Boxing Training & Improvement App

CO3201 Computer Science Project Dissertation

School of Computing and Mathematical Sciences,
University of Leicester

By **Hugo Hull**,

May 2024

Table of Contents

Declaration

All sentences or passages quoted in this report, or computer code of any form whatsoever used and/or submitted at any stages, which are taken from other people's work have been specifically acknowledged by clear citation of the source, specifying author, work, date and page(s).

Any part of my own written work, or software coding, which is substantially based upon other people's work, is duly accompanied by clear citation of the source, specifying author, work, date and page(s).

I understand that failure to do this amounts to plagiarism and will be considered grounds for failure in this module and the degree examination as a whole.

Name:
Hugo Hull

Signed:

Date:
03/05/2024

Abstract

This dissertation discusses the creation of a boxing training app that provides interactive and real time training experiences using camera-based punch tracking technology. The goal of this project was to offer a solution that doesn't require external equipment making advanced training accessible to everyone. The app offers training modes like shadow boxing, structured sessions and a competitive mode to meet user needs by utilizing real time data. By following the Waterfall methodology and focusing on user centered design and gamification the development process was well structured to enhance engagement and effectiveness. The dissertation also addresses challenges faced during development, including software design decisions and integration of technologies while highlighting the applications impact on sports training technology and its potential to revolutionize methods. Although the project successfully created a feature training app there are opportunities for improvement such as enhancing accessibility and adding support for a broader audience. This work presents an approach, to incorporating technology into sports training providing a solution that could shape future advancements in fitness technology.

1. Introduction

Boxing is a sporting event that has been enjoyed by people for hundreds of years, with the earliest sanctioned fight dating back to Ancient Greece when it was recognised as an Olympic sport in 688 BC. [1]. While there have been many rule changes in the sport of boxing, originally having no weight classes [1], there has been little development in the technology front. The most notable introduction of technology into sport is VAR in football which was adopted into the premier league in 2018 [2] as well as advanced implementation into training. Some advanced training tools are beginning to be introduced at the professional level, but no such solutions are available for the average user at a low price. There is a significant gap in the market for applications that provide advanced, interactive, and real-time boxing training experiences available to the average person.

1.1 Aims

The project aims to fill this gap by providing an innovative boxing training application that leverages real-time data and interactive training modules to enhance the training for users at a low cost. The application will generally focus on a live punch video tracking feature, a feature which has not yet been implemented in a boxing application. Implementing the feature in this way will allow users to improve their boxing skill in a way that previously would mean using a specific piece of external and costly hardware. While the application is mainly focused on providing a 1 on 1 training experience, a competition mode will also be implemented to encourage other users.

1.2 Objectives

1. Create a frontend for the application using Python [3].
2. Create a backend for the application using PyQt5 [4].
3. Using OpenCV [5], punch tracking functionality will be implemented:
   a. Shadow boxing punch tracking.
   b. Training mode.
   c. Competition/game mode.
4. The user's history for workouts will be tracked.
5. The user should be able to view their history using graphs and charts.
6. Thorough testing will take place for both application features and UI.
7. The application will be accessible for all people.

2. Background Research

In this section, I will conduct three different types of research: the existing solutions on the market, the wants of the market and a final survey of the literature.

When looking for literature, it's key to note that aspects of what I am aiming to achieve with this application will be a first on the market. However, technology that has parallels to my software has been implemented into other sports. Also, where aspects have been implemented in other applications, I will aim to improve upon the idea and implement it in the simplest possible way for the user.

2.1 Existing Solutions

Currently, there are two prevalent methods for tracking punches in fitness apps: bag-tracking straps and wrist trackers. I will explore both technologies by examining the leading products in each category—PunchLab and FightCamp, respectively, both supported by dedicated mobile apps.

Additionally, a new technology gaining traction is the wall-mounted punch pad. Unlike the former methods, there is no clear market leader for this emerging technology yet, so my review will consider the category as a whole. It's noteworthy that, as of now, there are no desktop applications that offer punch tracking or utilize camera-based tracking, highlighting a potential gap in the market which my application will fill.

2.1.1 PunchLab Bag-tracking Strap

PunchLab [6] is a mobile app designed to enhance boxing skills through "Boxing workouts you can do at home" [6]. It offers a range of exercises suitable for all skill levels, making it accessible and beneficial for users looking to improve their health. Additionally, the app includes an activity page that displays past performance statistics, a feature many users find useful for enhancing consistency and tracking progress. A feature which existing users of this product see as a big benefit.

Furthermore, PunchLab offers an optional bag-tracking strap for a substantial additional cost. Priced at £36.99, this strap requires a separate yearly premium membership costing

£70 and does not include essential accessories such as boxing gloves or wrist wraps. This high cost and the need for a boxing bag can deter beginners from using this product. Conversely, for more experienced boxers, this setup might be appealing.

In contrast, my application significantly reduces the entry barrier. Potential users would only need a laptop or PC and a pair of boxing gloves (which would be provided upon purchase of the app), eliminating the need for a boxing bag. While pricing is yet to be finalized, it will likely be much more affordable than PunchLab's setup and require fewer pieces of equipment.

Another drawback of the PunchLab system is the necessity to attach a mobile device to the boxing bag. Some users might prefer to keep their device at a distance during workouts. My application addresses this concern by allowing the recording device to remain separate from the activity area, offering a more user-friendly approach for those uncomfortable with mounting their devices on equipment.

2.1.2 FightCamp Wrist Trackers

FightCamp [7] is a mobile app designed to enhance users' boxing skills by employing wrist trackers [7] to monitor punches. This system has an advantage over the PunchLab bag-strap since it doesn't require a boxing bag for functionality, significantly lowering the entry barrier. This aspect brings FightCamp closer to the accessibility level of my app, though it does involve initial costs: the wrist trackers are priced at $99, plus a subscription fee for the app.

Like the PunchLab strap, the substantial cost of FightCamp may deter beginners who are hesitant to invest heavily in an activity they are just exploring. In this respect, my app presents a significant advantage by being more budget-friendly and accessible.

Additionally, while FightCamp offers a range of workouts, they do not match the quality and informativeness of those provided by the PunchLab app, a sentiment echoed in user reviews and critiques by prominent fitness influencers. Recognizing the importance of clear and high-quality content, I will ensure that my app is well-structured and engaging for the user.

2.1.3 Wall Mounted Electronic Punch Pad

The Wall Mounted Electronic Punch Pad[8] represents an innovative advancement in fitness technology. This product is designed to deliver an interactive and user-friendly experience by focusing primarily on perfecting a single feature—precision punching. Unlike other more complex systems, this punch pad emphasizes engaging users effectively by executing its core functionality superbly.

