An AI Based Point Scoring System for Boxing Using Computer Vision

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Declaration and Approval

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the research proposal contains no material previously published or written by another person except where due reference is made in the research proposal itself.

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Abstract

Fairness and Objectivity of points awarding in association boxing has been a longstanding concern, with controversies arising due to the subjective judgments by the human judges at boxing events. Such mishaps take away from the spectacle of the sport from being a 1v1 duel to being influenced by factors outside of the fighters' control.

This research aims to tackle this issue by proposing to implement an AI based solution using computer vision to enhance the objectivity and accuracy when awarding points in boxing bouts. By using machine learning and computer vision technologies, the proposed system seeks to reduce the over dependence on the judges subjective view of the match, thereby reducing biases and increasing consistency when awarding points across all levels of professional boxing.

The proposed solution will be implemented in real time during a boxing bout, and analyze the fighters interaction with each other, and award points in accordance with the rules of boxing. The system will detect attack ,defense and foul plays and act as a third eye to help the three judges be in sync with each other and with what is happening in the ring.

By implementing this proposed solution, the overall integrity of boxing as a sport will be restored, and boxing competitions will recover the value lost through bad officiating and corruption. Finally, this solution aims at revolutionizing the sport in the new age of technology by gathering useful data that might help judges, fighters and also spectators in how they view this sport.

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List of abbreviations

3D – Three Dimensional

ANN – Artificial Neural Network

AI – Artificial Intelligence

IDE – Integrated Development Environment

CNN – Convoluted Neural Networks

DFD – Data Flow Diagram

ERD – Entity Relationship Diagram

GPU – Graphics Processing Unit

KNN – K-Nearest Neighbor

ML – Machine Learning

SSD – System Sequence Diagram

TPU – Tensor Processing Unit

WBA – World Boxing Association

WBF – World Boxing Federation

WBO – World Boxing Organization

Chapter 1. Introduction

1.1 Background Information

Sports has long been revered as a symbol of fair competition, where athletes display their prowess, dedication, and determination to emerge victorious. For this to happen, a level playing field has to be created to allow for proper duel where the best man wins. This means that stakeholders invest physical, emotional, and more importantly financial resources to ensure that victory is on their side. Therefore, coming out victorious in a sporting duel brings about pride to oneself and to those associated with such success. Although what comes out of sport seems positive, a vice still casts a shadow over the integrity of it: match fixing.

Match fixing is dishonest activity to make sure that one team or individual wins a particular sports match. Under the Crimes Act 1961, match fixing is the manipulation of the overall result of a sports match or racing event (or any event within the match or event) with intent to influence a betting outcome (McCully, 2014).

The most common reason for match fixing is to achieve financial gain through betting with bookies or individuals. Other reasons to match fix is to maintain the reputation of a favorite by preventing losses for them and or making the underdog perform better for the value of entertainment. Match fixing is a contentious issue in amateur, semi-pro and professional sports all over the world. Sport governing bodies invest a lot of time and money ensuring that the sport they govern is free from fixing scandals.

Association boxing, as much as any sport, suffers from match fixing in semi pro and professional fights. The most common match-fixing methods are pre-determined outcome before the event and manipulation of the scorecard by officials during the fight. In this research, we will focus on the latter.

In association boxing, award points based on each round of a boxing match three judges. The points are awarded based on the following criteria; Ring Generalship, Effective Aggression,

Such scoring metrics bring about ambiguity in the scores given after each round by the three judges, and therefore have an outcome on the final verdict, as there is no definitive on what action scores what point. This therefore makes the point scoring be subjective rather than objective, which sport should all be about.

1.2 Problem Statement

Point scoring in all levels of sports should be standardize and or have a guide on what action scores which point. However, in boxing, although having a scoring system based on key metrics laid out, points by judges might still be awarded based on perception of a judge. Such vague metrics makes the points scoring subjective as one judge might have a different view of the fight to the others in the panel. A suspicion of match fixing can therefore arise from the varying points awarded system that there is today in association boxing.

A difference in the judge's opinion might be because of influence from promoters to alter the result and create a draw, which then forces a rematch, or financial gain. In this case, objectivity is required to maintain the value of the sport and separate it from corruption claims. Therefore, an automated points scoring system is required to assist the judges and to also be a guide for decision making in combat sports.

1.3 Objectives

The objectives of this research proposal are as follows.

1.4 General Objectives

The general objective of this project is to develop a point scoring system for association boxing that uses AI and computer vision.

1.5 Specific Objectives

i. To study and analyze the current point scoring system in association boxing and its challenges
ii. To develop a point scoring system that uses computer vision and machine learning to create a scorecard in association boxing.
iii. To test the developed system.

1.6 Research Questions

i. What is the current point scoring system in association boxing and what challenges does it experience?
ii. How can officiating in association boxing be improved using machine learning?
iii. How has computer vision and AI been used in combat sports today?

iv. What are the effects of using the current point scoring technique on the outcome of the match or on the stakeholders?
v. How will the proposed solution deal with the challenges of the currently in place solution?

1.7 Justification

Objectivity in ruling of boxing matches is always desired by stakeholders of the sport. However, this can be difficult to achieve using the current methods of point awarding in boxing, which heavily depends on the judges understanding of the rules and view of the match.

The outcome of this research could be beneficial in advancement of computer vision on live sports for aiding officials or referees in quick decision making, therefore removing the burden on them of quick and error prone judgements.

