Training for the Perfect Penalty Kick in Soccer

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Abstract

Penalty kicks, while crucial in soccer games, currently suffer from training methods that are repetitive, lack clear feedback, and ultimately prove tedious. This results in many players disengaging from continuous penalty kick practice and having limited knowledge on how to improve their skills. To address these issues, an interactive game that can be used by amateur soccer players is developed. Evaluation results validated the effectiveness of the developed prototype in enhancing users' penalty kick skills and encouraging sustained engagement. This research presents a promising direction in utilizing technology to boost sports training, demonstrating potential for further refinement and broader applications beyond penalty kicks.

Acknowledgments

I would like to express my deepest gratitude to my supervisors Mannes Poel and Max Slutter, who have provided invaluable advice and guidance throughout the course of this project. Their constant support, thorough critiques, and insightful suggestions have been instrumental in shaping the design and execution of the system.

Furthermore, I extend my sincere thanks to all the friends who participated in the evaluation phase of this project. Their willingness to engage with the system, their thoughtful feedback, and their honest critiques significantly contributed to the final stages of this work.

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1. Introduction

1.1 Background

Football (soccer) is one of the most widely played and watched sports in the world, with an estimated 3.5 billion fans [1]. Penalty kicks are a crucial aspect of the game, often determining the outcome of a match. A penalty kick is a free kick taken from 12 yards away from the goal, and is awarded when a player commits a foul inside the penalty area [2]. Penalty kicks require a combination of technical skill, mental focus, and strategic decision-making, making them one of the most challenging aspects of the sport.

In the 2022 Qatar World Cup, penalty shootouts were responsible for determining the winner of five games, including the final between Argentina and France [3]. These high-pressure situations demonstrate the importance of developing effective penalty kick training programs that can improve players' accuracy and success rate.

Penalty kick accuracy is influenced by a variety of factors, including the run-up, approach angle, foot placement, and ball placement [4,5,6]. Coaches traditionally emphasize the importance of these elements, as well as psychological pressure, when training players for penalty kicks [7]. However, even the best players in the world can struggle to execute penalty kicks consistently due to the complexity of these factors, as shown in ***Figure 1*** where it can be seen that France missed half of their four shots during the penalty shootout in the 2022 World Cup final [3].

Therefore, to increase the success rate of penalty kicks and prevent mistakes, there is a need for penalty kick training that can effectively address these challenges and help players improve their performance. Traditionally, penalty kick training involves a lot of repetition and practice of technique. Players typically practice alone or in groups, and receive feedback from coaches on their technique.

However, this traditional approach to training has some limitations. While repetition and practice are crucial, it lacks specificity, immediate and objective feedback, and motivation or engagement, leading to boredom or disengagement [8]. It has been also found that in general learning scenarios, specificity of feedback [9] and goal setting [10] can significantly influence skill acquisition and performance improvement. Feedback specificity allows learners to understand exactly what they need to improve and how to do so, providing a clear path to performance enhancement [11]. Goal setting gives learners a clear target to strive for and can significantly enhance motivation [4].

For instance, within the context of penalty kick training, players who repetitively practice without specific goals or varying routines does not experience effective improvement. They take countless penalty kicks in the same manner, aiming for the same spot in the goal, without making any adjustments or progress. When coaches provide feedback and it is not specific enough, players struggle to comprehend and apply the improvements needed. Moreover, the absence of objective data or performance metrics could hinder the players from accurately gauging their progress.

Figure 1. Result of the 2022 World Cup final between Argentina and France [3]

1.2 Problems and goals

As highlighted earlier, prevalent penalty kick training methods demonstrate certain limitations in terms of player engagement and direct feedback. A survey conducted among students and coaches who are active in university soccer clubs revealed a lack of specific, universally accepted methods for penalty kick training. Often, players resort to repetitive, unstructured practice of striking the ball without a clear understanding of which aspects to improve or whether their performance is improving. The monotony of this approach can lead to disengagement from training. The need for a structured, engaging, and feedback-oriented training method is crucial, especially for target users: amateur soccer players. These players, regardless of skill level, are eager to enhance their penalty kick performance and deepen their game engagement.

Traditional training methods are not suitable for these players who require more guidance and support to develop their skills. Therefore, there is a need for innovative training methods that can effectively identify and address players' issues while keeping them motivated and engaged.

One promising way to solve these problems is through the use of sensor technology. Sensors can provide real-time feedback on a player's technique and performance, allowing players to adjust their approach and improve their accuracy. Additionally, sensors can help players track their progress over time and provide customized training programs to target specific areas for improvement [12]. Thus, amateur soccer players can detect their problems, such as which approach angle is best for individual players. Sensor-based training systems have the potential to provide real-time feedback to players and be applied with gamification elements to make training more engaging and fun.

Applying gamification elements is another way to solve problems. Given the effectiveness of gamification in engaging users and enhancing their learning experience, as evidenced in various sports training contexts [13], this project seeks to incorporate gamification elements into the design of the sensor-based penalty kick training system. The aim is to transform the often monotonous and repetitive penalty kick practice into a more interactive and engaging experience.

Gamification can inject an element of competition into the training process, which has been proven to increase motivation and engagement [14]. By incorporating game-like features such as points, levels, and rewards, the system can promote a sense of achievement and progress, thereby encouraging players to practice more frequently and improve their skills.

Therefore, the problem addressed in this thesis project is how to design and evaluate a sensor-based training system that incorporates gamification to improve the accuracy and success rate of penalty kicks in an engaging and enjoyable manner. The solution to this problem will require a thorough understanding of the factors contributing to penalty kick accuracy, as well as the design principles and gamification features that can enhance training engagement and enjoyment. Moreover, the effectiveness of the proposed system needs to be evaluated using appropriate research methods to ensure that it meets the needs of the target users.

In this project, the primary target users are amateur soccer players. Typically, they do not participate in important matches frequently, but are often involved in penalty kicks during friendly games or club activities. In these contexts, refining the technical aspect of penalty kicks takes precedence over handling mental pressure.

Thus, particular emphasis will be placed on two key elements affecting the accuracy of penalty kicks: approach angle and run-up distance, as explained in ***Figure 2***. These factors are selected due to their significant impact on the success of a penalty kick, as highlighted in various studies. For instance, research has shown that the approach angle can vary widely among players and need to be personalized for optimal results [4,5,15]. Additionally, the distance of the run-up can influence not only the force exerted on the ball but also the psychological dynamics between the kicker and the goalkeeper [5,16]. Recognizing that there is no one-size-fits-all strategy and individual players have their preferred run-up distance that enhances their performance [14], this system aims to provide personalized feedback. By focusing on these specific aspects, the sensor-based training system will be designed to provide targeted feedback and apply gamification elements to enhance players' engagement, thereby respecting the uniqueness of each player's penalty kicking technique.

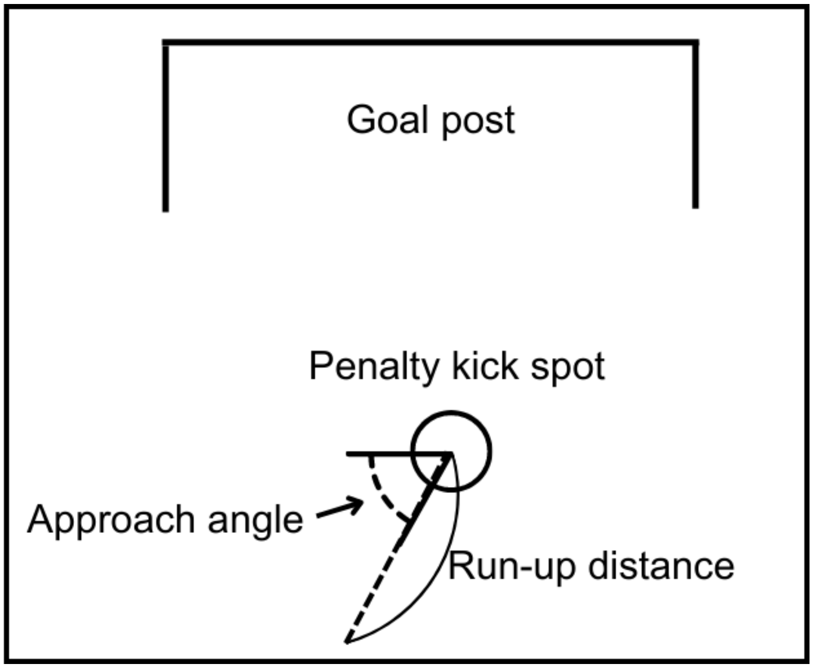

Figure 2. Approach angle and Run-up distance

1.3 Research Question

The following questions will be answered:

Research question:
"How can a sensor-based training system be implemented and evaluated to improve the accuracy of penalty kicks in an engaging way using gamification elements?"

Sub research questions:

- What specific physical and psychological factors affect the accuracy of penalty kicks?

Motivation: Understanding the factors that can influence the accuracy of penalty kicks is crucial to designing an effective training system. This sub-question aims to find physical (e.g.,run-up distance, approach angle), and psychological (e.g., player's stress level, focus) elements. This comprehensive understanding of factors will allow the training system to account for and address these variables, thereby improving the player's penalty kick accuracy.

- What methods of data collection and processing are most effective for providing real-time feedback to users during penalty kick training?

Motivation: Gathering relevant data and processing it in real time is key to providing immediate feedback to users. The type and accuracy of data collected can directly influence the effectiveness of feedback. This sub-question aims to identify and develop the most efficient and accurate methods of data collection and processing for real-time feedback during penalty kick training.

- What kind of feedback system can be implemented to provide immediate and effective feedback to the users during penalty kick training?

Motivation: Immediate and effective feedback is critical for improving performance in sports training. This sub-question aims to identify the most effective method for providing real-time feedback, allowing users to make timely adjustments to their performance.

- How can gamification elements be incorporated into the training system to motivate and engage users during penalty kick training?

Motivation: Gamification is a powerful tool to increase engagement and motivation in learning scenarios. This sub-question seeks to identify the most effective gamification elements that can be integrated into the training system to enhance user motivation and engagement.

2. Background Research

In this chapter, literature review first will be explored. Then, state of the art will be given.

2.1 Literature review

This section commences with an exploration of the literature, focusing on the various elements that determine penalty kick accuracy in soccer. Both physical and psychological factors are considered to provide an inclusive understanding of the complexities involved in a penalty kick. The narrative then shifts to the role and potential of sensor technology in sports training, underlining the importance of real-time data for enhancing performance. An examination of potential sensors that can be instrumental for this research project follows, demonstrating the array of technologies available. The chapter also sheds light on the concept of gamification in sports and its effectiveness in driving engagement and learning.

2.1.1 Factors that Affect Penalty Kick Accuracy

Penalty kicks are a crucial part of soccer, and training for them is necessary for players as they can often determine the outcome of a game. To ensure successful penalty kick training, it is important to understand the factors that impact accuracy. Many factors have been identified as influencing the accuracy of penalty kicks.

Psychological pressure

Psychological pressure is a critical element that influences the accuracy of penalty kicks. According to H. Woodward [11], soccer players experience anxiety during important matches, such as the World Cup, due to the fear of missing their penalty kick, which could lead to a decline in performance. Similarly, L. Arrondel et al. [7] discovered that the fear of losing and its accompanying anxiety could impact the success rate of penalty kicks, where the result of the game could pivot on a player's shot.

In addition to the players' own psychological stress, the goalkeeper's movements before the shot can also affect the shooter's mental state and, consequently, the accuracy of the penalty kick. A study conducted by G. Wood and M. R. Wilson [17] demonstrated that the goalkeeper's movements before the shot could cause anxiety and lack of focus in the players, increasing the chances of them kicking towards the middle, thereby reducing the success rate of the penalty kick.

In conclusion, recognizing the importance of psychological pressure and its practical impact on penalty kick accuracy is crucial. This understanding is particularly relevant in studies exploring the mental aspects of sports performance. While this project's primary objective is to improve technical skills for amateur soccer players during penalty kicks, the role of psychological elements cannot be overlooked. Although it is challenging to directly address these psychological factors in this context, acknowledging their influence lays a valuable groundwork for future research in this area.

Approach angle

The approach angle significantly influences the accuracy of penalty kicks. Research findings suggest a range of 'optimal' angles from 20° to 60° [4,5,6]. These variations stem from the different methodologies used in these studies or the diverse skills and styles of the players observed. For example, J. Scurr and B. Hall [4] suggests that the optimal angle of approach for penalty kicks is between 45° and 60°, while C. Lee [5] argues that an approach angle of 20~30° is ideal. Meanwhile, Majelan et al. [18] found no correlation between approach angle and the accuracy of penalty kicks. Notably, T. B. Andersen and H. C. Dörge [15] concluded that a self-selected approach angle brings optimal results in accuracy, which could suggest that individual player preferences and techniques affect the ideal approach angle. Understanding these diverse findings is crucial for the present research as it emphasizes the need for a personalized, interactive training system that can cater to each player's unique style and preference.

Speed and distance of the run-up

The speed and distance of the run-up are two pivotal factors that can influence the accuracy of penalty kicks. The run-up represents the distance a player covers before kicking the ball, and its speed can regulate the force exerted behind the shot [5]. During the run-up, there's a significant mental duel unfolding between the kicker and the goalkeeper, thereby amplifying the importance of the run-up phase of the penalty kick.