In addition to its primary use, the device doubles as a Bluetooth speaker, integrating musical elements into workout routines. This unique feature synchronizes the user's punches with the rhythm of the music, enhancing the exercise experience and making workouts enjoyable and rhythmically engaging.

With its straightforward functionality, the Wall Mounted Electronic Punch Pad offers an appealing option for those who prefer a fitness device that combines entertainment with effective training, without the clutter of unnecessary features. This focus on simplicity and enjoyment can attract users looking for a straightforward, engaging workout experience.

One downside of this product is that users have reported that the hardware itself is not very long lasting and small. This would not be suited to larger or more experienced boxers, which alienates a large part of the potential customer base. Following this, I will make sure that my application is suited to users of all skill and sizes. Also, users report that the device is too aimed toward one singular feature, and they would prefer if it provided more features but with the same level of quality.

2.2 Market Research

During my market research, I will focus on addressing two main questions: Who is the target audience and what are their needs? And how can my application fill this gap?

2.2.1 Who is the target audience and what are their needs?

The largest proportion of the target audience for this application are amateur athletes who have been training boxing who are seeking to improve their skills through accessible, innovative training methods. Another smaller group includes fitness enthusiasts who are looking to get into boxing. They require a solution that is simple enough for them to use but also has the scalability for them to improve beyond basic boxing training while keeping them entertained.

However, there are also a group of professional athletes who are looking for a solution to enhance their individual training. I will look to offer a solution to this group of people also as I believe they can be satisfied with a similar software. For this demographic I asked boxers at my boxing gym- Unity boxing gym [9]- for their personal needs and they stated that having something that can assist with their shadow boxing, would be perfect for them.

In terms of cost most users are happy to spend up to £60 including the gloves, some companies use a subscription-based model, but I believe more users would be comfortable using a one-time payment app.

2.2.2 How could my project fill this gap?

To fill this gap, I will develop an application that has a few key features that will keep the user entertained as well as pushing their boxing ability to the next level. It will have good scalability so a boxer of any level can use it and progress further. The application will have a competitive mode, a mode for training and a mode for free boxing. This will help satisfy all areas needed that were identified for the target market.

The application will have a simple, but aesthetically pleasing UI and an easy to navigate page structure. Many users reported that a lot of fitness apps have a clunky and over complicated UI, so this will be a priority.

For more interested users, a history will be kept of their number of punches, types of punches and completed rounds. This will cater to the intermediate to advanced boxers and will also become something for the beginners to take advantage of once they become more interested in boxing.

2.3 Literature Survey

This section will discuss key ideas that were considered when designing the application as a whole and will then describe how they were implemented.

2.3.1 Gamification and User Engagement

The term "gamification" involves applying game design elements and principles to game contexts with the aim of enhancing user engagement and motivation. Initially gaining attention in the 2010s, gamification has been recognized as a strategy to improve user interaction by making tasks enjoyable and fulfilling. According to Deterding et al, gamification is defined as incorporating game design elements into game scenarios, a definition widely embraced in academic and practical fields [10].

Studies have indicated that integrating features such as points, badges, and leaderboards can notably elevate both user engagement levels and motivation across domains like education, health, and business. A comprehensive review by Hamari et al. [11] revealed that gamification yields positive outcomes in studies, although the extent of these effects may vary significantly.

In the field of education, for instance, gamification has been utilized to revolutionize learning environments by integrating game elements that render learning processes more interactive and rewarding. Lee and Hammer elaborate on how these approaches can enhance student engagement levels and facilitate learning experiences [12].

As technology platforms advance, the use of gamification techniques has grown beyond simple reward systems to include intricate gaming elements, like storytelling and role-playing. These additions can increase user involvement and satisfaction. However, Nicholson [13] cautions about drawbacks, such as the risk of diminishing intrinsic motivation. It is advised to implement gamification with clear objectives in mind.

In my project, a competition mode will be implemented to leverage this key psychological principle to boost engagement. However, I understand that too much of this will ruin a user's motivation in other modes or actual training so it will be used sparingly.

2.3.2 User-Centric Design

The concept of "user-centered design" revolves around customizing software to cater to the needs and preferences of users, with a focus on creating interfaces that are easy to use and understand. This design approach gained popularity in the 1990s, advocating for involving users in the development process to ensure that the final product is both functional and satisfying for its target audience. Norman and Draper [14] defined user-centered design as a method that prioritizes users' requirements, abilities, and behaviour during the design phase, establishing principles for developers.

Successful user-centered design heavily relies on usability testing and feedback from users, a practice supported by Nielsen who highlighted the significance of a design process—where designs are continuously tested and refined based on user input—to enhance software

usability [15]. This iterative approach plays a role in adapting products to align with user expectations and enhance the overall user experience.

Across industries such as healthcare, finance, and e-commerce, the implementation of user-centered design has proven indispensable. It ensures that software not only fulfils the demands of these sectors but also addresses the unique difficulties and requirements of their users. In the realm of e-commerce, prioritizing user experience in design enhances the shopping journey and lowers the chances of customers abandoning their carts by refining navigation and checkout processes. Studies conducted by Budiu and Nielsen in 2013 [26], reveal that a user-centric approach to web design can notably enhance user satisfaction, resulting in improved customer retention rates and boosted sales.

In the changing landscape of technological advancements, the significance of incorporating user-focused design principles cannot be overstated. Beyond visual appeal, a user-centric design ethos involves integrating the user's needs, emotions, and tasks into software development. As highlighted by Bødker, the key challenge lies in adapting to users' evolving demands and behaviours through research and innovation [17]. This comprehensive strategy has the potential to create successful software applications.

User-centered design is now widely acknowledged as a principle in software development, with substantial research backing its impact on user contentment and overall software efficacy. Consequently, it is a guiding principle that will play a role in shaping my software application's development process, as ensuring an exceptional user experience remains paramount.

2.3.3 Technology in Sports

In sports training, the incorporation of technology and performance evaluation has greatly transformed the methods athletes use to get ready and compete, especially in boxing. Recently, advanced tools like motion capture systems and performance analysis software have become essential in improving a boxer's skills and tactics. For example, high speed cameras and wearable sensors enable coaches to analyse boxer's biomechanics with accuracy pinpointing areas that need refinement [18]. This technology records data on punch speed, force and angle offering feedback that helps enhance a boxer's offensive strikes and defensive techniques.

Furthermore, virtual reality (VR) has emerged as a game changing tool in sports training. In boxing VR platforms replicate combat scenarios allowing fighters to practice against opponents. This application aids in sharpening reaction times and decision-making abilities. Also reducing the physical risks associated with actual sparring sessions [19]. Additionally cognitive training apps are employed to boost boxers' concentration levels and mental toughness— factors in high pressure situations where cognitive strain can significantly impact performance [20].