1.8 Scope, Delimitations and Limitations

1.8.1 Scope

This project is solely in determination to assist the current judges' award their scorecard in a concise and predictable manner, therefore removing the doubt of outside influence on the result of the match.

1.8.2 Limitations

This project is limited to only prerecorded content of boxing matches and not live feed overlay, which might be ideal, due to copyright issues.

1.8.3 Delimitations

This proposed solution only focuses on professional boxing matches as the video feeds are readily available and are in a standardized format.

Chapter 2. Literature Review

2.1 Introduction

This chapter illustrates on the information stated in the research topics. It emphasizes on the existing implementation of similar programs, technologies used in their implementations and challenges that occurred when doing so. The gaps in the systems are also analyzed to come up with a better solution. Finally, this chapter also illustrates on the conceptual framework of the proposed system and give a diagrammatic representation of the flow of the system.

2.2 Point System in Boxing Matches

A boxing match or duel, usually referred to as a bout, consists of 12 rounds, each of 3 minute durations, and a break interval between the rounds of a minute (Association of Boxing Commissions and Combative Sports, 2023).

The WBC as a rational way if scoring points introduced the 10-point must system in 1968. In summary, each boxer starts with 10 points at the start of a round deductions is made based on their performances in the ring. The scores are then awarded as follows:

The boxer who is hit the most in the round loses a point and all judges score a 10-9 in favor of the dominant boxer. If a boxer is knocked down, he or she loses an additional point and the scorecard reads 10-8. Each additional knockdowns in the same round loses the boxer another point, until the score reads 10-7 where the round is called in favor of the dominant fighter. If a boxer completely dominates a round, even without a knockdown, the judges may award a 10-8 round. If both fighters score a knockdown in the same round, the deductions cancel each other out, though the judges may still award the more dominant boxer 10-9.

At the end of 12 rounds, assuming the fight goes the distance, they tally the scores of all three judges and the final score is determined to come up with a winner.

A fighter can win a boxing match after all the three judges make a decision using the famous 10-point must system to score the fighters' performance. The following steps can arrive at a decision on the fight:

i. Unanimous decision win, where all three judges have on their scorecards one fighter winning the majority of the rounds after tallying.

ii. Split Decision Win, where two of the three judges agree on their final tally that one fighter won majority of the rounds and the other remaining judge having the other fighter as the winner on his/her scorecard.
iii. Majority Decision Win, where two of the three judges have on their scorecards one fighter winning, while the other judges has the match as a draw on the scorecard.
iv. Draw by Unanimous Decision, where all three judges, after tallying, have agreed to a draw on their scorecard.
v. Majority Draw, where two of three judges have the match as a draw on their scorecards and the remaining judge leaning towards a win for either fighter.
vi. Split Decision Draw, where all the three judges have different outcomes on their scorecards. A win for fighter A, a win for fighter B and a draw.

In some cases, three knockdown rule, where a fight is stopped once a fighter is knocked down three times in the same round, is used. However, the four major boxing organizations WBC, WBA, IBF, and WBO do not apply this rule (Ates, 2023).

2.3 Challenges Associated with 10-Point Must System

Boxing judges follow a standardized criterion when evaluating the action inside the ring. However, these rules allow free interpretation or subjectivity by the judges when applying these rules in a bout.

Judges make their decision on scores based on the following points:

Effective Aggression is one of the most important criteria the judges look at. For a boxer to score maximum points, they must land clean and hard punches without them themselves being hit, with the willingness to end the match either by knockdown or by judges' decision. If the opponent is blocking some shots and returning some, then this cannot be considered as effective aggression.

Ring Generalship is the second criteria and defines the ability of a boxer to dictate the pace, style and tactics of a bout vis-a-vis his opponent. The term is somewhat subjective, but for our purposes, ring generalship refers to a boxer's ability to manipulate space and positioning to dictate where and when the fight takes place in the boxing ring. A "ring general" fights on their terms, choosing a battlefield that deploys their strengths against the enemy's weak points. Because every style is unique, successful ring generalship can look different from fight to fight.

Defense is the third criteria used to judge boxing bouts. Since boxing is a sport of hitting and avoiding being hit, defense plays a big role in awarding of points by the judges.

Clean Punching is the final scoring criteria and is based on which fighter lands cleans and consistent punches on their opponent in a round.

2.4 Related Works

Some of the related used to guide this proposal include the following:

2.5 Hawk-Eye Line Calling System in Tennis

Hawk-eye is a technology used in tennis for determining if the ball is in play or out of bounds. This line-calling system uses multiple camera angles to trace the tennis ball's trajectory. Hawk-Eye uses six or more computer-linked television cameras situated around the court. The computer processes the video in real-time, and tracks the path of the tennis ball on each camera. These six separate views are then combined to produce an accurate 3D representation of the path of the ball as shown in Figure 2.1 (Wood, 2023). It is used in adjudicating close line calls that might not be clear to the human eye.

This system was introduced in 2011 in tennis to reduce the number of people on the active tennis court. It has also reduced the number of controversies and disputes in tennis over line calls by providing players, officials and spectators with a reliable tool for solving contentious issues in the sport. Figure 2.1 below shows a snapshot of a 3D image created from the Hawk-Eye system in tennis when the call of whether the ball is in play or out of play is made. This 3D image is then displayed to the judge (umpire), official and spectators on a screen, as the system calls out a decision.