Existing research indicates that there might not be an optimal run-up speed or distance universally applicable to all players. However, it does suggest certain strategies that can increase a player's success rate. For instance, C. Lee [5] proposes that varying the run-up speed can disrupt the goalkeeper's timing, thus heightening the chances of scoring. Additionally, T. B. Andersen and H. C. Dörge [15] posits that a player's self-set approach speed can enhance the speed of the ball, underscoring the need for personalized training that accommodates the player's individual preferences and strengths.

Regarding run-up distance, striking a balance that caters to a player's ability to adjust their shot's direction while keeping the goalkeeper's anticipation at bay is vital. J. Van Der Kamp [16] asserts that a penalty kicker should not change their shot's direction based on the goalkeeper's movement, as it reduce accuracy, given it takes a minimum of 400ms for a player to alter the direction of their kick. This emphasizes the need for each player to discover a comfortable run-up distance that allows them to control the ball's direction, irrespective of the goalkeeper's movements.

Conversely, C. Lee [5] claims the advantage of shorter run-up distances as they reduce the time the goalkeeper has to gather information and predict the ball's trajectory. This suggestion is not contradictory but complementary to the advice from J. Van Der Kamp [16], as determining the optimal run-up distance should involve considering both the kicker's comfort and the time allowed for the goalkeeper. This emphasizes the need for finding and determining the run-up distance. With this perspective, players can adapt their strategies to maintain control over the shot's direction while keeping the goalkeeper guessing.

In conclusion, it is most important for players to find an optimal run-up distance that not only controls their run-up speed but also skillfully adjusts the direction and speed of the ball according to the goalkeeper's movement. This requires a deep understanding of the level of comfort in run-up distance. Therefore, in order to optimize penalty kick performance, it is essential for the new training system to provide constructive feedback focused on helping players identify the optimal run-up distance for their strengths and preferences. Based on this finding, this project aims to find the best run-up distance for individual amateur players.

2.1.2 Sensor Technology in Training

Sensor technology has become increasingly popular in sports training due to its ability to collect accurate and objective performance data. Sensors are now being used in various sports fields to help monitor athletes' training progress from winter sports such as skiing to summer sports such as soccer and kayaking [19]. Wearable sensors, in particular, provide real-time biofeedback on various aspects of movement, including speed, acceleration, and posture [12]. Such data allows athletes to identify areas of improvement and adjust their training accordingly.

Moreover, studies have shown that athletes in various sports and at different levels of experience are motivated by real-time data provided by sensors, leading to greater participation and adherence to training programs [12,20]. Real-time feedback can improve user experience and performance during exercise. Wearable sensor-based training systems can also provide a sense of fun and safety for participants, leading to increased participation rates [20]. Therefore the inclusion of real-time data provided by sensors is a way to make penalty training more engaging.

However, it is important to note that sensors used in training should be built to suit athletes' characteristics and not interfere with their performance [21]. Despite this, the use of sensor technology in sports training continues to grow in popularity due to its effectiveness in improving performance and training outcomes.

In conclusion, the use of sensor technology in sports training has provided athletes with valuable data for monitoring their performance and identifying areas for improvement. The real-time feedback provided by sensors has also been shown to motivate athletes and increase participation rates in training programs.

2.1.3 Sensors and Data for Measuring Penalty Kick Accuracy

Penalty kick accuracy can be influenced by a multitude of factors, and various types of sensors and data are used to monitor and improve this aspect of gameplay. The types of sensors and data can range from pressure sensors used for calculating the approach angle to heart rate sensors used for gauging a player's stress level. This section explores these various tools and their potential applications in penalty kick training. Starting with physical metrics, pressure sensors can be employed to calculate the approach angle. In addition, a pressure sensor can detect the ball when it hits the shoes. B. Zhou et al. [22] used fabric pressure sensors integrated with soccer shoes to detect the approaching angle and the impact between the players and the ball, as shown in ***Figure 3***.

Alongside physical metrics, understanding a player's psychological state is a crucial aspect of penalty kick training. Factors such as stress, anxiety, and psychological pressure can have significant impacts on a player's performance. Heart rate sensors provide a viable tool to track a player's stress level during training. Such wearable sensors can be seamlessly integrated into athletic wear for real-time monitoring [23].

Additionally, there are various sensors available to gauge a player's overall mental state. For instance, a portable electroencephalogram (EEG) is useful for observing brain signals in various sports. This can supply insights on how the brain reacts under different circumstances, thereby aiding in psychological training [24]. Cutting-edge devices like "EQ-Radio" developed by M. Zhao et al. [25], can discern a person's emotional state via wireless signals. By measuring slight variations in heart rate and breathing patterns, it can identify emotions such as happiness, excitement, anger, or sadness. This technology allows for an understanding of the psychological pressure experienced by players and can be used as a valuable feedback mechanism in training.

Ball speed is another factor for penalty kick accuracy. Athletes need to find the optimal ball speed with high accuracy. Accelerometer sensors can be utilized to estimate ball speed, and radar guns can be strategically placed behind the goal post to measure the same [26,27].

Furthermore, Data analysis and machine learning also play significant roles in penalty kick training. Through advanced algorithms, distinct types of penalty shots can be accurately classified [28]. This offers a granular understanding of the techniques and patterns associated with each type, enabling a more personalized approach to training.

Moreover, modern technology brings the potential of real-time tracking and feedback through video analysis. OpenCV, a tool primarily aimed at real-time computer vision, is of particular relevance in such scenarios [29]. It allows for the real-time tracking of a ball's movement during a penalty kick when recorded on video. Coaches and players can analyze these videos for a better understanding of a player's technique, providing immediate and precise feedback in training sessions.

In summary, the use of both physical and mental data can contribute to the observation and enhancement of penalty kick accuracy. The integration of sensor technology into training provides objective and precise data to identify areas for improvement, thereby aligning with the goals of projects focusing on the improvement of penalty kicks.

The pressure sensor will be used for this project. Considering the ability of the pressure sensor to detect objects, the pressure sensor will be attached to an obstacle and used.

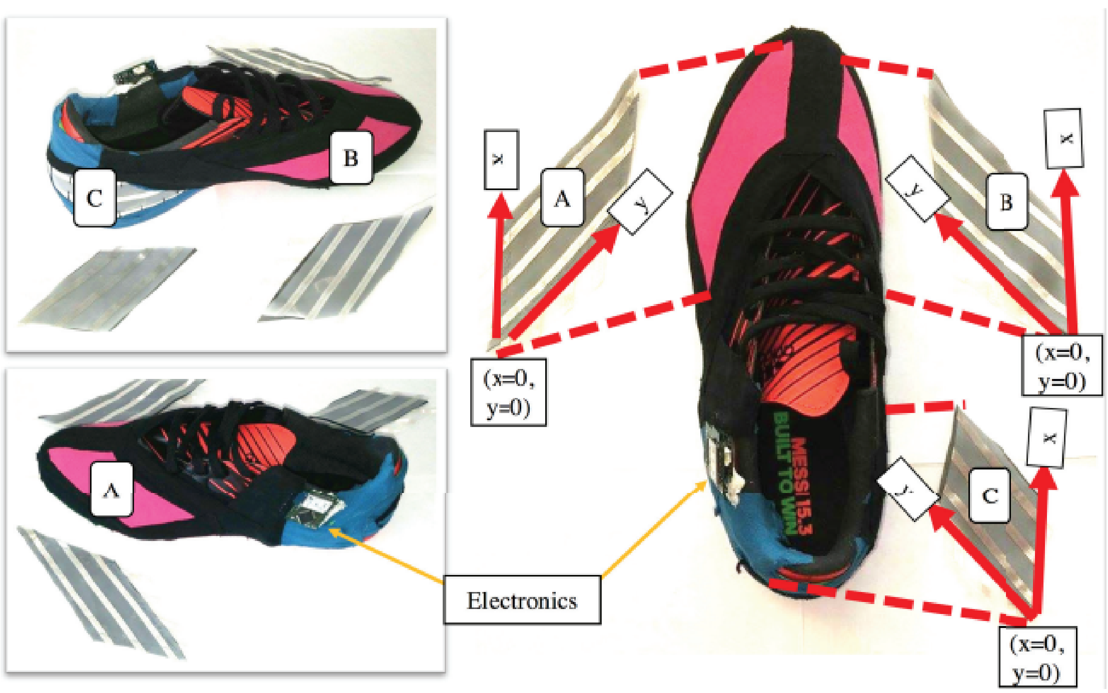

Figure 3. Instrumented shoe with dummy sensor patches on the side [22].

2.1.4 Gamification in Sport

Gamification has emerged as an effective tool to engage users in an enjoyable way [13]. While there is no universal definition of gamification, many researchers consider the definition from

Deterding et al. [30] as a standard [31,32]. According to Deterding et al.[30], gamification is the application of game design and elements in non-game contexts.

In sports training, gamification has been used to make training sessions more enjoyable and effective by incorporating game-like features such as points, levels, and rewards. Gamification helps to make repetitive and boring sports training fun, allowing athletes to engage more passionately in their training sessions. It is also effective when learning new skills or tactics in various sports [8].

A study has shown that gamification can increase motivation, particularly through extrinsic motivation, which is driven by external factors like rewards or goals. Common gamification elements in sports training include points, leaderboards, and challenges, which can make players more motivated to complete the task [14].

During the COVID-19 pandemic, gamification proved to be an effective solution for remote team sports training. A notable example is FC Barcelona's female team, which turned to gamified training sessions during the period of home confinement [33]. The coaching staff organized training sessions as if they were competitions, complete with leaderboards and various challenges, making each exercise a part of the "competition". This approach was designed not only to keep the players active but also to maintain social bonds within the team, making use of social networks, WhatsApp, Skype, and the HUDL tool for communication and coordination. The challenges were diverse and included conditional, technical, tactical, medical, nutritional, and psychological components, allowing every player to capitalize on their personal strengths. This innovative and adaptive gamified approach demonstrated the potential of gamification in maintaining team cohesion and competitive spirit, even during unforeseen circumstances such as the pandemic.

In conclusion, gamification is an innovative approach that has the potential to revolutionize sports training, making it more enjoyable and effective through the integration of game-like elements. The experience of FC Barcelona's female team during the COVID-19 pandemic illustrates how gamification can successfully maintain team cohesion and competitive spirit under challenging conditions. As the project aims to enhance the effectiveness and enjoyment of penalty kick training, the principles and practices of gamification can be immensely valuable. Implementing a system of rewards, challenges, and competitive elements into the training process increases engagement, motivation, and ultimately the performance of the players, which aligns with the project's objectives.

2.2 State of the art

This section discusses state-of-the-art technologies employed in soccer, with particular focus on those influencing penalty kick performance. Given the limited number of products directly associated with penalty kicks, the purpose of this review is to gain a comprehensive understanding of current technologies used in soccer training. This will identify areas of potential application in penalty kick training. The areas explored include ball tracking technology, virtual reality training, video analysis software, and wearable sensors.

2.2.1 Ball Tracking Technology: Hawk-Eye

Hawk-Eye Innovations, a Sony-owned company, provides ball tracking technology which has revolutionized the landscape of various sports, including soccer.

The Hawk-Eye system utilizes a network of high-speed cameras positioned strategically around the ground as shown in ***Figure 4***, generating a three-dimensional representation of the ball's trajectory. It processes thousands of images per second, with software algorithms analyzing the visual data and predicting the ball's path.

The Hawk-Eye system offers significant advantages such as detailed data on ball speed and trajectory, which can contribute to training and strategy development. However, while this data can help coaches and players refine their penalty kick techniques, it does not provide specific feedback on the approach angle and run-up distance of the players during the kick. This is one of the main focuses of this research, and as such, Hawk-Eye's current technology does not fully address this research needs.

Figure 4. The Hawk-Eye camera [34]

2.2.2 Virtual Reality Training: Beyond Sports

Beyond Sports, a Netherlands-based company, offers Virtual Reality (VR) solutions that transform soccer data into a game-like environment.

Using real match data, Beyond Sports generates a VR simulation that allows players to explore certain situations from their own perspective or that of others (***Figure 5***). This realistic simulation can help players familiarize themselves with different match scenarios, enhancing decision-making and strategic planning [35].

Beyond Sports' VR technology provides a unique and immersive training platform that allows players to experience the high-pressure environment of penalty shootouts. It is advantageous as it enhances decision-making and strategic planning. However, like Hawk-Eye, it also does not offer direct guidance or feedback on optimizing the approach angle and run-up distance, which is the primary concern of our research. Thus, while this technology offers significant advantages in other areas of football training, it is insufficient to address the specific needs of this project.