The utilization of performance analysis software further demonstrates how technology plays a role in the realm of sports. These software programs analyse information gathered during training sessions to create reports that keep track of a boxer's development over time monitor fatigue levels and anticipate injuries. This valuable information helps design training routines that enhance fitness and strategic readiness [21].

To sum up the advancements in technology within boxing, there has been a transition towards more data driven, precise and safer training techniques. These tools boost performance but also equip athletes with essential insights to excel mentally and strategically. My goal is to leverage technology to assist individuals of all proficiency levels in enhancing their boxing skills within my application.

3. Waterfall

The project was designed using the waterfall framework [22], I found this to be the methodology that best suited my personal style and I have had experience with it when making previous projects. The methodology includes 5 main stages: Analysis, Design, Implementation, testing and Maintenance with verification upon progression at each stage to ensure the progression of the overall project. During the development of the application, all stages were implemented except Maintenance as the application has not been released on the market. Below I will expand upon what was done at each stage.
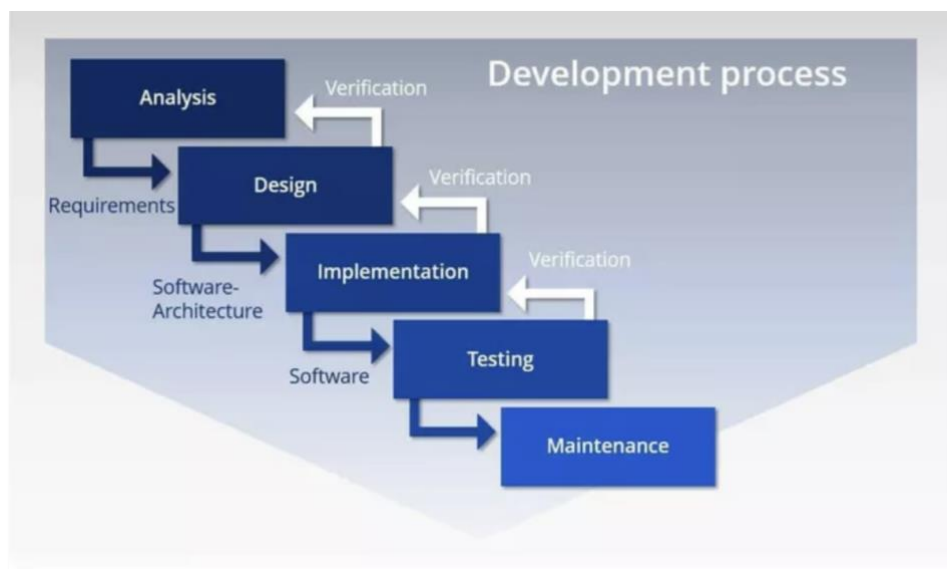
3.1 Analysis

During the background research section, due to the market research, I was able to come up with a set of user requirements that will satisfy all objectives of the application. The list is as follows:

- The user should be able to seamlessly navigate between different functionalities using a user-friendly interface.
- The user should be able to experience a consistent user interface across different devices due to responsive design.
- The user should be able to trust that their data, including punch tracking, user profiles, and workout histories, is processed efficiently and securely.
- The user should be able to rely on the system's scalability to handle an increasing number of users and simultaneous data requests.
- The user should be able to have their personal and workout data protected through robust security measures.
- The user should be able to accurately track and analyse punches in real-time across various modes such as shadow boxing, structured training sessions, and competitive challenges.
- The user should be able to log details of each workout session automatically, including punch count, types of punches and whether the combination was correct.
- The user should be able to view their progress over time through detailed statistics and graphs.
- The user should be able to ensure the application functions correctly through comprehensive feature and UI testing.
- The user should be able to access the application's features fully, even with disabilities, thanks to integrated accessibility features.
- The user should be able to use the application in multiple languages, making it accessible to a global audience.
- The user should be able to easily interact with the application, regardless of their age or tech-savviness, due to its intuitive design.

3.2 Design

In this section I will describe the design process in detail for the application

3.2.1 Language & libraries

3.2.1.1 Language

I opted for Python as the programming language for this project because of its support for quick development and the wide range of libraries that cater to the specific requirements of this application (particularly video tracking). Python's syntax is straightforward and concise

making it easier to maintain code clarity and organization which is crucial for this application where the code can easily become quite complex.

3.2.1.2 Selection of Libraries

The choice of libraries was based on their ability to address the user needs and project goals effectively. Here are all the external Python libraries used:

- PyQt5 & PyQtChart; These libraries offer tools for building the graphical user interface (GUI). PyQt5 stands out for its collection of GUI widgets and seamless handling of user interactions. PyQtChart an extension of PyQt5 is utilized to incorporate charting features into the application for real time visualization of user progress and analytics.
- Pyqtgraph; Recognized for its performance in plotting with real time update requirements pyqtgraph is used to generate faster and less resource intensive plots, particularly important for displaying rapidly changing data such as punch speeds and frequencies.
- Pydub and opencv python; These libraries play a role, in managing media processing tasks. Pydub is employed for manipulating files for incorporating alert sounds and feedback during training sessions.
- The opencv python package supports functions, for streaming videos and processing images enabling real time analysis to track punches effectively.
- The opencv contrib python library offers tools and algorithms to enhance the capabilities of opencv python for advanced image processing methods that can improve the accuracy and efficiency of punch detection.
- Utilizing gtts (Google Text to Speech) and playsound enhances user engagement by converting text instructions into words providing feedback during exercises to make the application more user friendly. Playsound complements this by offering a solution for playing files, crucial for auditory cues in training sessions.

These libraries were chosen not for their features but also because of their strong support communities and compatibility with Python. This ensures that the project remains manageable and scalable with resources for troubleshooting and improvements.

3.2.2 Software Architecture

The project utilizes a design approach, by breaking down the application into modules each represented by specific Python files that cater to different functionalities of the software. This structure enables parts of the application to operate while collaborating harmoniously to create a unified system. Here's a breakdown of the modules and their respective functions.

1. Main Module (main.py); Acts as the starting point of the application setting up the environment, configurations and linking all modules together for initiation and operation.

2. GUI Module (MainWindow.py); Controls the graphical user interface (GUI) of the application using PyQt5 to construct and manage elements like menus, toolbars and buttons within the window. It serves as the interface for user interaction.

3. History Management Module (HistoryManager.py); Manages data related to punch tracking handling tasks such, as loading, updating and saving data into punch_history.json. This module ensures data persistence and facilitates historical analysis functionalities.

4. Overlay Control Module (ImageLabel.py); Oversees overlays on the punch tracking window by utilizing PyQt for manipulating overlays that offer feedback during real time analysis.

5. The Punch Tracking Module, consisting of punch_tracker.py and VideoThread.py handles the core functions related to tracking punches. In punch_tracker.py you'll find the algorithms for detecting motion and recognizing punches while VideoThread.py manages threading to process video streams in time without causing delays, in the GUI.

