS chapter. This evaluation consists of a self-evaluation as well as comments from professionals in the technical, domain, and industry domains. The project's evaluation procedure is covered in this chapter.

9.2 Evaluation Methodology and Approach

Both evaluation methods were chosen because the study project uses both qualitative and quantitative models. Based on the tests conducted in the testing chapter, the research output of the prototype was appraised utilizing evaluation methods of recommendation systems from literature. This chapter will give expert comments in the form of a thematic analysis.
Link to the Demonstration Video: https://youtu.be/f_y_3W12wVc

9.3 Evaluation Criteria

Criteria	Evaluation Purpose
Choice of Research	to highlight the importance of the choices made regarding the study's topic, domain, research gap, and depth of exploration.
Research Contribution	to evaluate the value of any additional research contributions that are connected to baseball-specific advances in the field of action recognition.
Quality of Research Documentation	ensuring that the appropriate amount of material has been reviewed, the full research process has been documented, and the results have been presented with a suitable level of quality.
Development Approach	to ensure that the problem at hand was solved using the best development strategy, leading to the implementation of a prototype that complies with the highest standard.

Quantitative Analysis	To ensure the accuracy of the metrics used to evaluate and analyse the results of the investigation.
Possible Enhancements	to find improvements that might be pursued as remaining tasks with respect to the completed research.
Usability & UI/UX of most viable product	to verify that the demonstration product is suitable for end consumers and is user-friendly.

Table 20 - Evaluation Criteria

9.4 Self Evaluation

Based on the evaluation criteria previously mentioned, the research's author completed a self-evaluation.

Criteria	**Author Self Evaluation**
Choice of Research	The selected research topic focuses on a technological application that is very useful and pertains to a recently emerging and extremely well-liked sector that is expected to have many applications in the future.
Research Contribution	This research has contributed to a wide range of fields, and its creative field of study has opened a path for prospective possibilities.
Quality of Research Documentation	This study's documentation is of the highest caliber. This is demonstrated using Latex for all research documentation, including the thesis, as well as by the quality of the diagrams, content, and research articles generated.
Development Approach	Despite the limited amount of data that was initially available, a lot of effort was put into gathering and pre-processing the data to produce the best results. In addition, modern programming languages and tools were used all throughout the procedure.
Quantitative Analysis	Jupyter Notebooks were used to show graphical outputs in an understandable style, even though quantifying the quantitative analysis and evaluation of the system's outcomes may be difficult.
Possible Enhancements	Following input from knowledgeable field evaluators, efforts were made to address potential improvement areas. A more thorough

	quantitative assessment of the trends-based approach has been sought out.
Usability & UI/UX of most viable product	The final product's user interface and user experience were created with visual interest and usability in mind.

Table 121 - Self Evaluation

9.5 Selection of the Evaluators

Three kinds of selection can be used to group the project's assessors.

CAT ID	Category
1	Experts with research experience in the fields of machine learning, data engineering, computer vison and Artificial Intelligence
2	Experts with domain experience in the baseball.
3	End users of the application, baseball coaches and enthusiasts

Table 22 - Selection of Evaluators

CAT ID	Details	Reason
1	Dinith Minura Research Engineer Nanyang Technological University Singapore	Machine learning research engineer with experience over 3 years
1	Supun Ranawaka AI Engineer Dublin, Ireland	AI engineer with experience over 5 years' experience.
1	Minidu Kothalawala Software Engineer Millennium IT ESP	Software engineer with experience over 3 years
1	Dilanka Laknath Visiting lecturer University of Moratuwa COO iXD Labs Sri Lanka	Experience over 4 years in data science and software engineering
2	Malindu Hewage Sri Lanka National Baseball Head Coach	Experience in baseball coaching in 18 years

2	Vihanga de Silva Sri Lanka National Baseball Assistant Coach	Experience in Baseball coaching in 15 years
2	Makoto Harada Coaching Consultant Baseball Federation of Japan	Experience in baseball more than 35 years.
3	Chirath Karunarathna	Former Sri Lanka Baseball UN 18 Captain (2018) Baseball Captain of Nalanda College - 2019
3	Hasindu Udantha	Former Player at Sri Lanka national baseball team (2018)
3	Sashika Dulshan	Member of Sri Lanka Men's Baseball Team
3	Muditha Rajapaksha	Former Captain of University of Moratuwa Baseball team

Table 13 – Details of the Evaluators

9.6 Evaluation Results

The following themes might be seen as a result of the analysis of the received expert opinions.