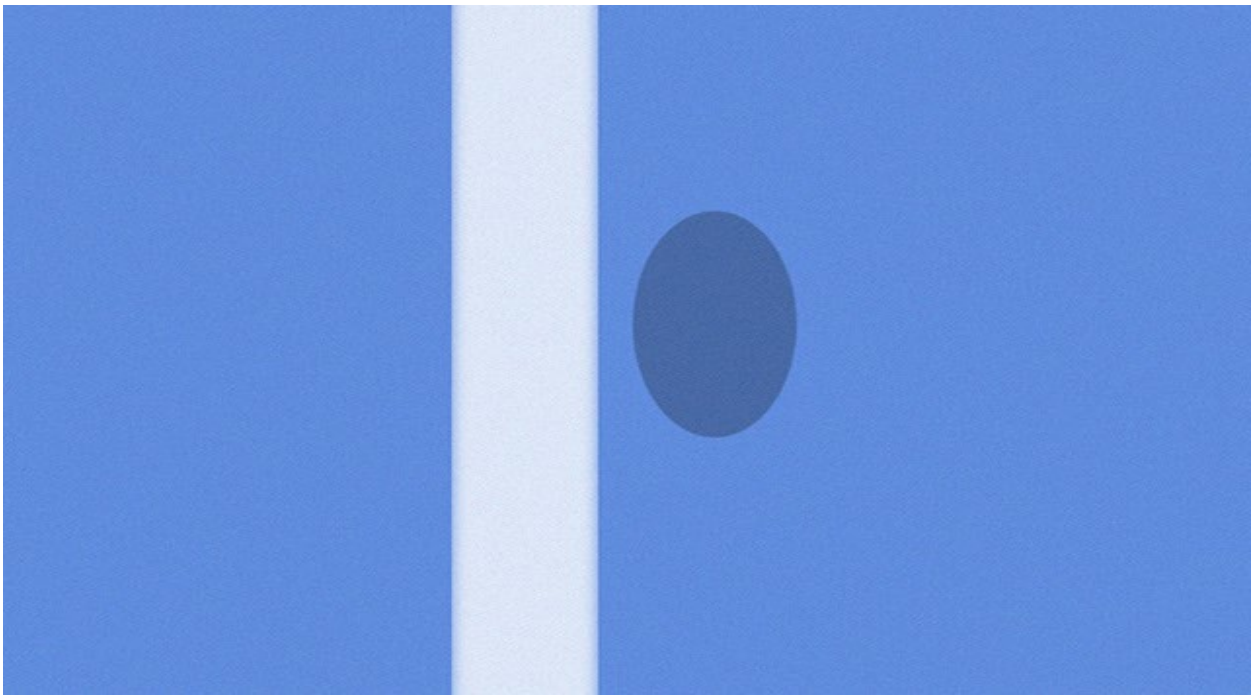


Figure 2.1: 3D Generated Image by the Hawk-Eye Technology

Figure 2.2 below shows a scenario when a 3D generated image had to be used in football to recreate the situation as it might have been missed by the linesman or on the on field referee. Once the whole ball crosses the goal line completely, a goal notification is sent to the watches of the on-field referee and he/she declares the goal.