6. The Style Management Module (styles.py) contains configurations to CSS for PyQt5 widgets. It centralizes design elements such as button styles ensuring an easily customizable user interface.

7. Within the Utility Module (utils.py) you'll discover utility functions utilized throughout parts of the application. These functions assist with tasks like showing error messages and other supporting functionalities that don't belong in a module.

Each module within this architecture is crafted to be connected yet tightly integrated following design principles. This approach simplifies maintenance and scalability and allows for individual testing and development of components, without impacting others. This helps the user requirements be met because the modular structure allows for easy and thorough testing. Also, all the modules laid out above satisfy all of the features that are needed in the user requirements.

3.2.3 Other usages

During the project development process, I made use of resources and third-party services. I have duly acknowledged each of them to maintain transparency and comply with the academic integrity of the university.

Images: The two images featured in the application were crafted using DALL E [23] and their copyrights are held by myself.

Motivational Quotes: The app includes a selection of quotes with attribution to each author for due credit.

YouTube Integration: Users can access motivational content through the YouTube API [24] in the app connecting specifically to the Chispa Motivation channel [25]. Any advertising revenue generated from views via the app supports Chispa Motivation, per YouTubes policies.

Sound Effects: The application uses sounds sourced from Freesound.org [26], a repository of copyright clips. These sounds come with licenses that allow use. Typically require attribution, which has been provided within the app.

3.3 Implementation

3.3.1 Development Environment Setup

To develop the Boxing application, I used PyCharm Professional as my Integrated Development Environment (IDE). I selected this IDE because of its Python support, built in debugging tools and smooth integration with the PyQT framework crucial for the GUI development. PyCharm's features like code completion and advanced analysis capabilities were instrumental, in maintaining code quality and enhancing productivity. It also made coding in PEP-8 easier than in other IDEs I have used.

For version control I managed the project codebase using Git version 2.39.3. Its integration with PyCharm simplified change tracking, code reviews and pull requests.

All project dependencies were managed through pip, the Python package manager. This decision ensured compatibility, with Python libraries required for my project, including PyQt5 and OpenCV. Using pip made it easy for users to set up the project by installing libraries with pip commands. The commands can be found within the README.md.

3.3.2 Backend

In this section, I will discuss the backend of the application, I will preface beforehand that all data for the user is stored inside of a JSON file that is managed by the HistoryManager.py file. The data is then read and updated in real time as the punch tracker and timer is working.

3.3.2.1 Live punch tracking mode

The live punch tracking mode is a mode where the user is shown a view of themselves via the webcam and they are presented with a virtual green line with a clear division in the middle, denoting a body and head punch. When the user throws a punch that reaches the

green line, a red or blue flash appears to show that a left or right-handed punch has been thrown respectively. This mode is designed to encourage the user to free flow and shadow box as they usually would, but with the added feature of tracking punches and completed rounds. Below is the code for the detection in this mode:

```python
# Find contours and draw them for red
contours_red, _ = cv2.findContours(mask_red, cv2.RETR_TREE, cv2.CHAIN_APPROX_SIMPLE)
for cnt in contours_red:
    area = cv2.contourArea(cnt)
    if area > 400 and track_punches_flag():
        x, y, w, h = cv2.boundingRect(cnt)
        if x > frameWidth / 2:
            cv2.rectangle(img, (x, y), (x + w, y + h), (0, 0, 255), 3)

# Detect red punches
contours_red, _ = cv2.findContours(mask_red, cv2.RETR_TREE, cv2.CHAIN_APPROX_SIMPLE)
for cnt in contours_red:
    area = cv2.contourArea(cnt)
    if area > 400 and track_punches_flag():
        x, y, w, h = cv2.boundingRect(cnt)
        if x > frameWidth / 2 and intersects_with_line(x, y, w, h, START, END) and can_detect_again('red'):
            body_part = "Head" if y + h / 2 < frameHeight / 2 else "Body"
            detected_punches.append(f'Left {body_part}')
            punch_history['Total Punches'] += 1
            punch_history['Total Left'] += 1
            punch_history[f'Total {body_part}'] += 1
            punch_history[f'Left {body_part}'] += 1
            save_punch_history(punch_history)
            if flash_screen_callback is not None:
                flash_screen_callback('red')
```

3.3.2.1 Training mode

This mode is very similar to the live tracking mode, except that the user is prompted visually and audibly with a combination that they are expected to throw. If the combination is correctly thrown an audible noise is made so the user knows they have thrown correctly as well as a green flash, conversely if the combination thrown is incorrect then a red flash appears. Also, the punch history is updated in real-time like with live punching and if the combination is correct or not. Below is the code for generating a new combination.

```python
# hugohull *
def generate_random_combination():
    punches = ['Left Head', 'Left Body', 'Right Head', 'Right Body']
    num = 0
    if skill_level is not None:
        if skill_level == "Beginner":
            num = 3
        elif skill_level == "Intermediate":
            num = 5
        elif skill_level == "Advanced":
            num = 7
    if num != 0:
        num_punches = random.randint( a: 1, num)
        return [random.choice(punches) for _ in range(num_punches)]

current_combination = generate_random_combination()
detected_punches = []
```

3.3.2.1 Competition mode

The competition mode is very similar to the training mode, except the line and detection zone is in the centre of the webcam view. Two players are required for this mode and they each have two gloves of the same colour: user one with red and user two with blue. Like with the training mode, a random combination is generated and the first user to throw the combination is awarded a point. At the end of the round, the user with the most points is selected the winner and the history is updated accordingly. Below id the code that decides who has thrown the combination first:

```python
if track_punches_flag():
    # Check if Red has thrown enough punches for a combination
    if len(detected_punches_red) >= len(current_combination):
        if detected_punches_red == current_combination:
            red_score += 1
            punch_history["Correct Combinations"] += 1
            save_punch_history(punch_history)
            red_score_callback(red_score)
            flash_screen_callback('red')
            play_correct()
            # Generate a new combination and reset detected punches
            current_combination = generate_random_combination()
            speak_combination(current_combination)
            detected_punches_red = []
            detected_punches_blue = []
            new_combination_callback(',  '.join(current_combination))
        else:
            flash_screen_callback('red')  # Red flash to indicate error
            play_incorrect()
            detected_punches_red = []
            punch_history["Incorrect Combinations"] += 1
            save_punch_history(punch_history)

    # Check if Blue has thrown enough punches for a combination
    if len(detected_punches_blue) >= len(current_combination):
        if detected_punches_blue == current_combination:
            blue_score += 1
            blue_score_callback(blue_score)
            flash_screen_callback('blue')
            play_correct()
            # Generate a new combination and reset detected punches
            current_combination = generate_random_combination()
            speak_combination(current_combination)
            detected_punches_red = []
            detected_punches_blue = []
            new_combination_callback(',  '.join(current_combination))
        else:
            flash_screen_callback('blue')  # Blue flash to indicate error
            play_incorrect()
            detected_punches_blue = []  # Reset blue's punches after evaluation
```

3.3.3 Frontend

The applications frontend is mainly managed in the MainWindow.py file making use of the functionalities of the PyQt library to ensure a user responsive interface. Some styling is kept in the styles.py page to make it easy to use and modulated.