Criteria	CAT ID	Theme	Summary of Opinions
Choice of Research	1	Systems choice gap	In especially in a unique and highly valuable unexplored field, the analysis of this system offers tremendous value and impact.
		Technical research gap	Due to the nature of action recognitions, it was wise to shift from the conventional approach, which created a promising research topic.
	2	Domain research gap	The field is new, and it has been identified that there is a noticeable research gap that needs to be filled.

	3	Domain research applicability for use	Considering how difficult it is to investigate a product, the field of application is novel and essential. The author's research is intriguing because it is original and hasn't been done before.
Research Contribution	1	Technical Contribution	The clear absence of any issues with standard methodologies has been addressed, and novel options to fill the research gap have been developed.
	2	Domain Contribution	Since there isn't another system like this one and data collection is difficult, the contribution is significant.
	3	Domain Contribution	This study makes a substantial contribution to the field because the author was able to locate and effectively explain useful recommendation characteristics and methodologies.
Quality of Research Documentation	1	Content presentation of content	The research was thorough, included the display of statistical data, and the use of Latex was quickly acknowledged and applauded.
	1,2,3	Approach taken to solve the problem	To solve the issue, various viewpoints were considered, and a scientific approach was employed.
Development Approach	1	Data pre-processing	As required for a system to produce the best results, a significant amount of data preparation was done.
	1,2	Selection of the model	The choice and application of the model output were thoughtfully and appropriately justified.
	3	Development approach	There was broad consensus over the route taken, and a methodical and systematic approach was used rather than jumping right into model development.
Quantitative Analysis	1,2	Analysis of the trends	The present evaluation approach includes a detailed study of technical factors and is logical and simple to understand. However, it would be advantageous for the researcher to get user feedback based on the results produced, with a stronger focus on model accuracy.

	1,2,3	Analysis of the trends	The graphical analysis of the models is clear and seems to be the best method for evaluating these models.
Possible Enhancements	1	Additional enhancements	Evaluate joint angles and swing speed of the batter.
	2	Analysis of trends based the system	Possibly evaluated using different parameters
Usability & UI/UX of most viable product	1	Requirement of a separate application	A separate application is not necessary because the prototype yields unmistakable results.

Table 14 - Evaluation Results

9.7 Limitations of Evaluation

As was said in the literature study, it might be difficult to assess and analyze a particular system, particularly one that is intended for a particular use case. Because of this, it was necessary to adapt the testing and evaluation techniques to the system's needs. The lack of data made it particularly difficult to assess the social trends-based analytical system. Few people could comprehend the system's impact and the thinking behind the decisions taken because the system's domain is new. Additionally, it was challenging to schedule meetings with evaluators and discuss the evaluation aspects of the research during the project's evaluation phase due to the situation in Sri Lanka.

9.8 Evaluation on Functional Requirements

No	Requirement Description	Evaluation	Priority
FR- 1	Anyone can be able to access the system	Implemented	Medium
FR- 2	Users Should be able to upload videos	Implemented	High
FR- 3	Output should be displayed	Implemented	High
FR- 4	The attached video type should be certified	Implemented	High
FR- 5	User uploaded videos should not store in the system	Implemented	High

FR- 6	Should have user friendly UI	Implemented	Medium
FR- 7	Should have a proper documentation	Implemented	Medium
FR- 8	Should do proper testing	Implemented	High
FR- 9	Should be able to download report	Not Implemented	Low