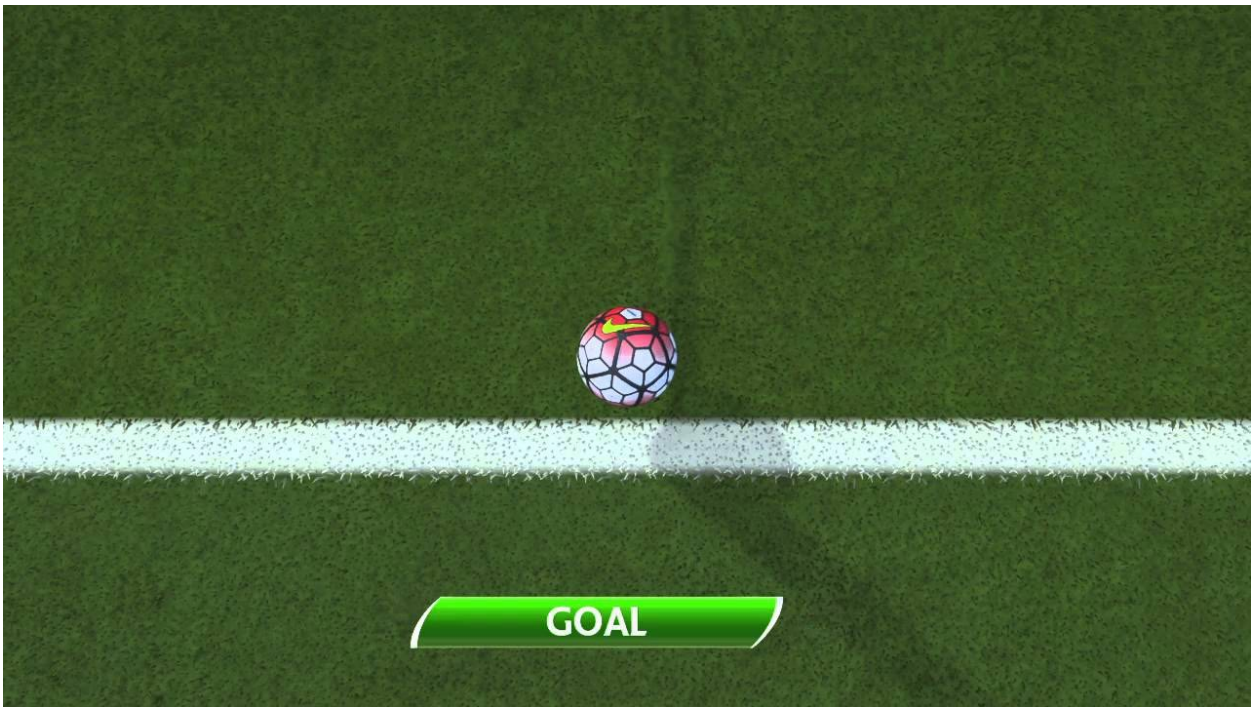


Figure 2.2: A 3D Image of a Contentious Goal Decision in Football

A group of researchers sought out to profile the physical performance of young boxers through unsupervised learning models and categorize them into different groups, thereby making guided decision making in admission to the baccalaureate in sports (Rodrigo, et al., 2023). They aimed at training a machine learning model using unsupervised learning, due to the nature if the dataset available to them, to determine physical characteristics of young boxers in Mexico city.

Two hundred and twenty seven (227) young athletes (44F; 183M; 15.65 (1.79) years; 63.66 (14.98) kg; >3 years of boxing experience) participated in this study. Body mass (BM), maximal isometric handgrip (HG) strength, the height of the countermovement jump (CMJ), the velocity of straight boxing punches (PV), and the rear hand punch impact force (PIF) were measured. The young boxers were profiled using unsupervised machine learning algorithms, and the probability of superiority (ρ) was calculated as the effect size of the differences. K-Medoids clustering resulted in two sex-independent significantly different groups.

The conclusion from this study was that there was no correlation between PV and PIF related variables and also sex did not influence the profile generation.

2.7 Application of an Artificial Neural Network to Automate the Measurement of Kinematic Characteristics of Punches in Boxing

The aim of this work was to study the automation of measuring the speed of punches of boxers during shadow boxing using inertial measurement units (IMUs) based on an artificial neural network (ANN). It was done with the goal of automating the characteristics of punches in a boxing match, which is the job of the match officials. Punch characterization is important because of its influence on the awarding of points in an official bout or for training purposes.

To automate this process, a model was developed using Artificial Neural Network and multi-layer perception (MLP). IMUs were also added to the boxers wrists to capture to capture the movements more accurately. The developed model showed a high level of accuracy in pinch recognition. The conclusion from this study was that ANN therefore accelerates collection of data on the kinetic characteristics of boxers' punches (Khasanshin, 2021).

2.8 Gaps in Related Works

One of the challenges of that such systems face is the integration of the AI systems into existing officiating workflow. It is essential that the technology is complementary to the human judges to increase its chances of acceptance in the sport. Another challenge in officiating of boxing matches using these systems is the ambiguity in from governing bodies. The different governing bodies such as WBO, WBC and WBA all have rules that are open to interpretation by the judges. This causes confusion among stakeholders when watching different fights under different organizing bodies, as the rules are be applied differently. The proposed system aims at tackling this by standardizing all rules and eradicate the ambiguity in officiating by awarding points based on the criteria the machine-learning model is trained on. This will remove the room for interpretation that exists in many boxing matches today and make it a better sport for all stakeholders.

In relation to Application of an Artificial Neural Network to Automate the Measurement of Kinematic Characteristics of Punches in Boxing, the ANN model developed was used to measure the speed of punches of a boxer in shadow boxing. The boxers had to wear IoT devices on their wrists such as IMUs, so as to collect relevant information to be used as parameters in model training. The IMUs were used to ensure effectiveness and accuracy of the ANN guided model. It is not feasible to carry such IMUs in a professional boxing match, hence the study only focusing on shadow boxing and training purposes. The model in this solution also relied on parameters provided from the IMU sensors on the wrists, which are expensive.

Finally, in the study regarding Profiling the Physical Performance of Young Boxers with Unsupervised Machine Learning: A Cross-Sectional Study, unsupervised model of machine learning was applied to find out correlation between parameters. This study did not cover image classification in the case when it is presented with new data. It utilized specialized equipment to accurately capture the parameters to be tested.

2.9 Machine Learning Models

Both supervised and unsupervised machine learning techniques have been regarded for the development of the proposed solution.

Supervised learning, also known as supervised machine learning, is a subcategory of machine learning and artificial intelligence. It is defined by its use of labeled datasets to train algorithms that to classify data or predict outcomes accurately. As input data is fed into the model, it adjusts its weights until the model has been fitted appropriately, which occurs as part of the cross validation process. Supervised learning helps organizations solve for a variety of real-world problems at scale, such as classifying spam in a separate folder from your inbox (IBM, 2023). Some of the algorithms include neural networks, linear and logistic regression, Support Vector Machine (SVM), KNN and random forest.

Unsupervised learning on the other hand, unsupervised learning uses unlabeled data. From that data, it discovers patterns that help solve for clustering or association problems. This is particularly useful when subject matter experts are unsure of common properties within a data set. Common clustering algorithms are hierarchical, k-means, and Gaussian mixture models. Semi-supervised learning occurs when only part of the given input data has been labeled.

In the context of developing the proposed solution, supervised learning technique was preferred due to the nature of the dataset available to us. Neural network algorithm, Convoluted Neural Network in this case, is selected as the model of choice due to the nature of our dataset.

CNN is a class of neutral networks that specializes in processing data that has grid like topology, such as an image (Mishra, 2023). It is designed specifically for processing & analyzing visual data such as images & videos, and hence the decision to implement it in the proposed system. As a result, the advantages it has over other models for the development is minimal computation, higher accuracy at image recognition and no human supervision.