3.3.3.1 Home page
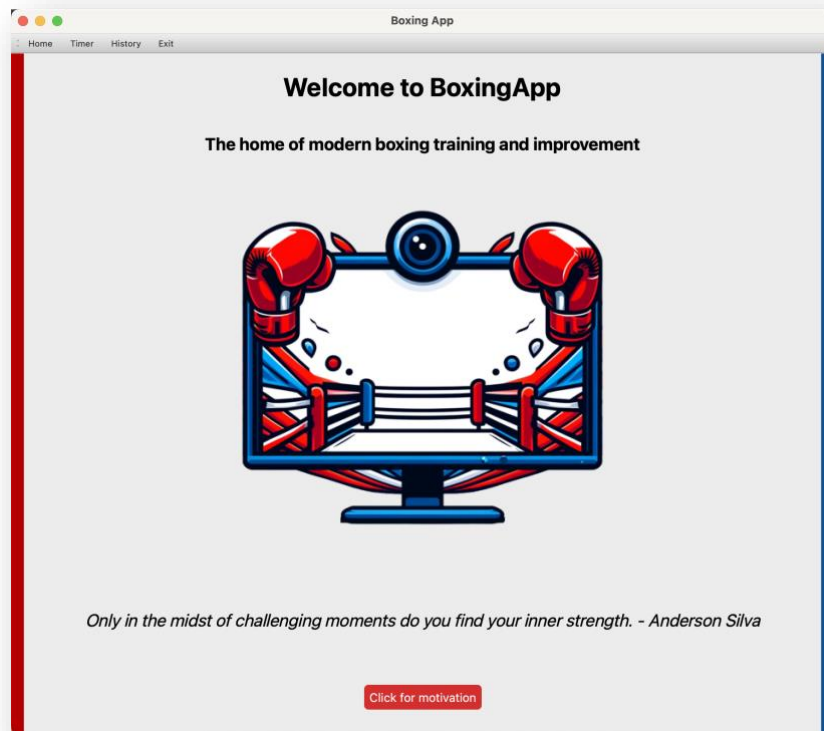
The homepage acts as the starting point for users, designed to be inviting and easy to navigate. Important features such as the NavBar and logo are showcased. It also features a randomly selected quote that changes every time the page is reloaded as well as a button that when pressed will open a motivational YouTube video. This is designed to inspire the user to be excited to use the applications features.

3.3.3.2 Timer Page:
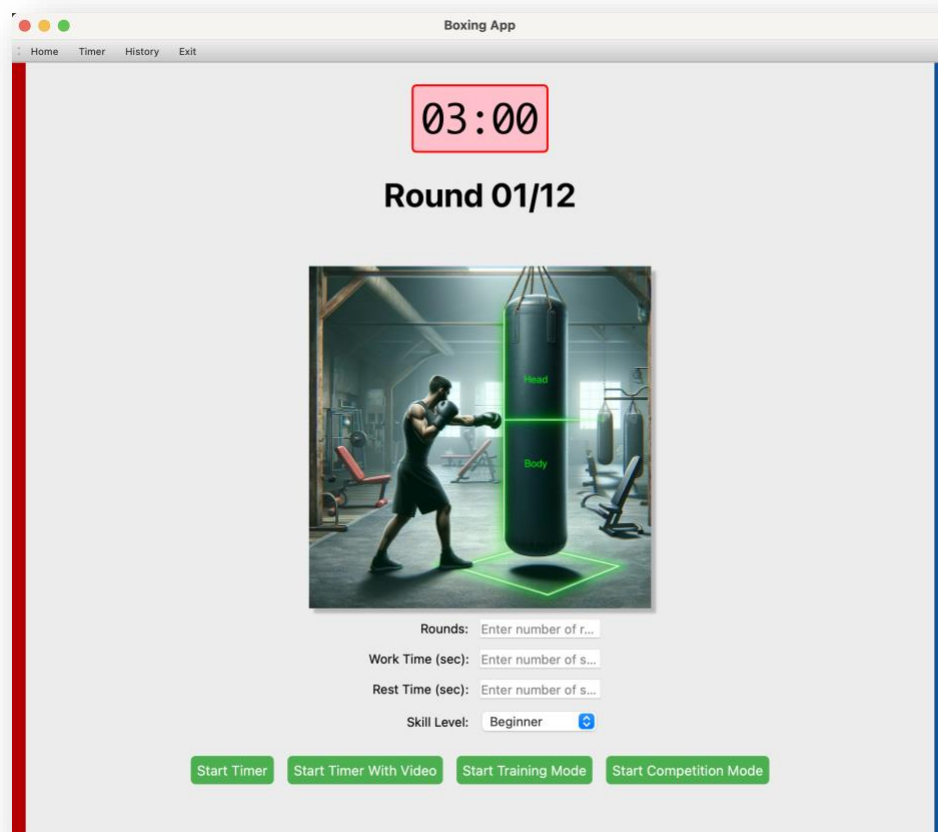
This page showcases a displayed timer that's easy to read with buttons for starting the mode the user wants, choosing exactly how many rounds and how long they want each round to last. It also features a combo box that allows the user to select the difficulty they would like the mode to select, when using training modes. In the centre of the window, there is an image that shows the user exactly how to set up the webcam and where the lines for body and head detection will be.