Table 15 - Evaluation on Functional Requirements

9.9 Evaluation on Non-Functional Requirements

No	Requirement	Description	Evaluation
NFR- 1	Accuracy	The output of the system and the results of the algorithms must be accurate.	Implemented
NFR- 2	Reliability	The desired outputs should be produced as a result of the system's interaction with the user.	Implemented
NFR- 3	Performance	The output of the system must be produced quickly and efficiently.	Implemented
NFR- 4	Usability	UI should be user friendly and easy to use	Implemented
NFR- 5	Reusability	The programming and system deployment should be simple and practical for both present and future usage.	Implemented
NFR- 6	Maintainability	The system's documentation needs to be thorough and easy to understand in order to support future developments.	Implemented
NFR- 7	Security	The user must go through authentication, and any data pertaining to the user should be encrypted.	Not Implemented

Table 16 - Evaluation on Functional Requirements

9.10 Chapter Summary

This chapter discusses how a research study is evaluated. The rationale for selecting each of the several evaluation methods are discussed by the author. Prior to the author performing a self-assessment and receiving input from evaluators, evaluation criteria were defined. The evaluation team's comments were organized into themes and presented in accordance with the predetermined standards. The evaluation of functional and non-functional requirements came last.

CHAPTER 10: CONCLUSION

10.1 Chapter Overview

The research thesis is ended in this chapter by summarizing the major findings and talking about how the project significantly advanced the field of study in regard to its aims and objectives. The author also discusses the difficulties they ran into while conducting their research and clarifies how they made use of their past knowledge and the degree-related courses they had studied. The chapter also emphasizes the new information and abilities gained through the endeavor.

10.2 Achievements of Research Aims & Objectives

10.2.1 Research Aims

Aim is to put in place a system that allows baseball hitters to train themselves accurately and efficiently by analyzing their bat swing footages using a system that does not require the assistance of a physical coach.

10.2.2 Research Objectives

The above-mentioned Aims and Research Questions are expected to be met and answered with the successful delivery of the following Objectives. These objectives are achieved and the research is also completed successfully.

10.3 Utilization of Knowledge from the Course

Module	Description
Programming Principles I and II	The modules laid the foundation for studying programming by providing an introduction to languages like Python and Java.
Web design and development and Client-Server Architecture.	Both the front-end and back-end system integration modules were taught, and their use

	was especially helpful because a web application was selected as the user interface.
Software Development Group Project	A collaborative research endeavor that included both research and implementation aspects made up the module. Given that it included problem identification, design, implementation, and testing, it was comparable to a senior project. This project benefited greatly from the knowledge and abilities I gained working on that project.
Computer Science Practice	The module concentrated on the research-related components of a project while also offering chances to develop presenting and verbal communication abilities. The session also covered lessons on the basics of OLTP (Online Transaction Processing) and OLAP (Online Analytical Processing).

Table 17 - Utilization of Knowledge from the Course

10.4 Use of Existing Skills

Through its curriculum, the degree program gave students a variety of skills that were essential to the completion of their project. Particularly helpful in creating the project's model and backend were the Python fundamentals that were introduced at the start of the course. During their second-year project, the author developed their data science knowledge and experience, which inspired them to pursue a data science solution for their final-year project. The author also used their understanding of HTML, CSS, and JavaScript when creating the project's front end using ReactJS.

10.5 Use of New Skills

ReactJS - The user improved their knowledge of ReactJS while developing the GUI by studying. online resources and taking courses.

Data Science - While working on the project and doing research on the subject, the author

developed a greater understanding of Machine Learning, Deep Learning, algorithm, implementation, and model training.

10.6 Achievement of learning Outcomes

Learned Skills Description	Learning Outcomes
The experience and information acquired throughout the research phase of this project are the main learning outcomes. The ability to conduct research is one that will help the author in their job. The author developed abilities in time management, critical analysis, research methodology, and other pertinent research skills through these endeavours.	LO2 LO3
The project's model was built using reprocessing data and required the author to master new mathematical ideas. To ensure the project's success, the author also investigated neural networks and data processing.	LO3 LO4
The author was able to improve their academic reading and all-around skills during the endeavour.	LO1 LO2 LO3
The economic crisis and covid pandemic made the assignment extremely difficult for the author, However, the author found value in this difficult experience.	LO6
By carrying out quantitative research, the author developed skills in developing questionnaires and information gathering, which are crucial goals of any research.	LO5

Table 18 - Achievement of learning Outcomes

10.7 Problems and Challenges Faced

Problem / Challenge	Solution
Limitations of the computational resources	Some python libraries and anaconda plugins are not working in Mac M1 and had to change the machine and it delayed the project almost week and had to work extra hours to cover that time.