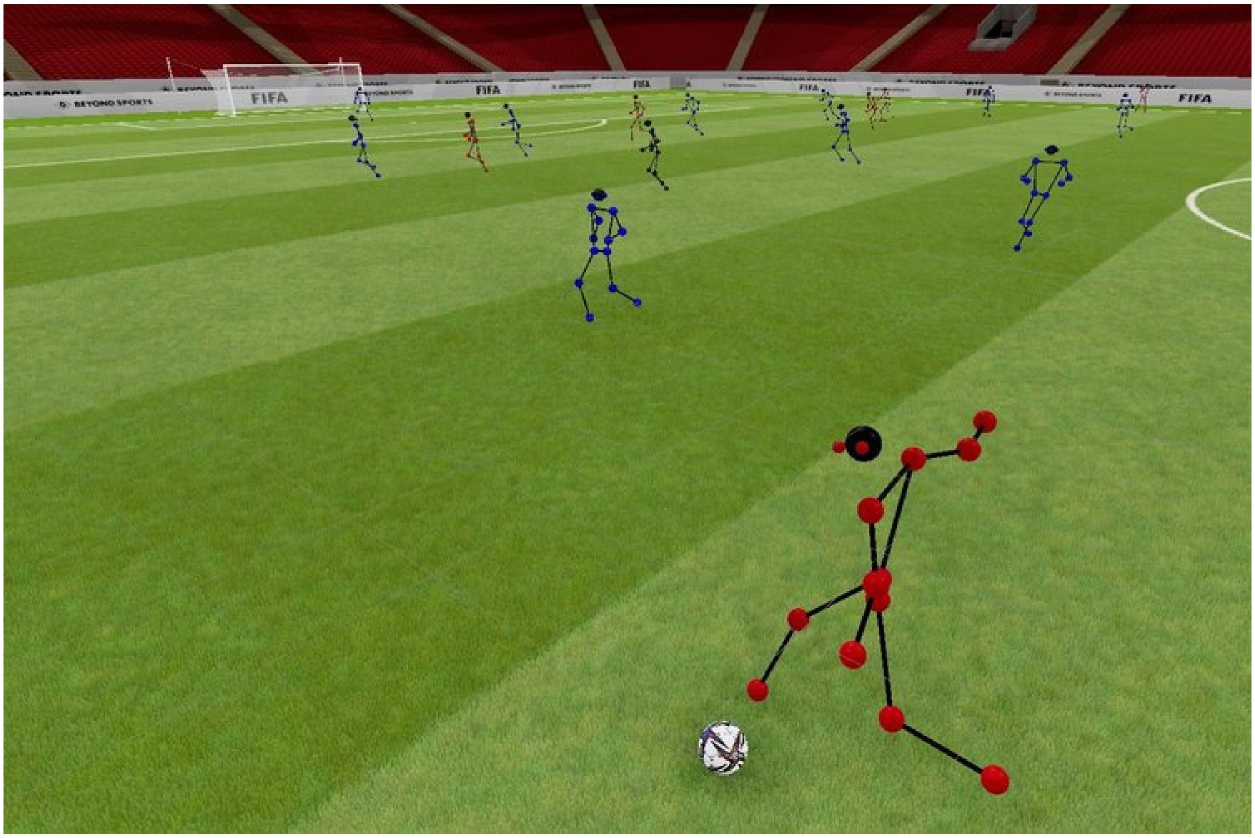

Figure 5. Beyond Sport - VR simulation [35]

2.2.3 Video Analysis Software: Wyscout

Wyscout is a comprehensive tool for soccer video analysis and scouting.

The platform (***Figure 6)*** allows detailed examination of matches, with the ability to focus on specific instances, players, or actions. Coaches, players, and analysts can review and annotate videos, providing a collaborative platform for team discussions and strategy planning.

For penalty kicks, Wyscout provides a valuable tool for studying both team and enemy. Players can observe patterns in the goalkeeper's behavior, player's preferred placement. By learning from historical successes and failures, teams can refine their penalty strategies and increase their chance of success in future shootouts [36].

Figure 6. Wyscout platform [36]

2.2.4 Wearable Sensors: Zepp Football Sensor

The Zepp Football tracking sensor, produced by Zepp Labs, is a wearable designed specifically for soccer.

Figure 7 shows Zepp Football Sensor. Mounted onto the player's calf sleeve, it collects data about the player's kicks, including impact, foot placement, and leg swing. It works alongside a mobile application, which provides visual data analysis and even personalized training tips based on the recorded data.

With Zepp's detailed analysis of each kick, players and coaches can optimize penalty kick techniques, making necessary adjustments to factors like foot placement, swing speed, or impact point, thereby improving overall penalty success rate [37].

Figure 7. Zepp Football Sensor [37]

2.3 Conclusion and Discussion

The literature review focused on four primary areas: factors affecting penalty kick accuracy in soccer, the role of sensor technology in sports training, the specific sensors and data used for measuring penalty kick accuracy, and the application of gamification in sport. These interrelated aspects are crucial for the research project's development, which aims to design a sensor-based, gamified training system for improving penalty kick performance in soccer.

Understanding the factors that affect penalty kick accuracy is essential. Elements such as psychological pressure, approach angle, and speed and distance of the run-up can significantly determine penalty kick success. Each player's unique response to these factors suggests that personalized training methods yield the best results. This concept aligns with the research project's goal of offering an interactive training platform.

Sensor technology has a fundamental role in sports training, demonstrated by its increasing use to improve performance and training outcomes. By providing precise, real-time data to athletes, these technologies allow for targeted improvement. Wearable sensors offer real-time biofeedback on various aspects of movement, which is integral for the development of a customized training system. The potential of sensor technology to enhance the user experience and comply with training programs is paramount to the success of the project.

Identifying and using the right sensors and data to measure penalty kick accuracy is central to the research project. Various sensors, including pressure sensors, heart rate monitors, EEG devices, accelerometer sensors, radar guns, and video analysis, have the potential to provide a broad spectrum of data for a comprehensive understanding of a player's performance. While not every sensor will be employed in the project, this review underscores the potential variety and scope of sensor technology, contributing to the ideation process.

Gamification, with its proven potential to engage users and promote learning, is another essential component. Implementing game elements such as points, challenges, and leaderboards can enhance player motivation and engagement. The experience of FC Barcelona's female team during lockdown conditions demonstrated the immense potential of gamified training in fostering team cohesion, competition, and motivation. This reinforces the importance of adding gamification elements to this project.

In conclusion, the information obtained from the literature review highlights the importance of a personalized, sensor-based, gamified approach to improving penalty kick accuracy in soccer. These results show the need for various sensor technologies and data, along with the use of gamification to improve player engagement and learning. The research project, by merging these elements, proposes to provide an innovative solution for penalty kick performance improvement.

The literature review focused on four primary areas: factors affecting penalty kick accuracy in soccer, the role of sensor technology in sports training, specific sensors, and data used for measuring penalty kick accuracy, and the application of gamification in sport.

The variety of technologies reviewed in relation to state-of-the-art penalty kicks emphasizes the unique benefits each can offer. However, these technologies do not provide direct solutions for the issues this project aims to address. Specifically, this project focuses on improving penalty kicks by considering the approach angle and run-up distance, aspects not explicitly addressed by the technologies detailed in section 2.2.

In conclusion, while current technologies offer exciting advancements in soccer training, a gap remains in providing direct, actionable feedback on improving penalty kick performance through optimizing approach angle and run-up distance. This project seeks to fill that gap, offering a novel solution to this specific, yet critical aspect of soccer training.

3. Methods and Techniques

This chapter presents the design methodology and techniques employed in this project. It begins with a description of the chosen design method and provides a brief overview of how the project adheres to each step of the design method. The techniques used in each phase are also explained.

3.1 Design Method

The Creative Technology Design Process (CTDP) developed by Mader [38] serves as the design method for this project. The CTDP, illustrated in ***Figure 8***, comprises four main phases: ideation, specification, realization, and evaluation.
The first phase, ideation, involves discussing user needs and stakeholder requirements, generating creative ideas, and identifying suitable technologies for the project. The second phase, specification, encompasses proposing and evaluating various prototypes with user feedback to develop a refined prototype. This phase also involves collecting functional and non-functional requirements. The realization phase follows, detailing the actual creation of the prototypes proposed in the specification. Finally, the evaluation phase verifies whether the final product meets the requirements discussed during the ideation phase. This include conducting user tests and refining the final prototype as needed.

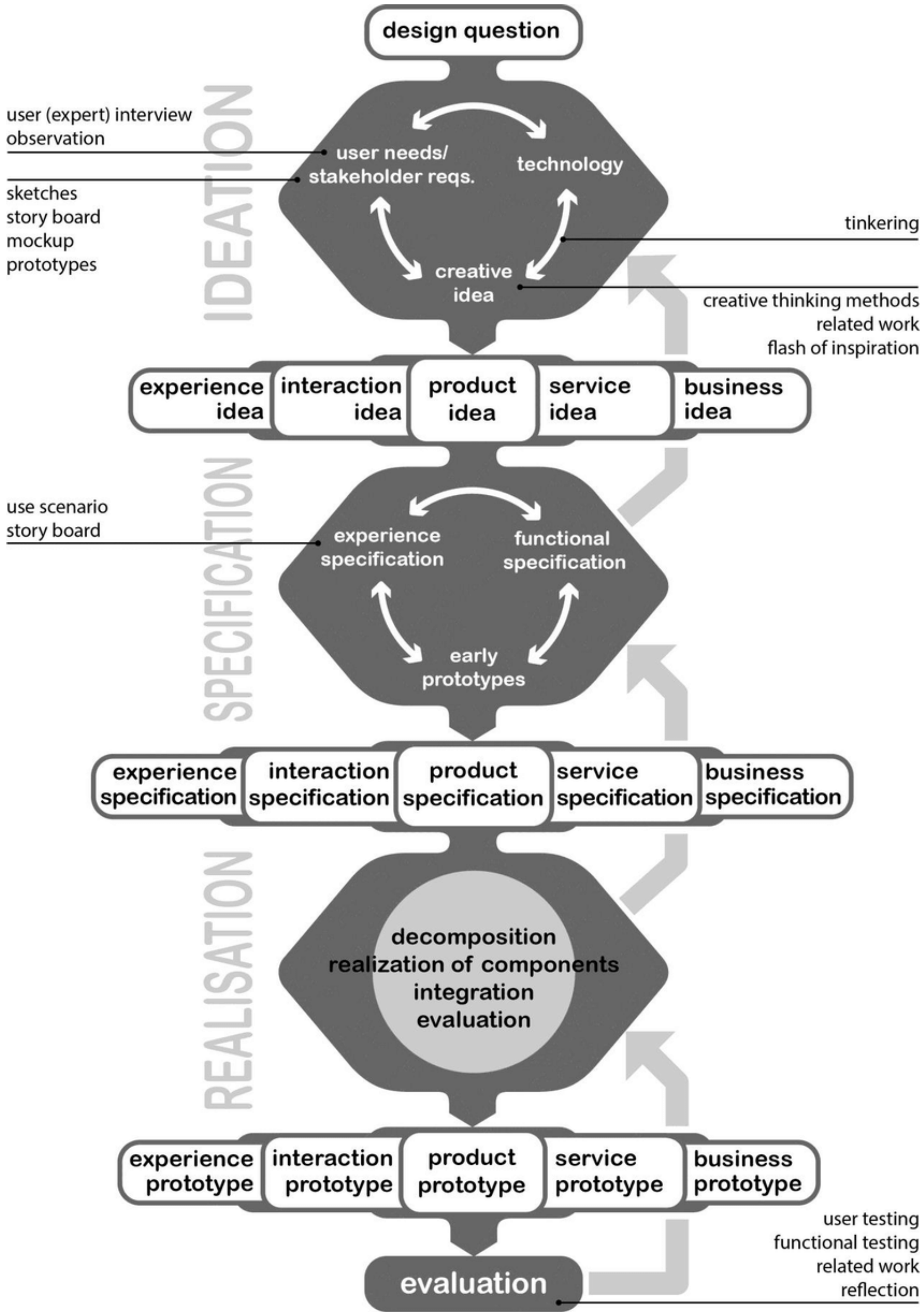

Figure 8. A Creative Technology Design Process [38]

3.1.1 Ideation

The ideation phase of this project commenced with stakeholder identification and analysis. For stakeholder analysis, a power versus interest matrix was utilized [45]. Stakeholder requirements were outlined, and a wealth of potential ideas was brainstormed using the Osborn-Parnes Creative Problem Solving (CPS) process [39]. This method is a structured approach to brainstorming, encouraging the generation of innovative ideas by focusing on divergent and convergent thinking phases [39]. This approach aids in identifying a broad range of potential ideas, selecting the most promising ones, and refining them to maximize their effectiveness.

User-centered design is a design philosophy that places the user's needs at the center of the design process, thereby ensuring that the product is not only functional but also user-friendly and meets stakeholder requirements [40]. As such, user needs and feedback were incorporated in brainstorming sessions, and the project's specifications were refined accordingly.

Finally, suitable technologies for the project were selected. The most appropriate concept was chosen with consideration of the available technology and the requirements identified during this ideation phase.

3.1.2 Specification

During the specification phase, personas and interaction scenarios will be created to gain insights and identify areas of improvement. At this stage, a low-fidelity (lo-fi) prototype will be developed using a design tool called ProtoPie [41] to make general rules of the game and evaluate the concept. This prototype presents the layout and functionality of six game screens, enabling users to engage with the application in a manner that closely simulates real-world usage.

Following the creation of the lo-fi prototype, a lo-fi test will be conducted with the participation of 3 random individuals. This test will be a scenario based user interview. The interaction scenarios will be provided to participants for better understanding of users. The feedback and interaction with the app from users shape the definition of the functional requirements. Stakeholder requirements, requirements from background research, and requirements gathered from user testing will then be compared to compile a final list of requirements for the prototype.