3.3.3.3 Active mode page
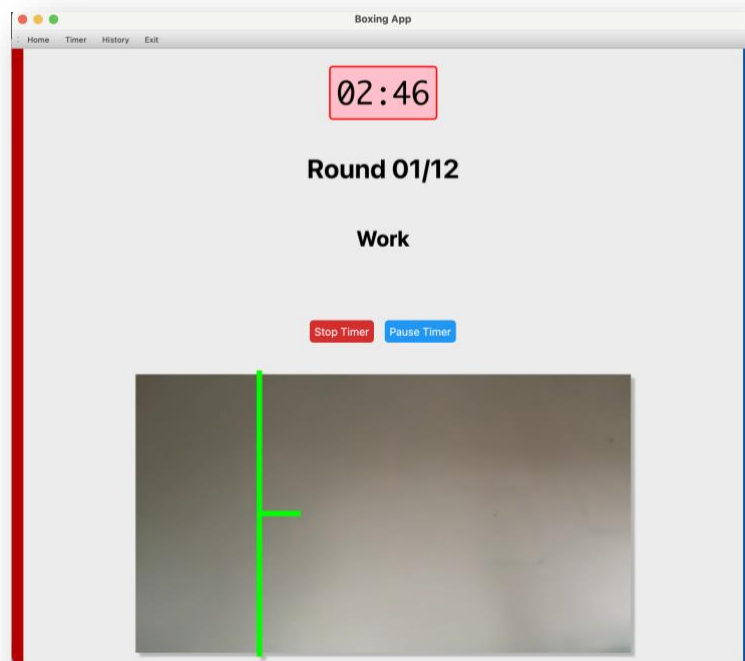
Here you can see an example of what the application looks like when a mode is selected, in this instance it is the live punch tracker mode. The buttons are changed to stop and pause timer and a phase label is shown to indicate whether the user is supposed to be resting or working. The placeholder image is replaced with the live webcam output which features an overlay, with the line in the centre showing the boundary between a body and a head punch. When a punch intersects with the green line, a red or blue flash will appear depending on whether a left or right-handed punch is thrown respectively.

3.3.3.4 Graph page
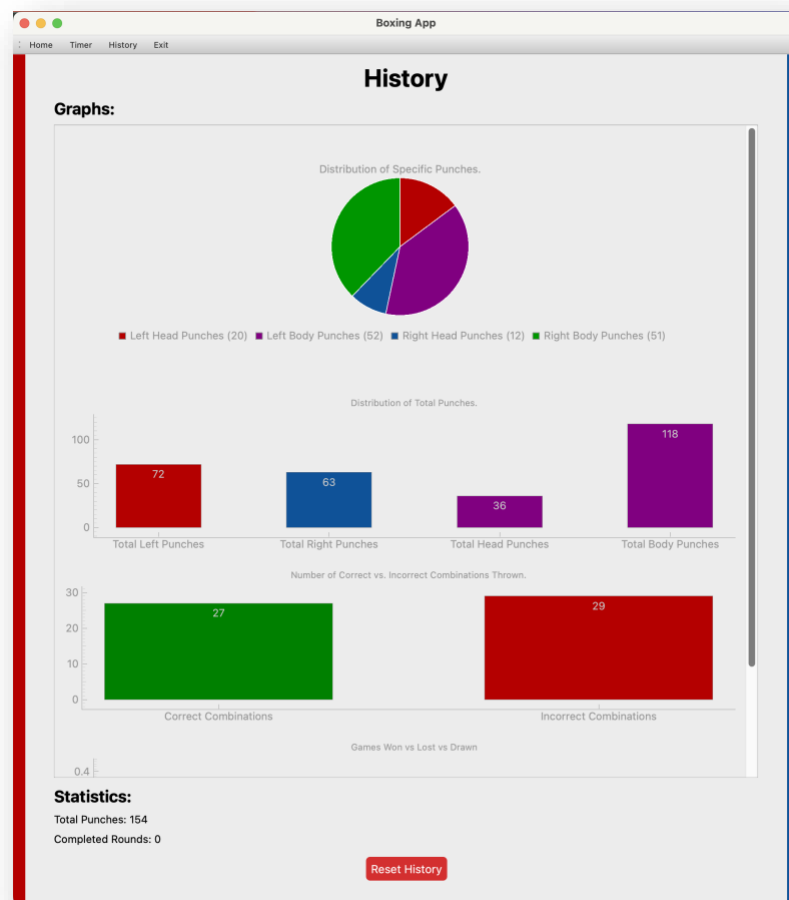
The graphs that display the users punch tracking data use the pyqtgraph and QChart, QChartView and QPieSeries libraries. A scrollable area contains all four of the graphs: Distribution of specific punches, Distribution of total punches, Number of correct vs Incorrect combinations and Games Won vs Lost vs Drawn. Below this there is a button that when pressed and confirmed, will reset the user's history to zero, resetting all graphs in the process. There is also a statistic area where the user can see the number of punches thrown and number of rounds completed.

3.3.4 Challenges and Solutions

3.3.4.1 Dealing with Threading Challenges and GUI Constraints

During the stages of development, I encountered some difficulties when trying to combine threading with my GUI, which was originally created using Tkinter. The application worked fine with a thread, like when running a timer. However, things got complicated when I

introduced a second thread to manage live punch tracking. Having multiple threads caused errors that disrupted the smooth operation of the application.

Upon investigating these issues, I found out that Tkinter doesn't naturally support multi-threading, which was the reason for the disruptions. This limitation in Tkinter's structure posed a huge problem since my project needed multi-threading capabilities to handle real time data processing and UI updates simultaneously.

While Tkinter's simplicity was handy for prototyping, it fell short when faced with the intricate demands of the project. For example, it lacked flexibility in UI design like not being able to include placeholder text, in text entry fields. These restrictions pushed me to explore GUI frameworks that could better cater to both my technical and visual requirements.

3.3.4.2 Implementing an advanced GUI Framework

After research and comparing frameworks available I made the decision to switch the GUI from Tkinter to PyQt.

This framework natively supports threading and provides a wide range of customization options that were crucial, for the application. Transitioning to PyQt promptly resolved the threading issues eliminating errors and significantly boosting the applications performance and reliability.

Furthermore, PyQt offered data visualization capabilities enabling us to integrate punch tracking visuals into the application interface— a feature that would have necessitated external solutions with Tkinter. This integration notably enhanced the user experience by delivering time feedback directly within the main application window.

3.3.4.3 Reflections and Lessons Learned

This experience emphasized the significance of choosing the appropriate tools and frameworks based on the projects specific needs rather than opting for convenience or familiarity. The decision to switch to PyQt while initially time intensive ultimately drove the project forward better aligning with my performance objectives and user experience goals.

3.4 Testing

3.4.1 System Testing

I conducted the system testing by imitating how regular users would interact with the application. I focused on verifying the functionality of features, like real time punch tracking, updating the history and purposefully misusing the software, playing the role of end users. I also carefully assessed the user interface to ensure that data updates appeared promptly on the screen and that switching between features was smooth and occurred with no issue.

This hands-on approach to testing was crucial in confirming that the application delivered a user-friendly experience across all its functions.

3.4.2 Usability and Acceptance Testing

The stages of acceptance and usability testing were milestones in the project as they centered on evaluating the readiness of the application and its alignment with user expectations. I engaged a group of users of all boxing skill levels to interact with the application under controlled conditions resembling real life scenarios. These sessions were instrumental in validating whether the application fulfilled user needs and effective scalability when faced with varying levels of user interaction.

The usability testing was specifically aimed at assessing how easy it was to use the application and how accessible it was for users. I strived to make sure that the app was easy to use and accessible, for people of all ages and abilities including those with disabilities.