Wide learning curve	Had to learn deep learning, and data science from the beginning and to overcome that author had to refer documentations and online certifications.
Difficulties in finding dataset	It was very important to find a data set as expected and author had to create a data set.
Limited time	While doing the research author had to spent time on other subjects and it took lot of time to create a data set and author had to work extra hours.

Table 19 - Problems and Challenges Faced

10.8 Deviations

The planned solution experienced relatively minor changes while the project was originally being developed. Both technical and domain experts proposed that the scope be narrowed throughout the requirements-gathering phase. This project was initiated because the initial intention was to assess the accuracy of several video analysis algorithms prior to their actual implementation. The experts thought that by concentrating their efforts, they might come up with a more workable and efficient solution.

10.8.1 Scope related deviations

The initial development and design approach that was suggested has changed from the approach that was first chosen. The originally proposed method has been modified to use the Structured Systems Analysis and Design Methodology (SSADM). To guarantee that the project can be completed more successfully and effectively, a change in strategy was made. A well-known technique, SSADM offers a systematic and all approach to software development and design, making it the best option for the present project. The project team can be sure that they are executing a structured and well-defined process by adopting SSADM, which will raise the likelihood of success and lower the risk of failure.

10.9 Limitations of the Research

- The proposed technique is restricted to simply studying baseball players' side swings.

- The accuracy and generalizability of the system's results could be harmed by a lack of sufficient data.
- Swing speed and arm angles, which are crucial components of the baseball swing, are not disclosed by the method.
- The proposed approach may not be relevant to players at higher levels or in other countries because it is created exclusively for Sri Lankan school-level players.
- External elements including lighting, camera quality, and the player's attire may have an impact on the system's accuracy.
- The complexity of the swing may have an impact on the system's performance, and it might not be able to effectively assess additional swing techniques.
- The player's overall success in the game, mental health, and physical fitness are not considered by the suggested approach.

10.10 Future Enhancements

- To provide a more thorough analysis of the player's technique, the system's capacity should be increased to assess swings from other perspectives, such as the front and back views.
- creating a system that, maybe with the aid of machine learning algorithms, will offer the player tailored feedback and suggestions for improvement based on a study of their swing.
- To ensure consistent and trustworthy analysis, the system will be strengthened to be more resilient to external elements including lighting conditions, camera quality, and player attire.
- It is advised to increase the number of samples in the data set in order to achieve more precise grouping and better outcomes.

10.11 Achievement of the Contribution to body of knowledge

10.11.1 Domain Contribution

The author's research contribution can be summarized as follows:

- Creating a dataset with images containing baseball batting stance, shot execution, and leg movement.

- Create system to analyze school level baseball player's bat swings considering any height and weight.

- Analyze baseball bat swing without any external devices or sensors.
- Analyze baseball bat swing using batter's side angle view.

10.11.2 Technological Contribution

This work targets to analyze baseball swing in the video. While recent methods typically represent actions by statistics of local video features, here author argues for the importance of a representation derived from the baseball swing. To this end, the author proposed a new Pose-based Deep Neural Network descriptor for baseball swing analysis. The descriptor aggregates motion and appearance information along tracks of human body parts. The author investigates different schemes of temporal aggregation and experiments with DNN features obtained both for automatically estimated and manually annotated human poses.

10.12 Concluding Remarks

The project and thesis are summarized in this section by determining if the original aims and objectives were met. It also explains how the author used their previous studies, professional experiences, and knowledge to apply their skills to this project. It also draws attention to any new information learned, challenges faced, and project constraints. Future improvements are suggested, and any legal, social, professional, and ethical issues that came up during the project are addressed in the section's conclusion.

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