2.10 Conceptual Framework

Figure 2.3 shows the conceptual framework of the proposed system to be developed. A video feed is captured, a still image is analyzed, and the system detects the body parts based on what is in the database. During preprocessing stage, the dataset is cleaned, transformed and organized into a format that is suitable for the algorithm, enhancing the model's accuracy, generalization, and efficiency. The model is trained, validated and tested based on the labeled data in the database. The data in the database is labelled accordingly to enhance the training process of the model.

The relevant features are extracted from the raw data and then finally fed through for classification using the CNN model. The algorithm then compares the moves in the images to the ones in the moves database and displays them on screen with their corresponding scores. The model also displays the total number of punches landed, missed and any foul plays. Finally, the total action scores in the round are then tallied up and an output score is displayed in screen as an overlay.

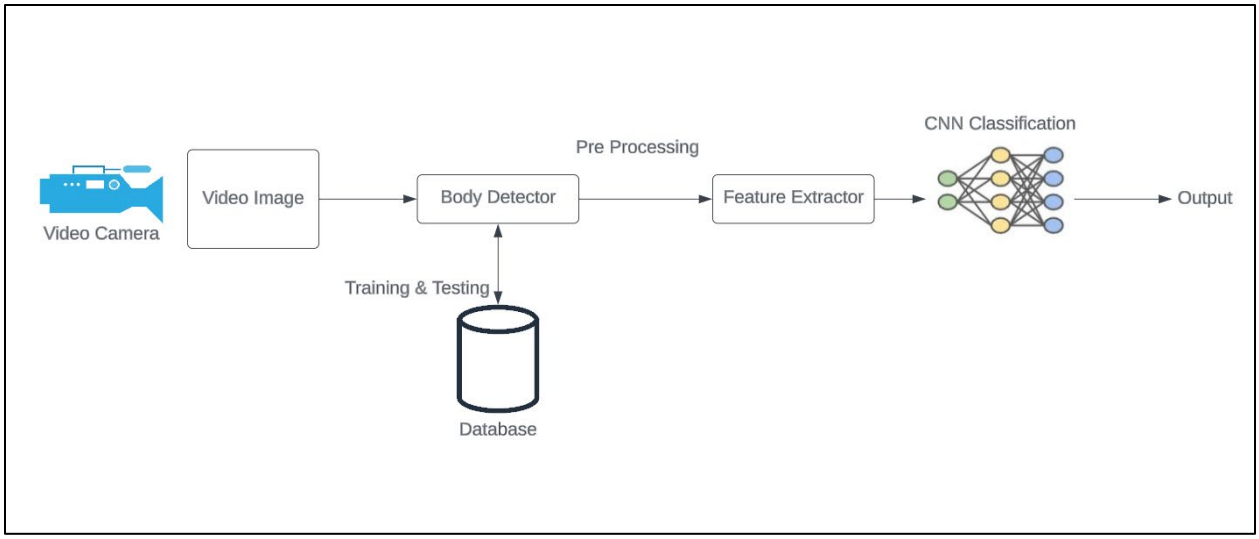


Figure 2.3: Conceptual Framework for the Proposed Solution

Chapter 3. Methodology

3.1 Introduction

This chapter discusses the System Development Methodology that will be used in this proposed project. In this section, the system diagrams will also be highlighted in reference to the methodology used, and the expected system deliverables will also be outlined. Finally, development tools and techniques used in this proposed solution will be stated and their role in coming up with the solution.

3.2 Methodology

At its essence, a software development or software engineering methodology is a set of principles and techniques used to guide the entire software development life cycle toward the successful completion of projects. It typically encompasses a number of steps and stages, such as requirements gathering, prototyping, design, coding, testing, deployment, and maintenance. Each step is designed to ensure the software works correctly and meets the end user's needs (Tran, 2023). The proposed system will make use of a hybrid of Software development methodologies to enable for quick and efficient development. Preferably Dynamic Software Development Method (DSDM) for simplicity purposes.

3.3 Justification

Agile design paradigm is preferred to help increase team performance, improve customer satisfaction and increase project versatility. DSDM is preferred in this proposed solution because it capitalizes on the greater depth of understanding and so ensures that the Deployed Solution meets the true business need. DSDM enables change through iterative development, with regular reviews to make sure what is being developed is what the business really needs (Choosing DSDM, 2022).