3.4.3 Results from the testing phases

During the testing stages I discovered design issues that I promptly resolved. Specifically, bugs were found that related to managing threads which sometimes led to performance glitches especially when users ended sessions prematurely. I also fixed validation errors in input handling, such as dealing with null or zero inputs, which were vital for maintaining data processing capabilities.

Feedback on the graphical user interface (GUI) from usability tests suggested that users felt the original design was a bit plain and lacked engagement. In response enhancements were made to the GUI by adding vibrant colours and dynamic elements to enhance visual appeal and user interaction. These changes greatly improved the applications aesthetics and boosted overall user satisfaction and engagement.

These continuous improvements based on direct user input have greatly enhanced both the functionality and interface of the application ensuring it is not robust and functional but also appealing and accessible to the target audience.

4. Results and Discussion

This section assesses the projects outcomes in comparison, to the aims and objectives set at the beginning of the dissertation. The main goal of creating a cutting-edge boxing training app that utilizes real time data and interactive training modules has been mostly achieved, with several key features put into action.

4.1 Implementation Successes

1. Development of Frontend and Backend; The apps frontend was effectively developed using Python while the backend was built with PyQt5 laying a foundation for the app's functionality.
2. Punch Tracking Capability: By leveraging OpenCV the app now includes punch video tracking in modes.
3. Shadow Boxing: Enables users to practice punches solo with their movements tracked and real time feedback provided.
4. Training Mode: Provides training sessions with instant punch tracking and feedback.
5. Competition/Game Mode; Involves users in a scenario to enhance entertainment and usability of the app.
6. Workout History Monitoring and Visualization: Users can monitor their workout history. Visualize analytics through graphs and charts aiding in progress tracking and goal setting.

The app introduces an innovative live punch tracking feature, an addition to boxing training apps that typically required hardware, for similar functions. This characteristic improves the quality of training. Also makes advanced training more accessible and cost effective.

4.2 Limitations and Challenges

One of the goals was to ensure that the application is accessible to everyone. However, this goal was not completely achieved. The application lacks features that would make it user friendly for individuals with disabilities and those who do not speak English. This limitation is significant given the user base is worldwide.

4.3 Discussion

The project has effectively integrated technologies to develop a functional and innovative boxing training app. Nevertheless, accessibility remains a challenge. The absence of support and accessibility features for users with disabilities means that the application is not universally usable yet. Addressing these issues would align with the project objectives and ensure compliance with software development best practices.

Looking ahead the project should prioritize improving accessibility; Incorporating voice commands, screen readers and alternative user interfaces to accommodate users with disabilities. Another key feature that's missing is multilingual support. By focusing on these areas, the application can truly achieve its goal of being accessible to all users maximizing its impact, in the realm of boxing training.

5. Critical Appraisal

5.1 Summary and critical analysis

The main goal of the project was to create a boxing training app that includes real time data and interactive training features, this objective was successfully met. Introducing a live punch tracking feature, an addition to boxing apps, signifies a technological advancement. This new feature improves training capabilities and establishes a higher standard in sports app development.

While the project achieved success overall, there was a shortfall in making the app accessible to all users, which was a goal. This limitation hinders the apps usability and potential reach in the market for users with disabilities or non-native English speakers.

A significant technical obstacle emerged when it was discovered that Tkinter, the chosen GUI toolkit did not have built in support for threading. This issue affected the development timeline and resource allocation shifting focus from essential tasks like improving accessibility.
Dealing with Tkinters lack of threading support required me to spend an amount of time searching for a library that could seamlessly integrate with the rest of the application without causing any issues.

In hindsight conducting a initial evaluation of the technology stack particularly focusing on the GUI toolkits capabilities, like threading support would have been beneficial. This approach would ensure that all technical requirements are met upfront without needing workarounds. Having an understanding of technical challenges in advance, could result in a more even allocation of resources guaranteeing that important aspects such, as accessibility receive proper attention.

5.2 Discussion of Context

This application has potential to be very impactful in several fields, I will detail how below. Although this is speculative and could not be truly tested unless the application was deployed with funding for things like marketing and distribution.

5.2.1 Social Influence

The app carries implications particularly in boosting users' self-assurance. By improving their boxing skills, users may see a rise in self-esteem. This proves advantageous for individuals lacking confidence, granting them a feeling of achievement and empowerment. Additionally, the competitive elements of the app could cultivate a user community enriching engagement and shared experiences among participants. Nonetheless it's essential to note risks like users substituting virtual training for professional guidance, which could result in incorrect techniques and possible injuries.

5.2.2 Environmental Context

Although sustainability matters are not directly addressed by the project, its digital nature indirectly contributes to sustainability by reducing the need for resources typically associated with conventional boxing training, like equipment and space. Digital training solutions curb material consumption. The fact it can be accessed from any location reduces travel needs and as a result, the carbon footprint.

5.2.3 Business and Economic Influence

By making it easier for people to start learning boxing it allows more individuals to get involved in the sport. This inclusiveness could result in more people participating, potentially increasing sales and influencing the market, for sports training. From this standpoint this innovation may create job opportunities in areas like tech support, marketing and developing content specifically designed for boxing training software. The technology being utilized, such as time data processing and video analysis using OpenCV has applications beyond sports technology and into industries indicating possibilities for business growth.

5.3 Assessment of personal development

Throughout the development of this boxing training app, I've greatly improved both my expertise and my grasp of the intricacies involved in managing a large-scale project. This hands-on experience has played a role, in honing my skills in various aspects.

Working on this project using the Waterfall approach for the first time has taught me lessons in effectively organizing and sequencing tasks. It underscored the significance of project phases and meticulous planning to ensure timely project completion. Building this application has also allowed me to gain knowledge in Python programming and areas of Computer Vision. These proficiencies are vital for my career goals in software development in sectors like real time data processing and interactive technologies. Incorporating features like live punch tracking, required real time data processing enhancing my capability to handle dynamic data streams and apply these techniques across technological domains such as sports technology.

Also, this project has deepened my appreciation, for boxing as I acquired an understanding of both its demands and strategic elements. This deeper appreciation helps in developing user intuitive training programs showcasing a holistic approach to software development. By blending aspects of sports science, technology and user experience design, my perspective has broadened, equipping me with skills highly sought after in today's job market. The skills honed through this project align closely with my aspirations in software engineering and tech innovation. Proficiency in Python and Computer Vision is in demand across industries such as sports tech, automation and AI.

This project acts as a portfolio piece showcasing my coding prowess problem solving acumen and dedication to tackling challenges. It will play a role in conversations with employers by highlighting my ability to lead intricate projects effectively and my passion, for leveraging technology creatively.