The list of requirements is organized using the MoSCoW method [42]. This method categorizes requirements into four groups: Must have, Should have, Could have, and Won't have. The Must have category includes essential requirements for the project. The Should have category consists of elements that can improve the quality of the product but are not crucial. The Could have category contains less critical elements, and the Won't have category includes items that should not be incorporated into the final product. The benefit of using the MoSCoW method is that it helps prioritize the different elements of the project, ensuring the most critical aspects are addressed first. However, the challenge with this method is that it requires a clear understanding of the project's objectives and user needs, as incorrect categorization of requirements could affect the overall success of the project.

3.1.3 Realisation

The proposed idea from the specification phase will be developed into a high-fidelity (hi-fi) prototype. The system architecture of the hi-fi prototype will be explained first. Then, the hardware and software used in the hi-fi prototype will be explained. Then, the final prototype will be explained with figures and the functional requirements will be reviewed.

3.1.4 Evaluation

The evaluation phase incorporates user testing to assess the prototype's effectiveness and usability. A central part of this phase is observation, where participants are encouraged to interact with the game. Observation, often utilized in user experience research, enables the researcher to document user behavior and pinpoint any areas of difficulty or confusion [43]. Additionally, a statistical table is used to track each participant's in-game data. This data will then be analyzed to evaluate if users are able to effectively receive feedback and demonstrate progress in their penalty kick performance after using feedback given. After that, semi-structured interviews [44] will be conducted to evaluate players' experiences of game rules, effectiveness of feedback, enjoyment factors, and skill improvement based on feedback.

4. Ideation

4.1 Stakeholders

4.1.1 Stakeholders identification

Table 1 shows five main stakeholders and their roles.

Stakeholder	**Role**
Designer	Develops the soccer training system
Supervisor	Provides guidance and feedback during the development process
Soccer players	Use the system to improve their soccer skills
Soccer coaches	Use the system to train and evaluate their players
Soccer clubs / organizations	May purchase and implement the system for their teams and players

Table 1. Stakeholders identification

4.1.2 Stakeholders analysis

The power-interest matrix (Ch 3.1.1) is used to analyze five stakeholders. ***Figure 9*** shows the power-interest matrix with 5 stakeholders which are developer, supervisor, soccer players, soccer coaches and soccer clubs/organizations.

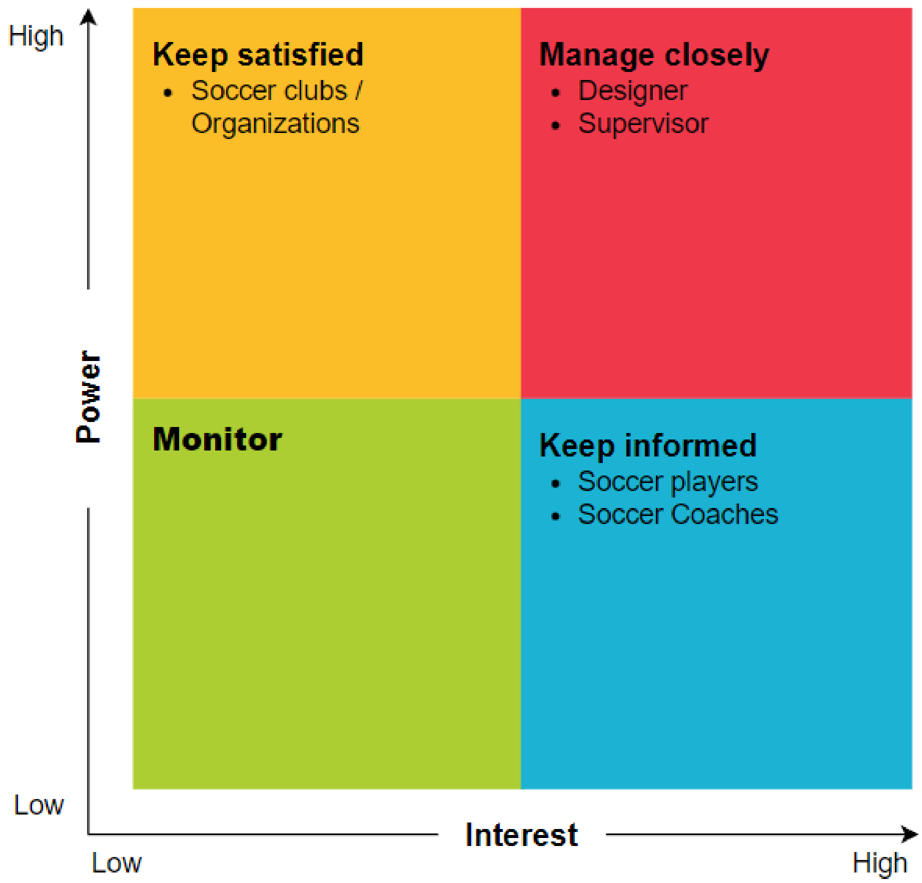

Figure 9. Power-Interest Matrix with Stakeholders

4.1.2.1 Designer

As the designer, Wonjun Jung is responsible for developing the sensor system concept, incorporating stakeholder requirements, and ensuring the project's success. Wonjun Jung will collaborate with the supervisor and gather feedback from end-users and other stakeholders during the design process. In the Power-Interest Matrix, Wonjun Jung falls into the High Interest/High Power category. As the person primarily responsible for the product's development, his power and interest in the project's outcome are significant.

4.1.2.2 Supervisor

Max Slutter and Mannes Poel will provide guidance and expertise throughout the project. They will review the progress, offer suggestions, and ensure that the project meets academic requirements. Within the Power-Interest Matrix, supervisors occupy the High Interest/High

Power quadrant due to their vital role in decision-making processes and vested interest in the project's success.

4.1.2.3 Soccer Players (End-Users)

Amateur soccer players are the primary end-users of the training method. Their feedback and requirements are crucial in designing a system that effectively improves penalty kick accuracy and meets their specific needs. Soccer players fall into the High Interest/Low Power quadrant in the Power-Interest Matrix. Although they lack the power to influence the project directly, their interest in the system's functionality is substantial.

4.1.2.4 Soccer Coaches

Soccer coaches play a vital role in implementing the sensor-based system during training sessions. Their expertise in soccer training techniques will help shape the system's design, ensuring it complements existing training methods. In terms of the Power-Interest Matrix, soccer coaches could be placed in the High Interest/Medium Power quadrant. They have substantial interest in the system's effectiveness, and depending on their relationship with the club, they can exert influence over the project.

4.1.2.5 Soccer Clubs/Organizations

Soccer clubs and organizations may invest in and adopt the sensor-based system to improve their players' performance. They can provide valuable input regarding the practicality and usability of the system, as well as any specific requirements or constraints. In the Power-Interest Matrix, soccer clubs/organizations fall into the Medium Interest/High Power quadrant. They possess significant power as they are the entities implementing the system but have varying levels of interest depending on their specific needs and circumstances.

4.1.3 Stakeholders requirements

To design a product that effectively meets user needs, a clear understanding of stakeholder requirements is crucial. This understanding has been shaped through a survey and in-depth conversations with five individuals with significant experience in the soccer community.These requirements have been prioritized using the MoSCoW method, a widely recognized technique for categorizing requirements by their level of importance and urgency. ***Table 2*** shows stakeholders requirements.

Category	Requirements	Explanation
Must	Improvement of penalty kick accuracy	The training should contribute to the user's penalty kick performance
Must	Measurement of elements that affect penalty kick performance (e.g., approaching angle, run-up distance, and speed)	Vital for identifying the optimal run-up conditions
Must	Provision of real-time feedback and performance analysis	Essential for enabling players to understand their performance and make immediate improvements
Must	Integration of gamification elements for motivation	Since it's a game, it should include elements that enhance player engagement and motivation
Must	Visual feedback for performance	Users can more easily comprehend visual feedback
Should	Applicability to various skill levels and age groups	Allows for broader usage and inclusivity

Could	Creation of a competitive atmosphere among players	Could enhance motivation and stimulate improvement
Could	Support for different field environments, such as indoor and outdoor training sessions	Allows users to utilize this training method in any location

Table 2. Stakeholders requirements

4.2 Ideas

A total of 4 ideas were generated through a self brainstorming session with the application of the Creative Problem Solving (CPS) process and user-centered design principles from chapter 3.1.1.

4.2.1 Carnival shooting game

The soccer shooting game is inspired by the carnival dart board game. Multiple obstacles with pressure sensors embedded in them are installed on the goalpost. The sensors are designed to detect the pressure changes caused by the ball hitting the obstacle.

To play the game, the player has 10 chances to hit as many randomly illuminated obstacles as possible. When the player kicks the ball and hits an obstacle, the pressure sensor in that obstacle detects the pressure changes caused by the ball and transmits the data to the computer system for analysis. The computer analyzes the pressure data and assigns points to the player based on their accuracy.

To incorporate run-up distance, a measuring device could be placed on the ground to track the player's running speed and distance before taking the shot. The device could be connected to the computer system that collects and analyzes the pressure data from the sensors on the obstacles. The computer can then provide feedback on the player's performance, including their accuracy, run-up speed, and distance, to help them improve their technique.

Each game will be played from a specific angle, and the final score will be displayed on the leaderboard. The leaderboard will show the players' rankings based on their scores, creating a competitive atmosphere and motivating players to improve their performance.

Overall, this idea could provide a fun and interactive way for soccer players to train their accuracy and improve their run-up speed and distance.

4.2.2 Monitoring application

The goal of this training system is to help soccer players find their optimal approaching angle and run-up speed and distance for penalty kicks. A large angle meter will be installed at the penalty kick location, which will allow players to view their approaching angle in real-time. Before kicking the ball, players will input their approaching angle into the app and press a button. The distance sensor will measure the player's run-up distance and count the time until the player kicks the ball. The success or failure of the kick will also be recorded in the app.

After several attempts, the app will display the success rate for each approaching angle and run-up distance on a graph, allowing players to easily see which combination of angle and distance is most effective for them. They can also share their results with friends to compare and compete with each other.

The system will use distance sensors to measure the distance between the ball and the player before the kick, but it will not track the ball's position during the kick. Instead, the success or failure of the kick will be input directly into the app.

4.2.3 Virtual Reality Training System

The Virtual Reality (VR) training system leverages immersive technology to help soccer players improve their approaching angle, run-up distance, and speed for penalty kicks. Players wear a VR headset, which simulates a realistic soccer field environment, including the goalpost and a virtual goalkeeper. In this virtual environment, the players can practice penalty kicks from various angles and distances, adjusting their run-up speed and distance as needed.

The VR system utilizes motion tracking sensors to monitor and analyze the players' movements, providing real-time feedback on their approaching angle, run-up distance, and speed. The system can also calculate the ball trajectory and its landing position within the goal, allowing players to assess their performance and make adjustments. The VR training system offers a safe, controlled environment for players and receive immediate feedback on their performance, ultimately improving their penalty kick skills.

4.2.4 OpenCV-based Penalty Kick Analysis and Training System

An OpenCV-based penalty kick analysis and training system can be developed to help players improve their approaching angle, run-up distance, and speed during penalty kick training. By using computer vision techniques and algorithms, the system can analyze real-time or recorded video footage of a player's performance during penalty kick practice sessions.

To implement this system, multiple cameras would be set up around the goal and penalty kick area, capturing different angles and perspectives. The captured video footage would be processed using OpenCV, a popular open-source computer vision library, to track the player's movements, the ball's trajectory, and other relevant parameters such as approaching angle, run-up distance, and speed.

The processed data can then be sent to a connected computer or smartphone application for further analysis and feedback. The application can provide real-time visual feedback and recommendations, helping players optimize their penalty kick technique. Additionally, the app can incorporate gamification elements, such as challenges, levels, and leaderboards, to motivate players to improve their performance.

4.3 Final idea

Taking into account the ideas produced in Section 4.2 and the stakeholder requirements specified in Section 4.1.3, the Carnival Shooting Game (4.2.1) has been selected as the final concept for this project. This concept not only tackles essential factors influencing penalty kick performance such as the approach angle and run-up distance, as discussed in Section 2, but also affords flexibility in incorporating various sensors and gamification elements. Moreover, it aligns with the project's objectives by providing a novel and interactive way for football players to enhance their penalty kick precision, run-up speed, and distance.

Figure 10 shows the initial design of the selected concept. The Carnival Shooting Game involves multiple pressure-sensitive obstacles mounted on the goalpost. These obstacles are programmed to detect pressure changes when struck by the soccer ball. Within a set number of tries, players are tasked to hit as many randomly lit obstacles as possible. This offers an exciting challenge while also providing a practical application, as it helps players find the most effective approach angle for their penalty kicks. The assignment of points based on hit accuracy introduces an element of competition and provides a measurable method of gauging performance.

With each round, players are given a designated approaching angle and asked to target the obstacles from this angle. This not only makes the game more challenging but also allows for more targeted training on penalty kicks from various angles. Additionally, the players receive real-time feedback on their performance, specifically their run-up distance and approach angle. This information is valuable as it can guide players in fine-tuning their strategies to improve their penalty kick skills.

To promote a competitive atmosphere, a point system is incorporated into the game. This system assigns points based on hit accuracy, fostering motivation for continuous performance enhancement. This competitive aspect does more than offer entertainment; it simulates the pressure of actual match situations, aiding players to adapt and perform optimally under stress.