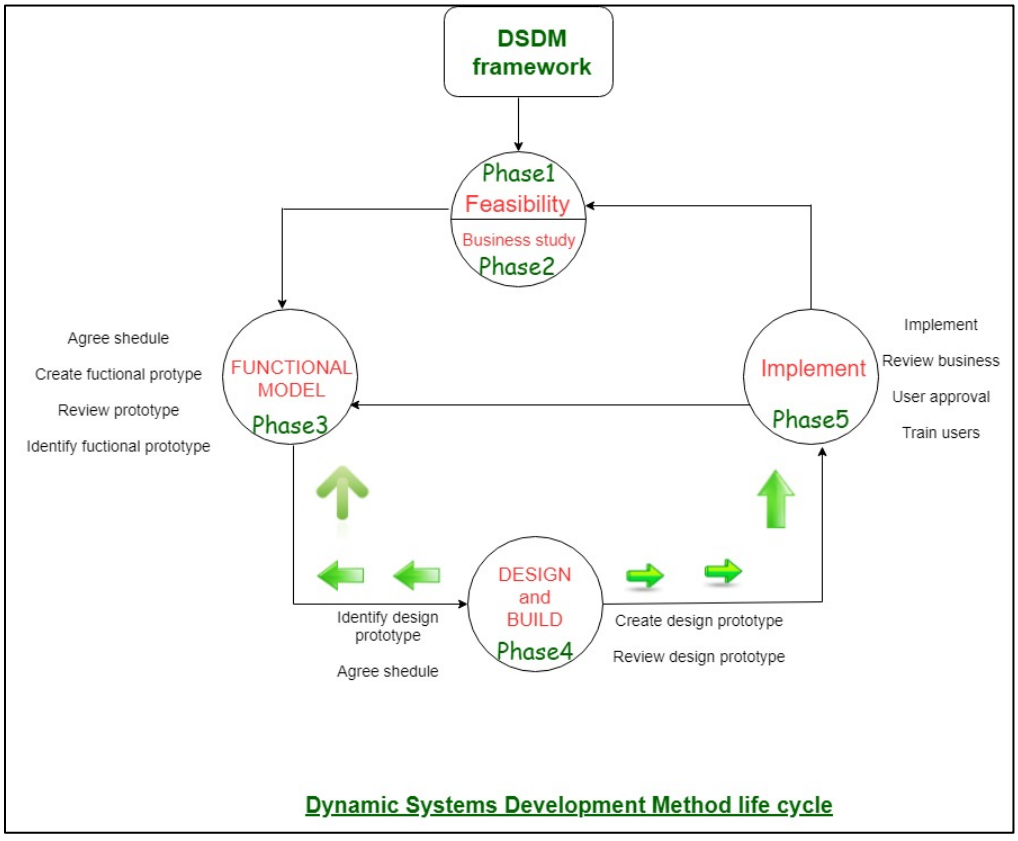
Agile software development method therefore allows for intervention when developing machine-learning projects, to check on the trajectory of what is being trained compared to the expected result.

Figure 3.1 illustrates the various steps in a DSDM development lifecycle. The first stage, Feasibility Study is where a detailed analysis on the project will be done covering all sectors to determine the practicality of the project being done and completed successfully. Business Study

stage is used to acknowledge necessities that may permit the applying to supply the business value. Additionally, it is the essential application design and identifies the maintainability necessities for applying. Functional Mode Iteration is a stage where the fictional model prototype is created to illustrate on all the modules the project will cover for easier development. The modules also help saving on time on development.

Design and Build Iteration stage is where the fine-tuning of the prototype to design a product is done. It revisits prototypes designed throughout useful model iteration to make sure that everyone has been designed during a manner that may alter it to supply operational business price for finish users. In some cases, useful model iteration, style, and build iteration occur at the same time (GeeksforGeeks, 2019).

Implementation stage captures quality assessment, training and development of the product based on client recommendations and expectations. Changes can still be requested and implemented in time for the final product.