6. Conclusion

Over the course of this project, I successfully created a boxing training app that combines real time punch monitoring and interactive workout elements without requiring equipment. This positions the app, as a brand-new tool in the field of sports technology. It offers training modes delivering feedback to users. While it met most of its goals there were gaps in ensuring access and multilingual support indicating areas for enhancements. The apps creative use of camera tech for monitoring punches sets an industry standard making advanced training more accessible to an audience at a reduced cost. Future efforts will concentrate on improving accessibility features and expanding language options to cater better to a user base. This initiative pushes sports training technology forward. It also establishes a scalable framework for further innovations, in integrating interactive technologies into fitness and personal workout apps.

References

[1]   N.Tsenkov, "Olympic Boxing: History & Facts", Fight Camp, Jul. 2017. [Online].
        Available at: https://blog.joinfightcamp.com/fight-news/olympic-boxing-history-
        facts (Accessed Mar. 15, 2024)

[2]   Premier League, "History of VAR", Premier League, Jun. 2020. [Online]. Available at:
        https://www.premierleague.com/news/1293198 (Accessed Mar. 15, 2024)

[3]   Python Software Foundation, "Python Documentation", Python Software
        Foundation. [Online]. Available at: https://www.python.org/doc/ (Accessed Mar
        15, 2024)

[4]   PyQt5, "What is PyQt5?", Riverbank Computing. [Online]. Available at:
        https://riverbankcomputing.com/software/pyqt/intro (Accessed Mar 15, 2024)

[5]   OpenCV, "OpenCV Overview", OpenCV. [Online]. Available at:
        https://opencv.org/about/ (Accessed Mar 15, 2024)

[6]   PunchLab SRL, "Company Overview", PunchLab SRL. [Online]. Available at:
        https://punchlab.net/about-us/ (Accessed Mar 16, 2024)

[7]   FightCamp HYKSO INC, "About FightCamp", FightCamp. [Online]. Available at:
        https://joinfightcamp.com/pages/about-us (Accessed Mar 16, 2024)

[8]   Uezeth, "Music Boxing Machine for Coordination", Amazon UK. [Online]. Available
        at: https://www.amazon.co.uk/Uezeth-Music-Boxing-Machine-
        Coordination/dp/B0CPBCZRRN/ref=cm_cr_arp_d_product_top?ie=UTF8&th=1
        (Accessed Mar 17, 2024)

[9]   Unity Boxing Gym, "Unity Boxing Club Leicester Facebook page", Unity Boxing Gym.
        [Online]. Available at: https://www.facebook.com/p/Unity-Boxing-Club-Leicester-
        100063539653191/?locale=en_GB (Accessed Mar 17, 2024)

[10]   S. Deterding, D. Dixon, R. Khaled, & L. Nacke, "From game design elements to
        gamefulness: defining gamification," in Proceedings of the 15th international
        academic MindTrek conference: Envisioning future media environments, 2011.
        [Online]. Available at: https://dl.acm.org/doi/10.1145/2181037.2181040 (Accessed
        Mar 20, 2024).

[11]   J. Hamari, J. Koivisto, & H. Sarsa, "Does gamification work? — a literature review of
        empirical studies on gamification," in 2014 47th Hawaii International Conference
        on System Sciences, 2014. [Online]. Available at:
        https://ieeexplore.ieee.org/document/6758978 (Accessed Mar 20, 2024).

[12]   J. J. Lee & J. Hammer, "Gamification in education: What, how, why bother?"
        Academic Exchange Quarterly, 2011. [Online]. Available at:
        https://www.researchgate.net/publication/233929634_Gamification_in_Education
        _What_How_Why_Bother (Accessed Mar 20, 2024).

[13]   S. Nicholson, "A user-centered theoretical framework for meaningful gamification,"
        in Games+Learning+Society 8.0, 2012. [Online]. Available at:
        https://scottnicholson.com/pubs/meaningfulframework.pdf (Accessed Mar 20,
        2024).

[14]   D. A. Norman & S. W. Draper, "User Centered System Design; New Perspectives on
        Human-Computer Interaction," Lawrence Erlbaum Associates, 1986. [Online].
        Available at:
        https://www.researchgate.net/publication/234753498_User_Centered_System_De

sign_New_Perspectives_on_Human-Computer_Interaction (Accessed Mar 22, 2024).

[15]   J. Nielsen, "Usability Engineering," Academic Press, 1994. [Online]. Available at: https://www.researchgate.net/publication/220403847_Usability_Engineering (Accessed Mar 22, 2024).

[16]   . Budiu & J. Nielsen, "User Experience for Mobile Applications and Websites," Nielsen Norman Group, 2013. [Online]. Available at: https://www.nngroup.com/reports/mobile-website-and-application-usability/ (Accessed Mar 22, 2024).

[17]   S. Bødker, "When second wave HCI meets third wave challenges," in Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles, 2006. [Online]. Available at: https://dl.acm.org/doi/10.1145/1182475.1182476 (Accessed Mar 22, 2024).

[18]   J. Roberts, "Enhancing Athletic Performance Through Motion Capture Technology," SportsTech Journal, Sep. 2022. [Online]. Available at: https://www.sportstechjournal.org/motion-capture-enhancing-boxing (Accessed Mar. 24, 2024).

[19]   L. Martinez, "Virtual Reality in Boxing: Training of the Future," VR Sports News, Aug. 2023. [Online]. Available at: https://www.vrsportsnews.com/boxing-vr-training (Accessed Mar. 24, 2024).

[20]   S. Thompson, "Cognitive Training Tools for Elite Athletes: An Overview," Peak Performance, May 2023. [Online]. Available at: https://www.peakperformance.com/cognitive-tools-athletes (Accessed Mar. 24, 2024).

[21]   . Hamilton, "Data-Driven Training in Professional Boxing," Boxing Analytics Weekly, Dec. 2023. [Online]. Available at: https://www.boxinganalytics.com/data-driven-training (Accessed Mar. 24, 2024).

[22]   Ionos Digitalguide, "Waterfall Methodology," 2024. [Online]. Available at: https://www.ionos.co.uk/digitalguide/websites/web-development/waterfall-methodology/ (Accessed Mar 30, 2024).

[23]   DALL-E, "DALL-E Image Generator," 2024. [Online]. Available at: https://openai.com/dall-e (Accessed Apr. 2nd, 2024).

[24]   YouTube API, "YouTube Data API," 2024. [Online]. Available at: https://developers.google.com/youtube/v3 (Accessed Apr 2, 2024).

[25]   Chispa Motivation, "Chispa Motivation YouTube Channel," 2024. [Online]. Available at: https://www.youtube.com/user/ChispaMotivation (Accessed Apr 2, 2024).

[26]   Freesound, "Freesound Licensing," 2024. [Online]. Available at: https://freesound.org/help/faq/#sounds-license (Accessed May 2, 2024).