The Carnival Shooting Game concept is versatile enough to be adjusted to suit various skill levels and age groups, fulfilling the needs of a broad user base. The adaptability of the design increases the potential of the concept as a universally accepted and advantageous training tool for football enthusiasts across all ages and capabilities.

Given these considerations, the Carnival Shooting Game has been chosen as the final concept for this project. The next stages will focus on how feedback will be provided to users, the types of sensors to be used, the game screen design, and the specifics of the game rules. Furthermore, strategies for assessing the effectiveness and efficiency of the concept in improving penalty kick performance will be developed.

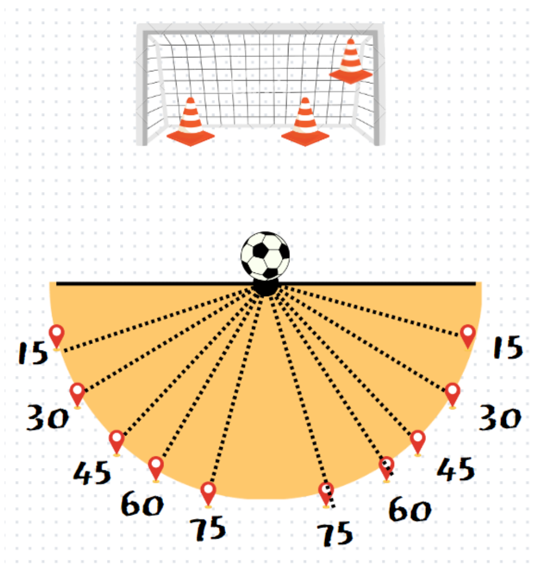

Figure 10. Initial design of carnival shooting game

5. Specification

5.1 Lo-fi prototype

A low-fidelity (lo-fi) prototype is made using a design tool called ProtoPie [41]. This prototype showcases the layout and functionality of five game screens. These game screens can be shown in ***figure 11***. The content in figure 11 is created from a brainstorming session of ideation phase. With ProtoPie, users can engage with these screens in a way that mimics real game experience. This early interaction provides valuable insight into the user experience and the design of the app, helping to refine and improve application. ***Table 3*** presents an overview of the five main screens included in the game's prototype, created using ProtoPie. Each screen has a unique purpose and functionality to guide the user through the game effectively.

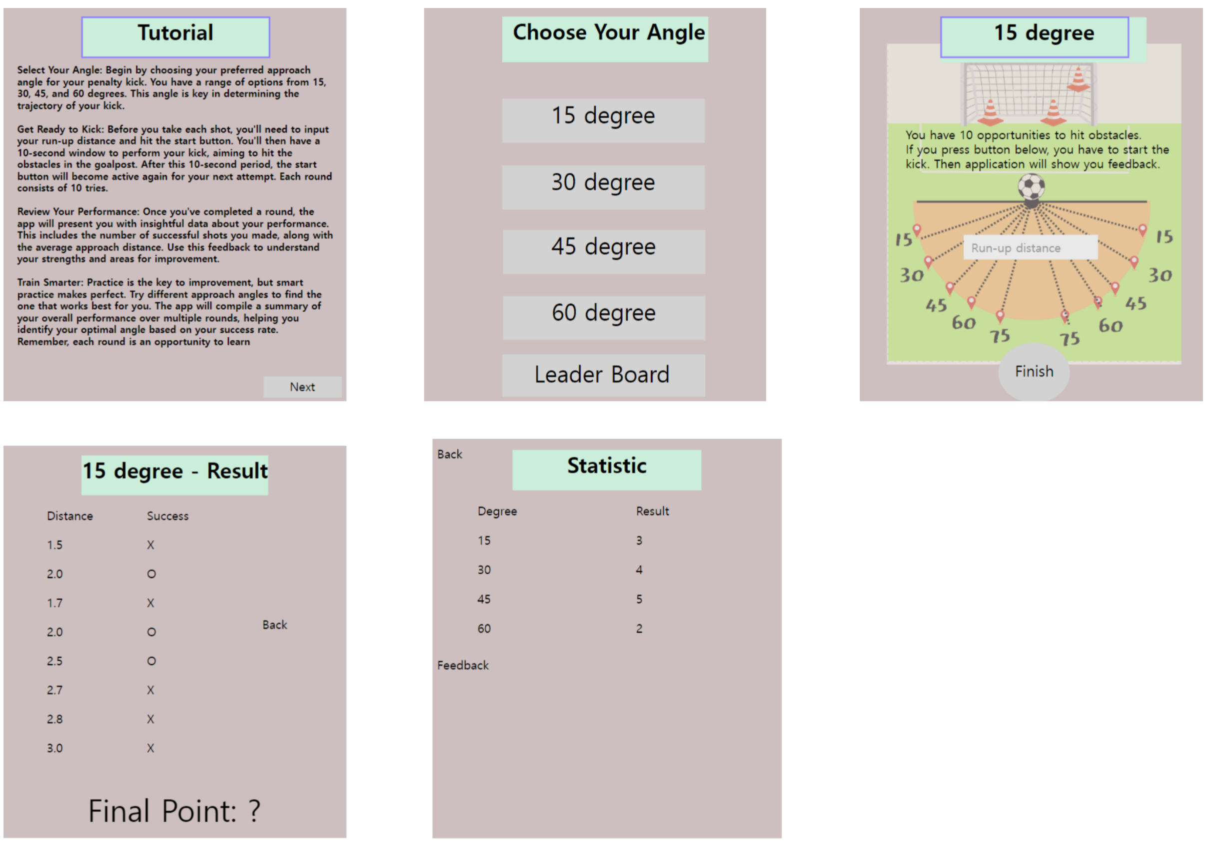

Figure 11. game screens of initial idea

Screen Name	Description
Tutorial	Designed to help first-time users understand the game mechanics. It explains how to enter the run-up distance, navigate the game, and interpret the feedback and statistics provided after each round. The objective of hitting the obstacles in the goalpost during each shot is emphasized.
Angle Selection	This screen presents users with the option to choose their preferred approach angle for the penalty kick. The available options are 15, 30, 45, and 60 degrees, each associated with different performance outcomes. Based on a literature review, optimal approach angles for penalty kicks are found to range between 20 and 60 degrees. However, due to the constraints of this project, it's not feasible to offer every possible angle within this range for selection. Each selected angle warrants a separate round of play, and having numerous rounds would be difficult to manage given the time limitations of this project. Therefore, it is chosen to provide angle options at 15-degree increments, offering a reasonable spread within the optimal range. This approach balances user experience, game pacing, and instructional value, ensuring that the application remains both fun and effective.
Action Phase	This screen transitions the user from the setup to the actual gameplay. Here, users enter their run-up distance and press the start button to initiate the 10-second shot window. During this window, the user attempts to hit as many obstacles in the goalpost as possible. After 10 attempts, the session ends.
Results	The results screen appears after each round. It displays the number of successful shots made by the user and the average approach distance for that round. Designed to provide immediate feedback on the user's performance, this screen encourages them to improve in subsequent rounds.

Statistics with Feedback	This screen provides a comprehensive summary of the user's performance across multiple rounds. It presents a more detailed view of the approach angles, successful shots, and average distances. The aim of this screen is to offer valuable insights into the user's performance trends and patterns, assisting them in identifying the optimal angle for their playing style and areas for improvement.

Table 3. Name of game screens and description

5.2 Lo-fi test

Participants were first provided with an oral explanation of the basic game concept. They were then shown the game screens, with detailed explanations on what actions are expected at each stage. The lack of a physical prototype for a realistic simulation of the penalty kick led to a strategy where participants were encouraged to imagine playing the game. After exposure to the tutorial screen, gameplay screen, and results and statistics screen, participants were asked a series of questions about their experiences. Once the game simulation was over, a set of general questions was posed to understand their overall experience. All questions and responses are documented in ***Table 4***.

5.2.1 Test result

Firstly, in the tutorial phase, participants were asked about their understanding of the game mechanism and whether they found the illustration on the Start screen to be engaging. Most participants appreciated the simplicity and clarity of the graphics. However, a common suggestion was to make the tutorial explanation more concise to hold user engagement.

During the action phase, participants were asked to imagine the game play based on the design and then asked about their preferences regarding the size of obstacles, the number of obstacles, type of the feedback, time duration to take one penalty kick, and where to place obstacles in the goal post. These preferences were crucial to shaping the game's main concepts in a balanced and fair manner. Feedback varied, showing differing user preferences, which indicates the potential to include customizable settings for the number and size of obstacles. Also, while there were mixed opinions on whether points should differ for each obstacle, the majority suggested keeping the points equal to focus on the skill of taking penalty kicks. Most participants agreed that around 10-15 seconds would be sufficient for each attempt. All participants answered that they had difficulty tracking their progress and performance during game play. In other words, it means that there needs to be some elements that show game progress such as time slider bar and current point.

When asked about the Results and Statistics screen, participants expressed a desire for more detailed statistics, such as ranking among other players and progress over time. They mentioned that the graphical feedback is appropriate to understand the approaching angle and run-up distance.

Lastly, participants were inquired about the key strengths and weaknesses of the game. They identified the innovative integration of physical activity with gaming as a strong point. Moreover, the real-time feedback mechanism was praised for its contribution to improving skills. However, they suggested that the tutorial be more concise and that there could be more customizable options for obstacles. In terms of usefulness, participants agreed that the system was beneficial for enhancing penalty kick skills, with the use of gathered feedback.

Questions	Participant 1	Participant 2	Participant 3
Do you find the illustration on the Start screen understandable and engaging?	Yes, the design is simple and clear.	Yes.	Yes, the graphics are engaging.
Is the game mechanism clear to you after reading through the tutorial explanation?	Yes, it was understandable	It was too long to read.	Yes, it was easy to understand but too long.

Are you able to grasp the objective of the game through the tutorial?	Yes	Yes, but I had to read it twice.	Yes, it was clearly explained.
How many obstacles are appropriate and how large should they be?	2~3 obstacles will be enough, the size should not be too small.	The number of obstacles should be adjusted based on the size of them. I think it would be enough if every obstacle took up more than half of the goalpost	Since it's a game for beginners, I think about three would be appropriate. It needs to be easy to hit, so I think it'll be about the size of a sofa cushion
Should the points awarded differ for each obstacle?	Yes, it could make the game more interesting. The point for each obstacle could be different based on the size of obstacles.	No, since evaluating penalty performance and improving it is the main goal, equal scoring of all obstacles is likely to reduce the luck factor	No, I think it should be the same for all obstacles.
What should be the criterion for obstacle placement?	I think it should be random to keep it interesting.	It should be based on difficulty levels. Or users can place it themselves where they want	I think it should be based on the skill level of the player. It would be nice if the user can place it.

How much time do you think should be given for each kick attempt?	10 seconds seems enough.	Maybe 15 seconds would be better.	I think 10 seconds is sufficient.
What type of feedback is appropriate for understanding the best approach angle and run-up distance?	Graphical feedback	Graph with statistics above	Visual feedback like graphs or bar chart
What is the key strong point of the game?	The innovative concept of combining a physical activity with a game.	The real-time feedback mechanism is great for improving skills.	The game is both educational and fun.
What is the weak point of the game?	The tutorial was a bit long.	The game might benefit from more varied difficulty levels.	The number and size of obstacles could be more customizable.
Do you believe this system is useful for improving penalty kick skills?	Yes, it provides a fun and engaging way to practice.	Yes, especially with the immediate feedback provided.	Yes, finding my best condition for penalty kick is useful.
What aspect of the game did you find the most enjoyable?	The challenge of hitting obstacles.	The real-time feedback and tracking my improvement over time.	The mix of physical activity and gaming.

Table 4. Interview questions and answers

5.2.2 Discussion and Implication

Insights gathered from the Lo-fi user testing provide crucial guidance for the further development and refinement of the gaming experience. User feedback not only validated the initial game concept but also revealed several areas in need of improvement. This encompassed adjustments to the overall game rules such as the number of obstacles, the point system, and the cool-down period for each kick.

Proposed Enhancements based on User Feedback:

1. Number of obstacles: The number of obstacles will vary based on difficulty level, as suggested by users. This will be addressed by introducing three difficulty levels (easy, intermediate, and hard). As the difficulty level increases, the number of obstacles will decrease, thereby scaling the challenge according to the player's skills.

2. Points per obstacle: Feedback suggested maintaining consistent points for all obstacles, since the difficulty level would be adjusted by altering the number of obstacles. However, if the size of the obstacles differs, different point allocations could be considered.

3. Placement of obstacles: Users will have the freedom to place obstacles according to their preference, allowing a more personalized gaming experience.

4. Time to take a penalty: In line with the feedback received for the time allotted for each kick, a duration of 10-15 seconds is considered adequate for each penalty kick attempt.

5. Feeling of improvement: A common sentiment among participants was the usefulness of the game in improving penalty kick skills. This was largely attributed to the real-time feedback mechanism. Therefore, the game will continue to emphasize this feature, providing immediate feedback to players to facilitate skill improvement.

6. Key strong and weak points: Participants appreciated the innovative concept of combining physical activity with gaming and the game's educational value. However,

feedback pointed to the need for more customizable difficulty levels and obstacles size and numbers. These suggestions will be incorporated into future game enhancements.