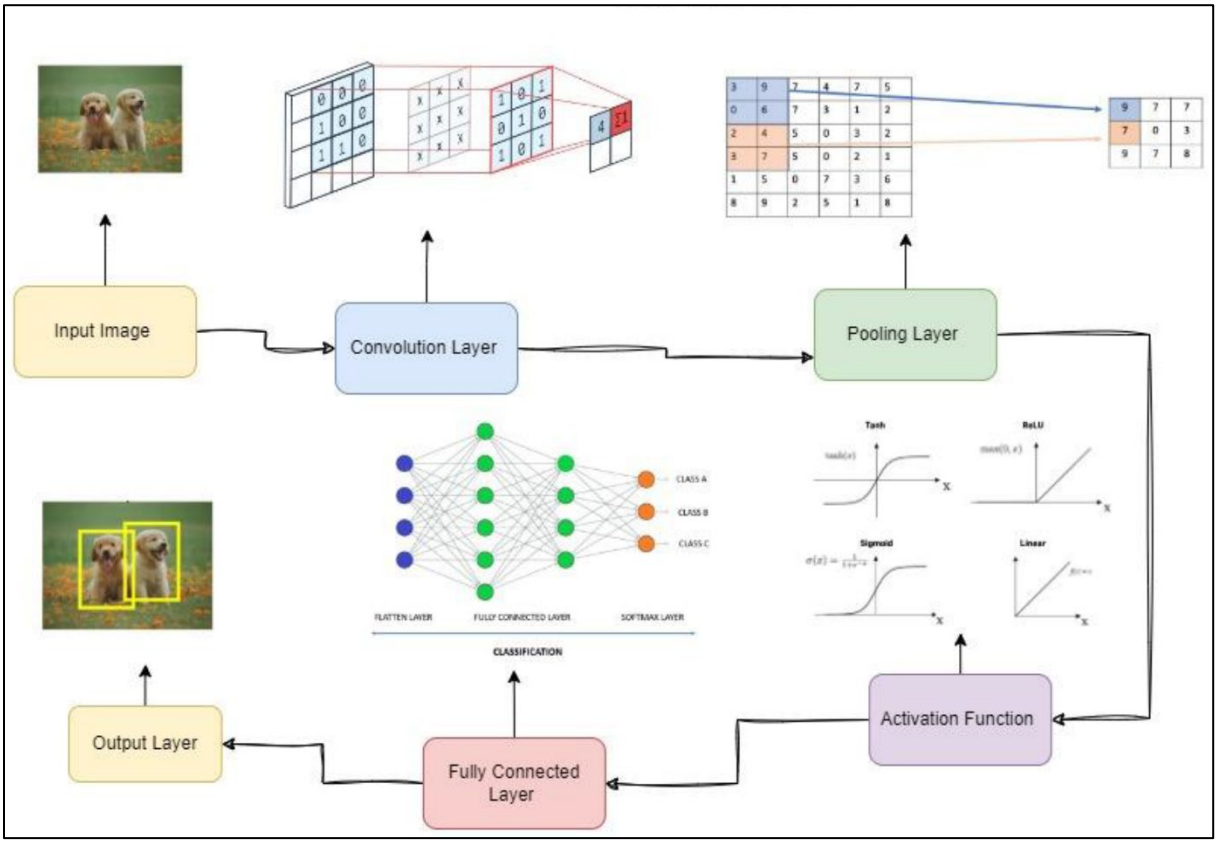


Dynamic Systems Development Method life cycle

3.4 Model Development

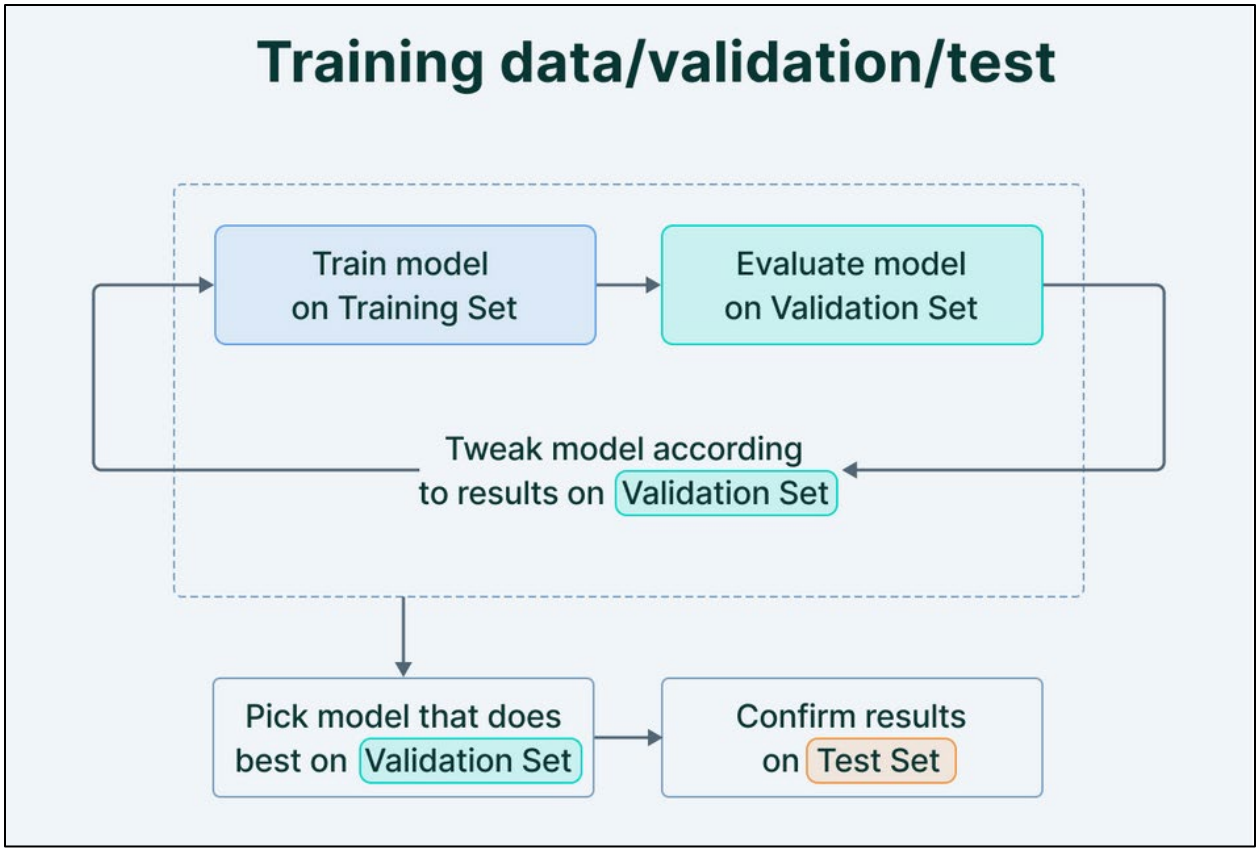
For this proposed solution, a pre-trained model is preferred. A supervised learning approach using CNN model is highly favored. The secondary dataset used in development of the proposed solution will be obtained from Kaggle, as it is high quality and quantity to be used training and testing the model. The dataset will be separated for both training and testing purposes. Figure 3.2 below show the architecture of a CNN model and its components.

In the convolution layer, feature extraction from the input image is done. In this layer, the mathematical operation of convolution is performed between the input image and a filter of a particular size MxM. By sliding the filter over the input image, the dot product is taken between the filter and the parts of the input image with respect to the size of the filter (MxM). The output is termed as the Feature map which gives us information about the image such as the corners and edges. Later, this feature map is fed to other layers to learn several other features of the input image.



For training and testing purposes of the CNN model, the dataset to be used will be split into testing, validation and training datasets, to avoid biasness and false impression of a higher model accuracy. In each epoch, the same training data is fed to the model repeatedly as the model continues to learn the features of the input data.

The validation set is used to validate our model performance during the training stage. This stage gives us information that will help us fine-tune the model with different parameters. It also guides us on whether the training is going in the right direction based on the expected results. The main idea of splitting the dataset into a validation set is to prevent our model from overfitting i.e., the model becomes really good at classifying the samples in the training set but cannot generalize and make accurate classifications on the data it has not seen before (Baheti, 2021). Finally, the test dataset is used after model training is complete. It provides an unbiased final model performance metric in terms of accuracy. Figure 3.2 shows the three perspective of this process.



3.5 System Analysis

This section focuses on the analysis tools used in the development process. It also mentions the analysis diagrams, which will be drawn in the system design as well as explaining their importance to the proposed solution.

3.5.1 Use Case Diagram

Use case diagram is the primary form of system/software requirements for a new software program underdeveloped. Use cases specify the expected behavior (what), and not the exact method of making it happen (how). Use cases once specified could be denoted both textual and visual representation (i.e. use case diagram). A key concept of use case modeling is that it helps us design a system from the end user's perspective. It is an effective technique for communicating system behavior in the user's terms by specifying all externally visible system behavior (Visual Paradigm, 2023).

3.5.2 Sequence Diagram

Sequence Diagrams are interaction diagrams that detail how operations are carried out. They capture the interaction between objects in the context of a collaboration. Sequence Diagrams are time focus and they show the order of the interaction visually by using the vertical axis of the diagram to represent time what messages are sent and when (Visual Paradigm, 2023).

3.5.3 System Sequence Diagram

System sequence diagrams, also known as SSD, are actually a sub-type of sequence diagrams, whose style and the Unified Modeling Language dictates notation. This language provides a toolkit for diagram creators to make and read diagrams that are comprehensible regardless of location or industry.

Standard sequence diagrams show the progression of events over a certain amount of time, while system sequence diagrams go step further and present sequences for specific use cases. Use case diagrams are simply another diagram type that represents a user's interaction with the system (Lucidchart, 2023).

3.5.4 Entity Relationship Diagram

An entity relationship diagram (ERD), also known as an entity relationship model, is a graphical representation that depicts relationships among people, objects, places, concepts or events within an information technology (IT) system. An ERD uses data modeling techniques that can help define business processes and serve as the foundation for a relational database (Biscobing, 2023).

3.5.5 Context Diagram

Context diagrams show the interactions between a system and other actors (external factors) with which the system is designed to interface. System context diagrams can be helpful in understanding the context, which the system will be part of. They are used early in a project to get agreement on the scope and can be included in a requirements document. A context diagram shows the entire system as a single process (University of Waterloo, 2023).

3.5.6 Data Flow Diagrams

A data flow diagram (DFD) maps out the flow of information for any process or system. It includes data inputs and outputs, data stores and the various sub processes the data moves through. DFDs are built using standardized symbols and notation to describe various entities and their relationship (Lucidchart, 2023).

3.6 System Design

This section describes the components that will be used in developing the proposed solution.

3.6.1 Logical Database Schema

A database schema is the skeleton structure that represents the logical view of the entire database. It defines how the data is organized and how the relations among them are associated. It formulates all the constraints that are to be applied on the data (Javatpoint, 2023).

3.6.2 Wireframes

A wireframe is a two-dimensional illustration of a page's interface that specifically focuses on space allocation and prioritization of content, functionalities available, and intended behaviors. For these reasons, wireframes typically do not include any styling, color, or graphics. Wireframes also help establish relationships between a website's various templates (Lynch, 2023).

3.6.3 System Architecture

A system is a plan of the whole system used to understand how different modules communicate and interact with each other. Having a good system architecture also eases the process of removing bugs from the code when testing in the feature. The proposed system will use this diagram to visualize how various components such as the database and the user interface interact.

3.7 Deliverables

The deliverables expected upon completion of this proposed solution include the following modules.

3.7.1 Model

A model that trained on relevant boxing data and award points to the fighters on the ring based on the organizations scoring criteria. This model is expected to be of high accuracy and in compliance with the boxing organizations scoring criteria. Training of this model, model documentation, its evaluation metrics and justification are all expected to be captured and the end on creation of the proposed solution.

3.7.2 System Proposal

A project proposal documentation that illustrates on the background information that led to the proposed solution, the gaps in the current solution in place, how it can be improved and how the proposed solution will be developed.

3.8 Tools and Techniques

The following development tools and techniques will be utilized during the development of the proposed solution.

3.8.1 Python Programming Language

Python is simple and consistent in its implementation, and has an extensive set of libraries and frameworks that can be utilized when doing machine-learning applications (Beklemysheva, 2022). Python is used to train and develop the model to be used in the proposed system. The development of the proposed will be done in python to utilize its vast libraries and frameworks for AI and machine learning, its simplicity and has as a wide community to gather information from.

3.8.2 Google Colaboratory (Colab)

Google Colab is a web based IDE that allows you to write and execute arbitrary python code through the browser, and is well suited to machine learning, data analysis and education. More technically, Colab is a hosted Jupyter notebook service that requires no setup to use, while providing access free of charge to computing resources including GPUs (Google, 2022).

Google Colab will give us access to GPUs and TPUs necessary to run ML algorithms that might not run easily locally due to hardware limitations.

3.8.3 Kaggle

Kaggle is a data science and machine learning community used for data acquisition purposes (Uslu, 2022). Kaggle is the source of secondary data for the training of the model to be used in the proposed solution.

3.8.4 Visual Studio

The Visual Studio IDE is a creative launching pad that you can use to edit, debug, and build code, and then publish an app (Microsoft, 2022). The development tools and extensions that come with this IDE will be helpful in the project development, management and finally deployment.

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Appendix

Appendix A: Gantt Chart