7. Enjoyment: Participants found the challenge of hitting obstacles and the mix of physical activity and gaming enjoyable. The real-time feedback mechanism and tracking improvements over time were also highly appreciated. To maintain this level of enjoyment, the game will continue to focus on these elements.

By implementing these improvements, the expectation is to deliver a more engaging and user-friendly game experience in future iterations.

5.3 Personas

This section introduces four personas in line with a user-centered design approach. These personas represent a range of potential users for the penalty kick training application, each embodying varying levels of interest, experience, and skill. By considering these diverse user profiles, a more comprehensive understanding of the application's usability can be achieved. Subsequently, in Section 5.2, interaction scenarios will be crafted based on these personas. This persona-driven approach enhances the application's design, making it more user-friendly and versatile, thereby catering to a wider user base.

5.3.1 John

Figure 12 shows one of the personas whose name is John. John represents one of possible future users that is a beginner of soccer and eager to play the game. He wants to enjoy the game rather than improving his penalty kick skills.

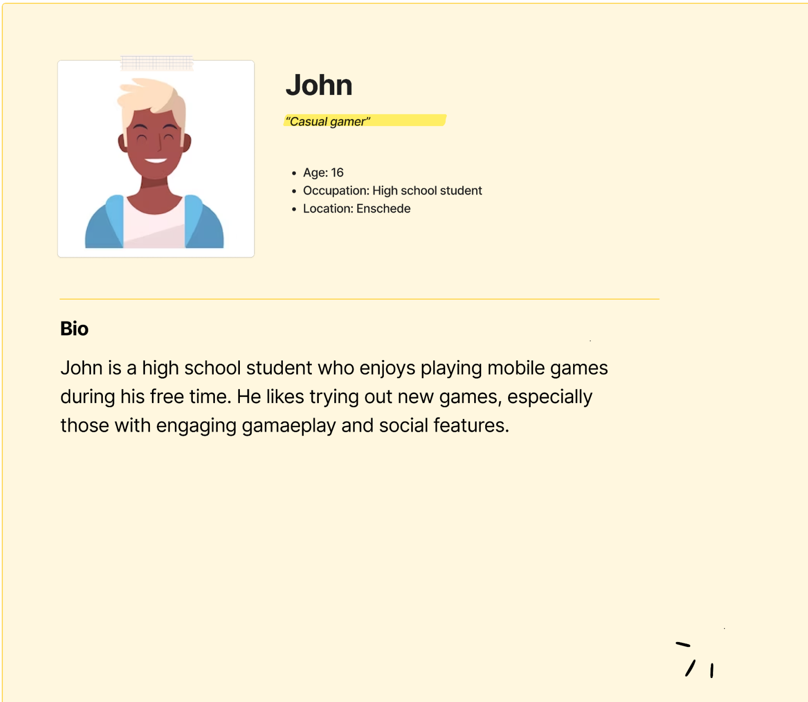

Figure 12. John

5.3.2 Laura

Figure 13 shows one of the personas whose name is Laura. Laura represents one of possible future users that is an intermediate of soccer and eager to play the game. She is looking for a game that can improve her penalty kick skills while competing with her friends.

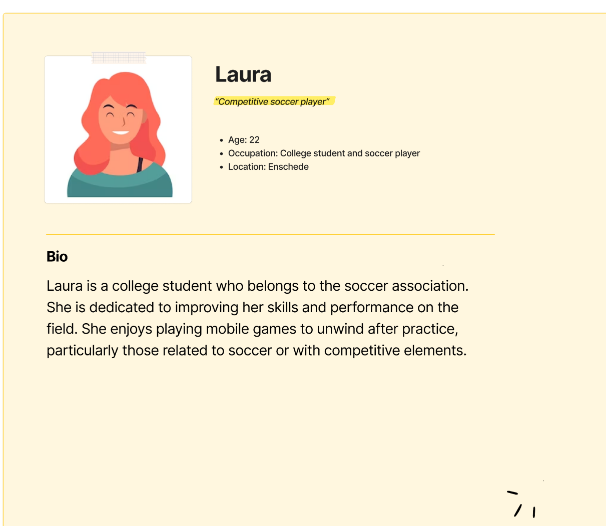

Figure 13. Laura

5.3.3 Tim

Figure 14 shows one of the personas whose name is Tim. Tim represents one of possible future users that is an amateur soccer player but wants to be a professional player. Thus, he is looking for a training method that can practice penalty kicks since he feel boredom from current repetitive penalty kick.

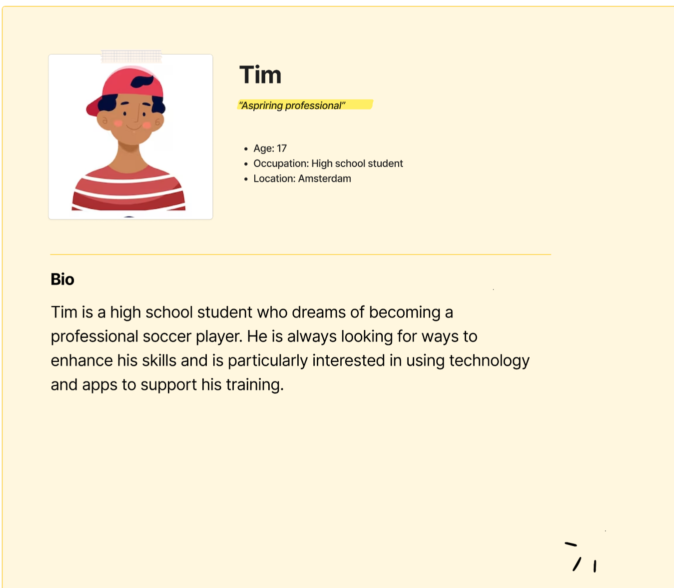

Figure 14. Tim

5.3.4 Sarah

Figure 15 shows one of the personas whose name is Sarah. Sarah represents one of possible future users that is an intermediate amateur soccer player and eager to play the game. She is looking for a game that can improve her penalty kick skills to show her penalty kick skills to friends.

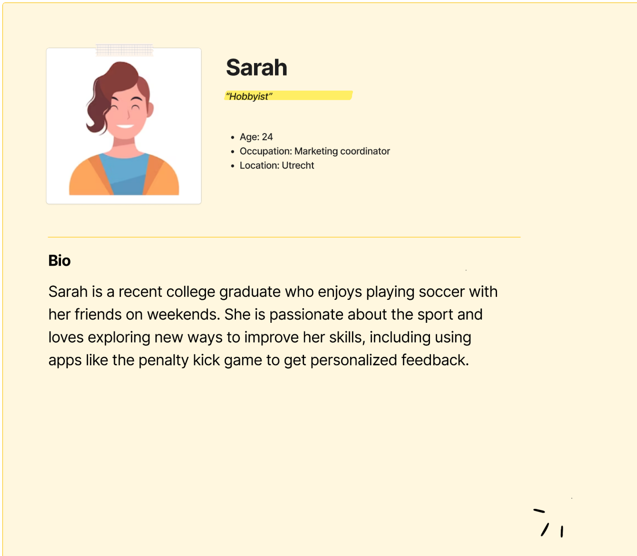

Figure 15. Sarah

5.4 Interaction Scenarios

The interaction scenarios for each persona help pinpoint specific usability issues and potential improvements for the penalty kick app. By envisioning how different users might interact with the app, design choices can be better informed, ensuring the app meets various user needs and preferences. For these interaction scenarios, initial design of the game screen explained in section 5.1 is used. In these scenarios, it is assumed that the feedback provided includes statistical data such as the number of successful shots, average approach speed, and average approach distance, as well as a graph of approach distance and angle per point. This initial concept is explained in ***Table 3.***

5.4.1 Downloaded the app but didn't know how to use it

John is a high school student who enjoys mobile games in his free time. He recently visited the University of Twente soccer field with a friend, where he noticed a unique penalty kick setup. The goalpost had four obstacles, and the penalty area featured sensors to measure distance and four marked spots indicating different approach angles. Intrigued, John downloaded the app designed to help train penalty kicks and launched it.

Upon opening the app, John was greeted with a tutorial screen explaining the game mechanics. However, he skimmed through it without paying much attention. On the next screen, John was prompted to choose an approach angle for his penalty kick. He selected 30 degrees from the options of 15, 30, 45, and 60 degrees without fully understanding the significance of the angle.

Using the randomly chosen approach angle, John put the run-up distance and attempted to shoot the ball past the obstacles in the goalpost. After ten attempts, the game ended, and John was presented with a results screen. This screen displayed his number of successful shots, average approach speed, and average approach distance. John paid little attention to this information and proceeded to start another round. After a few more rounds, John still doesn't understand what this result means.

5.4.1.1 John's progression

John, the casual gamer, continues to play the penalty kick game due to its addictive nature. Over time, he realizes that there seems to be a pattern between his success rate and the approach angle and distance he chooses. He starts to pay attention to the results screen and finds that his best results come from a 45-degree approach angle. He's surprised to find that an app for casual play is teaching him about soccer strategy.

5.4.2 Not interested in the feedback, only interested in the game elements.

Laura, a competitive soccer player, visits the University of Twente soccer field with her friends. She notices the unique penalty kick setup and learns about the accompanying app designed for penalty training. Curious about how it works, she downloads the app and starts the game.

Like John, Laura encounters a tutorial screen explaining the game mechanics. However, she skims through it, more interested in the competitive aspects of the game. She begins playing by choosing an approach angle of 45 degrees, focusing on hitting the obstacles and scoring points. Laura enjoys the game and pays little attention to the app's feedback on her performance, striving to surpass her previous high scores.

After playing multiple rounds at various angles, Laura finds her highest success rate at 45 degrees. At this point, the game results screen displays her average approach speed and distance, but Laura ignores this information, concentrating solely on achieving a higher success rate than her friends.

After the game, Laura feels satisfied with outperforming her friends but remains indifferent to the approach angle and speed. In Laura's case, she is able to enjoy practicing penalty kicks through the game, but she doesn't utilize the available feedback to improve her performance.

5.4.2.1 Laura’s competitive advantage

Laura continues to play the game, driven by her competitive spirit. She starts noticing that her friends are improving faster than she is. Curious, she asks them about their strategies. They mention the app's feedback that they've been using to improve their kicks. Laura decides to pay more attention to her performance feedback and discovers that her approach angle and speed are not optimal. She uses this information to improve her performance, taking her competitiveness to a new level.

5.4.3 Interested in the app's feedback, but misunderstand the feedback

Tim, an aspiring soccer player, visits the University of Twente soccer field with his teammates. He discovers the unique penalty kick setup and learns about the accompanying app designed for penalty training. Eager to improve his skills, Tim downloads the app and begins playing the game.

Unlike John and Laura, Tim pays close attention to the tutorial screen explaining the game mechanics. He starts playing the game by choosing an approach angle of 30 degrees, hoping to learn from the app's feedback and improve his penalty kicks. After several rounds, Tim receives feedback on his performance, including his average approach speed and distance.

However, Tim misinterprets the feedback and believes he needs to change his approach angle more frequently, rather than finding the optimal angle and refining his technique. He continues playing, switching between approach angles of 15, 30, 45, and 60 degrees, attempting to figure out the best strategy.

Despite Tim's engagement with the app's feedback, his misinterpretation prevents him from effectively improving his performance. He finishes his session feeling somewhat discouraged, as his success rate did not significantly improve.

5.4.4 Interested in the app's feedback and practice through feedback

Sarah, a soccer enthusiast, visits the University of Twente soccer field with her friends. She notices the unique penalty kick setup and becomes aware of the accompanying app designed for penalty training. Motivated to enhance her soccer skills, Sarah downloads the app and starts playing the game.

Like Tim, Sarah pays close attention to the tutorial screen explaining the game mechanics. She chooses an approach angle of 45 degrees and plays the game, keen on utilizing the app's feedback to better her penalty kicks. After several rounds, Sarah receives feedback on her performance, including her average approach speed and distance.

Sarah carefully analyzes the feedback and realizes that adjusting her approach angle and refining her technique can help her improve. She spends more time practicing at different approach angles, discovering that her success rate increases at an angle of 60 degrees. Sarah also focuses on her approach speed and distance, making small adjustments based on the feedback provided.

By actively engaging with the app's feedback and applying it to her practice, Sarah effectively improves her penalty kick performance. She leaves the session feeling accomplished and excited about her progress.

5.4.5 Discussion and Implication

In light of the various interaction scenarios presented, it becomes clear that the application must consider and address different user behaviors and expectations. Several improvements can be made based on these observations:

Tutorial Enhancement: The user interactions of both John and Laura indicate that the tutorial could be made more engaging and comprehensive to ensure users understand the game mechanics thoroughly. Incorporating a more interactive and visually engaging tutorial may promote better understanding and retention.

Clear Feedback: Tim's scenario emphasizes the need for clear and explicit feedback. Misunderstanding the feedback not only hinders progress but can also lead to discouragement. Thus, making the feedback simple and visually would support users in accurately understanding and effectively improving their performance.

Competitive Elements: As observed in Laura's scenario, the competitive nature of the game was a primary motivation. Adding elements like leaderboards, challenges, or multiplayer modes could further stimulate this competitive drive and enhance user engagement.

Progress Tracking: Sarah's case underscores the benefits of progress tracking features. Such a system could provide users with a visual representation of their improvement over time, further motivating them and giving them a sense of achievement.

5.5 Functional and Non- functional requirements

In this chapter, functional and non- functional requirements are defined considering the result of chapter 2, chapter 4, chapter 5,research questions and game concept.

5.5.1 Functional requirements

Table 5 shows functional requirements. The requirements are categorized using the Moscow method. The functional requirements are derived from the insight of lo-fi test, persona & interaction scenarios, literature review and game concept. This table includes explanation and the sources to prove why this requirement is defined.

Category	**Requirement**	**Explanation**	**Sources**

Must	Measure approaching angle and run-up distance	The approaching angle and run-up distance are key factors affecting a penalty kick's success. The hi-fi prototype's purpose is to identify the optimal conditions for these elements, thus it should be able to measure them.	Chapter 2, research question
Must	The app must sense the ball hitting the object when users kick the ball with 100% accuracy to give a point.	This requirement stems from the game concept. It is vital to ensure the accuracy of feedback given to users which is based on whether or not they succeed in hitting the target.	Game concept
Must	The unity must start a 10-second timer when the start button is pressed and deactivate the button during this period.	From the user feedback in the lo-fi tests, 10 seconds is sufficient time for users to prepare and take a penalty kick. Therefore, the game should follow this timing.	Lo-fi Test
Must	Provide real-time feedback	Immediate feedback is crucial for users to understand their performance and make quick improvements. This real-time response aids in the learning process and increases user engagement.	Game concept, chapter 2

Must	The app must store the result of all rounds and show feedback for approaching angle and run-up distance using these data.	The primary goal of the application is to provide feedback and facilitate performance improvement. To achieve this, it is crucial to store all round results, display scores, and provide a graphical representation of the performance trends like the relationship between run-up distance and success rate.	Game Concept, Chapter 2, Lo-fi Test
Should	The app should give various types of feedback ex) graph, chart, advice.	Different types of feedback will cater to different user preferences and can provide a more comprehensive overview of user performance. Thus, the app should strive to incorporate diverse feedback mechanisms.	Personas/ Interaction Scenarios, Lo-fi Test
Should	Provide progress tracking over time	The requirement of Progress Tracking is included based on the insights gathered from the personas and scenarios, as well as the responses from the users during the lo-fi testing. This feature is intended to provide users with a visual representation of their learning trajectory, thus assisting them in setting personal goals and maintaining motivation.	Personas/ Interaction Scenarios , Lo-fi Test

Could	Multiple difficulty levels	Offering varying difficulty levels can accommodate the diversity in user skill levels. This would make the game more inclusive and adaptable to the user's learning curve.	Personas/ Interaction Scenarios, Lo-fi Test

Table 5. Functional requirements

5.5.2 Non-functional requirements

Table 6 shows the non-functional requirements. The non-functional requirements are derived from the insight of lo-fi test, persona & interaction scenarios, literature review and game concept. These are also categorized using the Moscow method and provide explanations and sources to justify why these requirements are defined.

Category	**Requirement**	**Explanation**	**Sources**
Must	Simplified and concise tutorial	The tutorial needs to be brief, clear, and engaging to ensure users understand the game mechanics thoroughly and can quickly start playing the game.	Personas/Interaction scenario, Lo-fi Test
Must	Explicit and comprehensive feedback for approaching angle and run-up distance	The application must provide clear, actionable feedback on users' performance, it must show optimal approaching angle and run-up distance.	Personas/Interaction scenario, Lo-fi Test
Must	Customizable obstacle placement and difficulty	The application must allow users to place obstacles according to their desired	Lo-fi Test

		difficulty level. This flexibility in obstacle placement and difficulty customization will cater to a wide range of users, enhancing the appeal and accessibility of the application.	
Must	Incorporation of competitive elements	Elements such as leaderboards, challenges, or multiplayer modes should be incorporated to enhance user engagement and motivation.	Personas/Interaction scenario
Should	Visual representation of progress tracking	The application should visually represent the user's progress over time, allowing users to easily track their performance improvement and maintain motivation.	Lo-fi Test
Should	The app should be playable both alone and with friends.	The application should include diverse game mode like single mode and multiple mode	Personas/Interaction scenario
Could	Wide compatibility across mobile devices	The application should be compatible with a wide range of mobile devices, to reach a wider range of users.	Game concept

Table 6. Non-Functional requirements

6. Realisation

6.1 System architecture

The system can be broadly categorized into four main components: User, Main System, Feedback System, and Obstacles. Firstly, the General System Architecture and its overall workflow will be explained. Following this, the Specific System Architecture, which covers user interaction, data collection, and the feedback system, will be elaborated.

6.1.1 General system architecture

Figure 16 shows a general system architecture diagram. Users select their desired approach angle and run-up distance in the main system, Unity. They then attempt to kick a ball towards the obstacle. The obstacle, equipped with sensors, detects the impact and relays this information back to the main Unity system. This data is then stored and sent to the Feedback System, which processes the data and generates visual feedback for the users.

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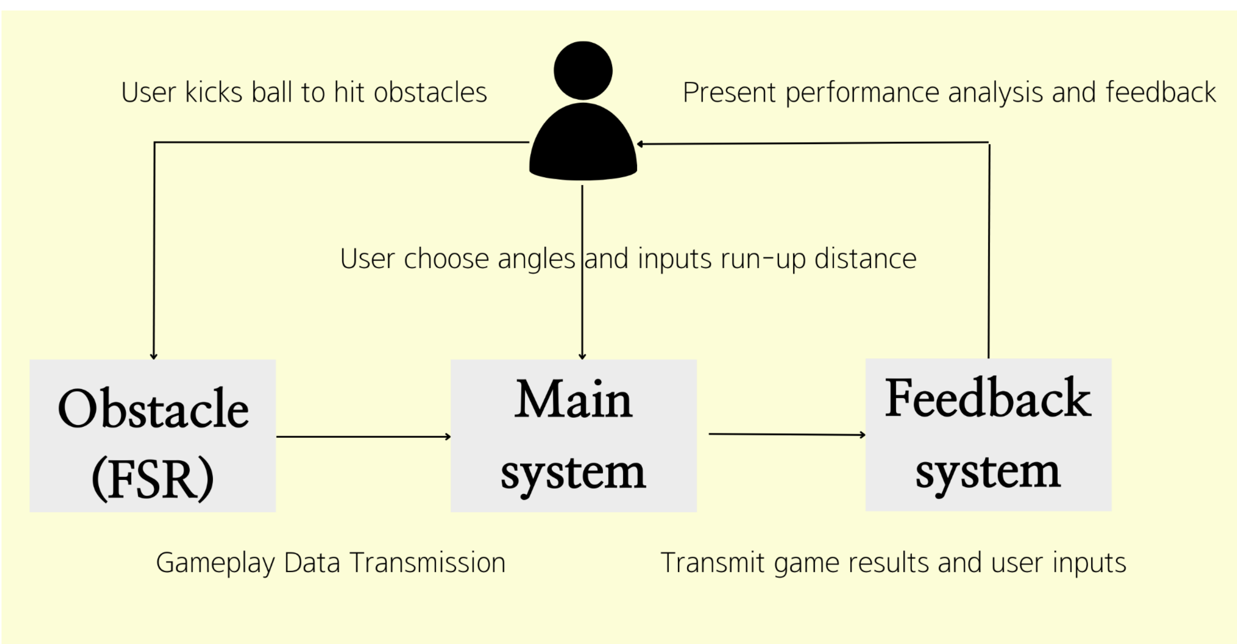

Figure16. General system architecture

6.1.2 Hardware-Software Interaction

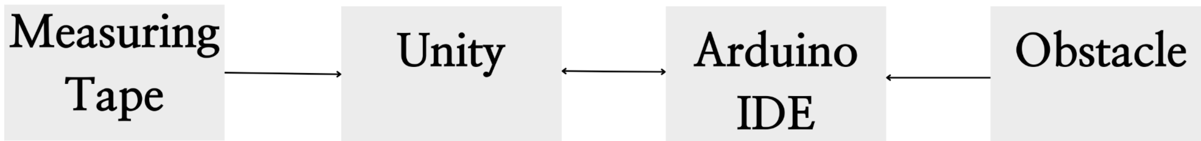

Figure 17. Hardware-Software interaction diagram

The core of the system revolves around the interplay between the hardware components and the Unity game software.

Figure 17 shows the connections between hardware and software used in the hi-fi prototype. The initial point of interaction is established through the measuring tape. A player must input their current approaching angle and run-up distance in the app. These parameters can be found on the measuring tape, placed on the ground, guiding the player's physical positioning. Once players input these, unity stands ready to process data from the Force Sensitive Resistor (FSR) sensor.

The next stage of interaction occurs when the player kicks the ball towards the obstacles. The FSR sensor, embedded within the obstacles, detects this impact. The consequent change in sensor resistance, corresponding to the force of the strike, is read and interpreted by the Arduino Uno.

Programmed through the Arduino IDE, the Arduino Uno converts this physical interaction into a digital signal. This microcontroller establishes a connection between the physical and digital elements of the system, forwarding the impact data to the Unity application installed on a laptop.

On the software front, the Unity program receives and processes the impact data from Arduino Uno. The game, engineered to dynamically respond to the input data, updates the game state accordingly. This includes computing scores and generating visual feedback, thereby closing the loop of interaction from the measuring tape to the Unity application.

6.1.3 Specific System Architecture

The Specific System Architecture dives deeper into three main processes: user interaction, data collection, and the feedback system

6.1.3.1 User interaction

Figure 18 visualizes the interaction between the User, Unity (the main system), and the Obstacle from the user's perspective. Firstly, the user selects one of three levels in Unity: easy, intermediate, or hard. Depending on the level, a varying number of obstacles are installed in the goalpost. Easy level includes three obstacles, intermediate has two, and hard consists of only one. Then, the user selects one angle out of 15, 30, 45, 60, or 75 degrees. After choosing the angle, the user finds their preferred run-up distance, inputs it into the app, and then presses the start button. After pressing start, the user kicks the ball towards the obstacle. This sums up the user interactions. The detection of the ball by the obstacles, user's selected angle and run-up distance, and the hitting of the obstacle are detailed in the next section.

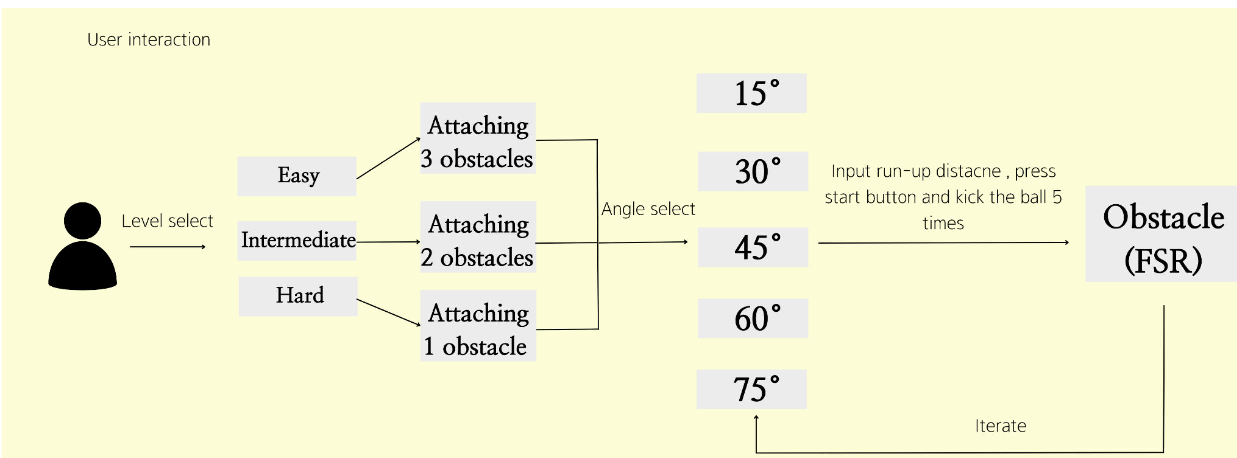

Figure 18. User interaction with Unity and Obstacles

6.1.3.2 Data collection

Figure 19 displays the data collection process. The obstacle is controlled by Arduino, which sends its sensor readings to Unity. If any sensor value received by Unity from Arduino surpasses 500 within 10 seconds, Unity assumes the user has hit the ball successfully and adds a point. If all values remain under 500, Unity assumes the ball was not hit and does not add a point. After 10 seconds from the start button press, Unity stops receiving values from Arduino and stores all data. Each penalty kick's data is stored in the format, for example, {Round:1, Selected angle:15, run-up distance: 2m, point:0}. After five attempts, data from Round 1 through Round 5 is stored.

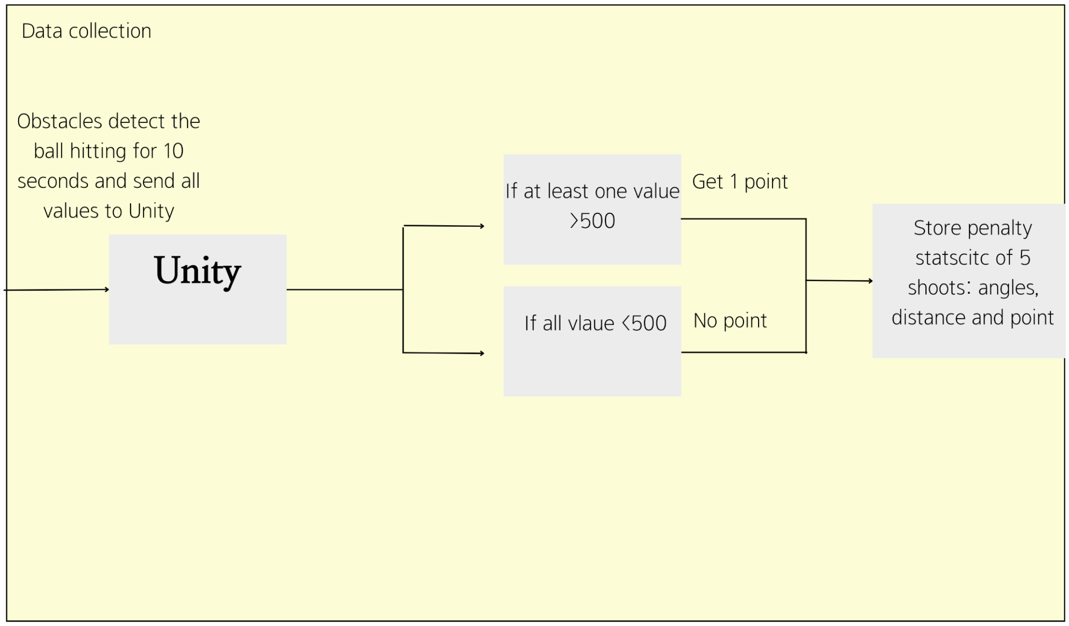

Figure 19. Data collection diagram

6.1.3.3 Feedback system

Figure 20 illustrates the feedback generation process. The graph generation function within Unity receives and stores all data from the Main System. The data for five penalty kicks, in the form {Round:1, Selected angle:15, run-up distance: 2m, point:0}, is received from the Main System and grouped into one session. A session represents the largest unit of data in this system, storing data for five rounds and aggregating the average run-up distance and total points. An example of session data would be {Session:1, Selected angle:15, Round:1, average run-up distance: 2m, total point:2}.

The Approaching Angle Feedback is generated using this session data. Using the pairs of (selected angle, total points) from all sessions, a graph is generated with the selected angle as the x-axis and total points as the y-axis. For instance, if there exist two data pairs with the same approach angle such as (15°, 2) and (15°, 1), the y-axis value will be the average of the two, in this case, 1.5. This allows users to find the optimal angle through the angle-specific graph.

The Run-up Distance Feedback utilizes round data, a smaller unit of data compared to session data. The round data includes angle, run-up distance, and point values. Here, pairs of (run-up distance, points) are used. The graph is created with run-up distance on the x-axis and points on the y-axis. Like the Approaching angle, if x-axis values are duplicated, the y-axis value is calculated as the average for graph creation.

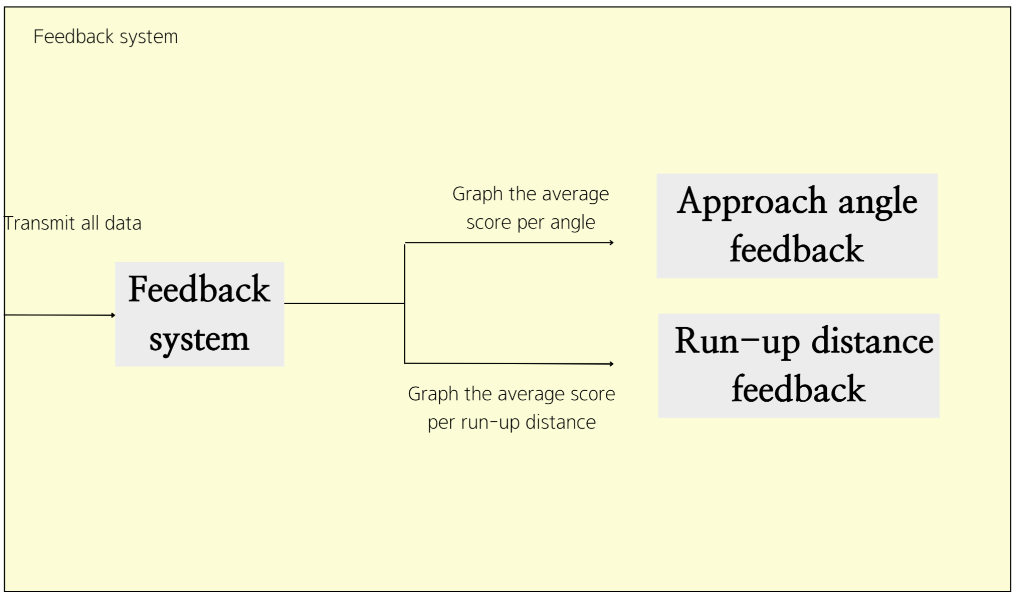

Figure 20. Feedback generation process diagram

6.1.4 Time Sequence diagram

Figure 21 illustrates the interactions and flow of events involving three main components: User, App, and Field Sensor. The diagram provides a clear representation of how these components work together to create a smooth and efficient user experience.

When the app starts, the user see a tutorial screen explaining the game mechanics. After interacting with the app, the user can choose the difficulty level and based on these levels, users are asked to place 1~ 3 obstacles in the goal post. Then, the User is prompted to choose an approach angle for the penalty kick. The App then confirms the selected angle and displays the game screen. Users have to put a run-up distance and press the start button. Simultaneously, the Field Sensor detects the penalty kick and gathers data, such as speed, distance, and angle.

As the User takes the penalty kick, the App provides real-time feedback based on the data collected by the users and Field Sensor. Once the session is complete, the App presents the game results, which include the number of successful shots and average approach distance.

By returning to the angle selection screen after each round, the app enables the User to practice various approach angles. After completing all angles, the app displays the final results for each approach angle and identifies the best angle and run-up distance with the highest success rate.

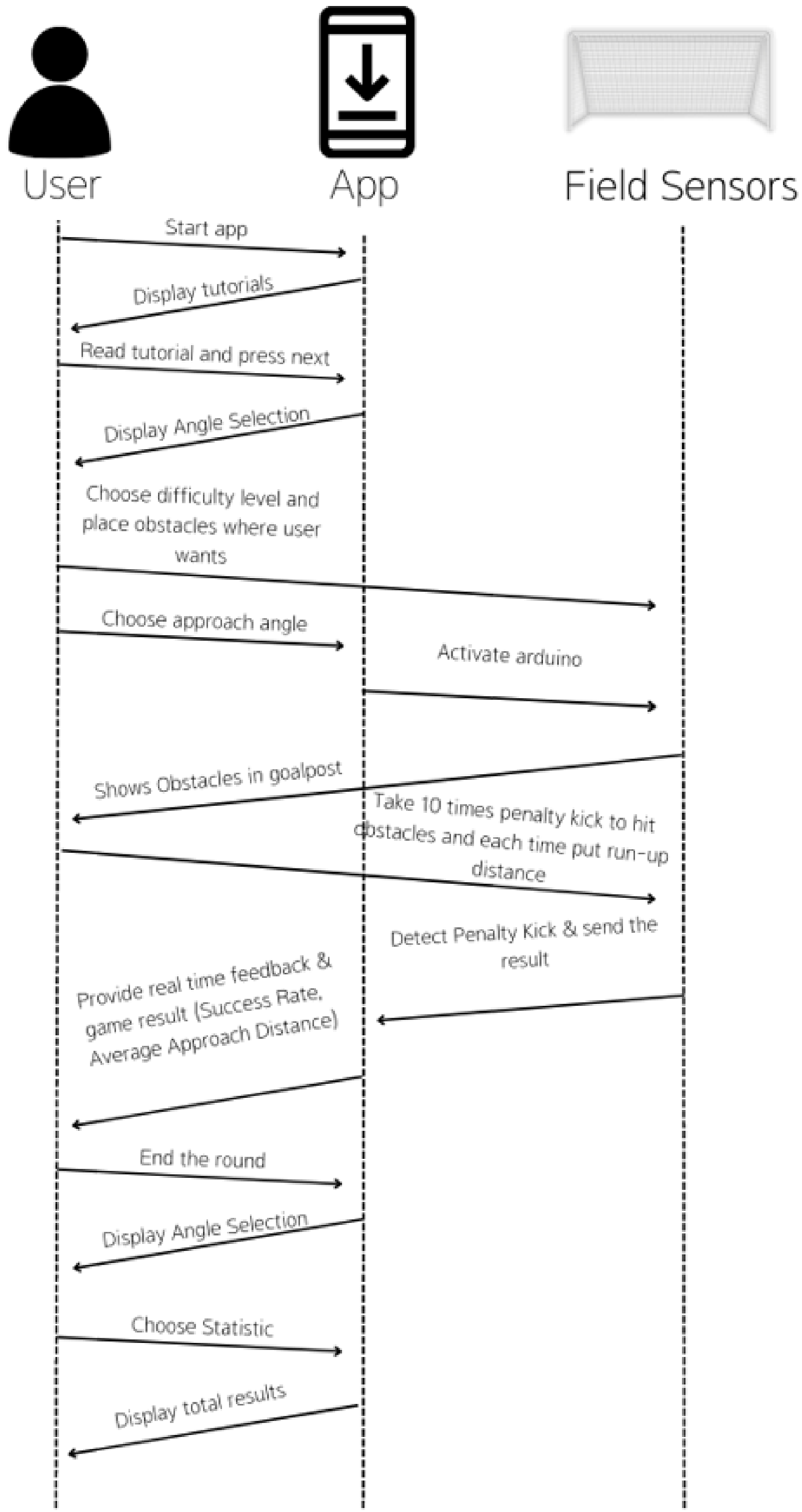

Figure 21. Time Sequence diagram

6.2 Hardware

This section provides an overview of the essential hardware components deployed within the system, elaborating on their functions and significance.

6.2.1 Arduino Subsystem

6.2.1.1 Arduino Uno

Arduino Uno (***Figure 22)*** is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins, 6 analog inputs, a USB connection, and a power jack. In this project, it is used to receive signals from the Force Sensitive Resistor (FSR) sensor and transmit the information to the laptop.

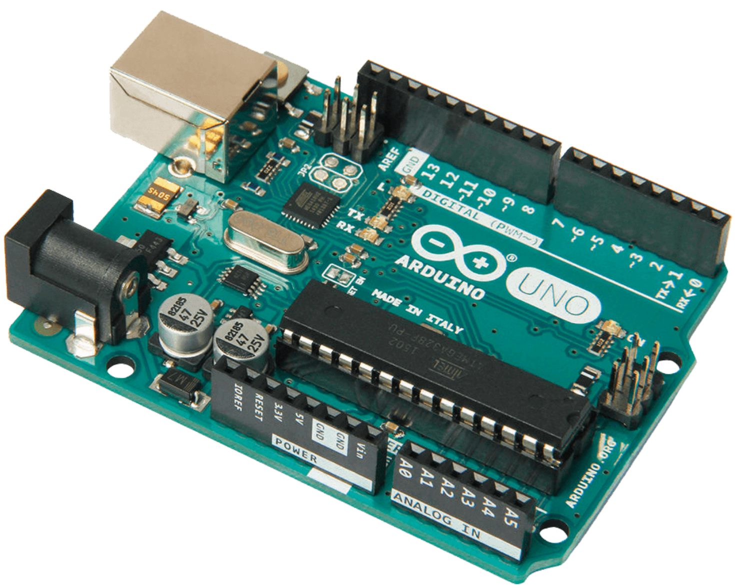

Figure 22. Arduino Uno

6.2.1.2 FSR Sensor

Force Sensitive Resistor (FSR) sensor (***Figure 23)*** is a sensor that allows measuring static and dynamic forces applied to a sensor. An FSR sensor is attached to each obstacle in the game, enabling the system to detect when the soccer ball hits an obstacle.

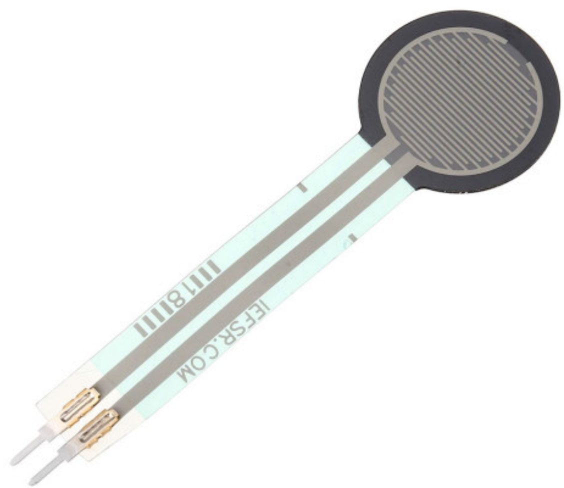

Figure 23. Force Sensitive Resistor (FSR) sensor

6.2.1.3 Scheme

Figure 24 describes how the Arduino Uno and the FSR sensors are connected. The Arduino Uno receives input from the FSR sensors when force is applied to them (i.e., when the soccer ball hits an obstacle), and sends this information to the laptop via a USB connection.

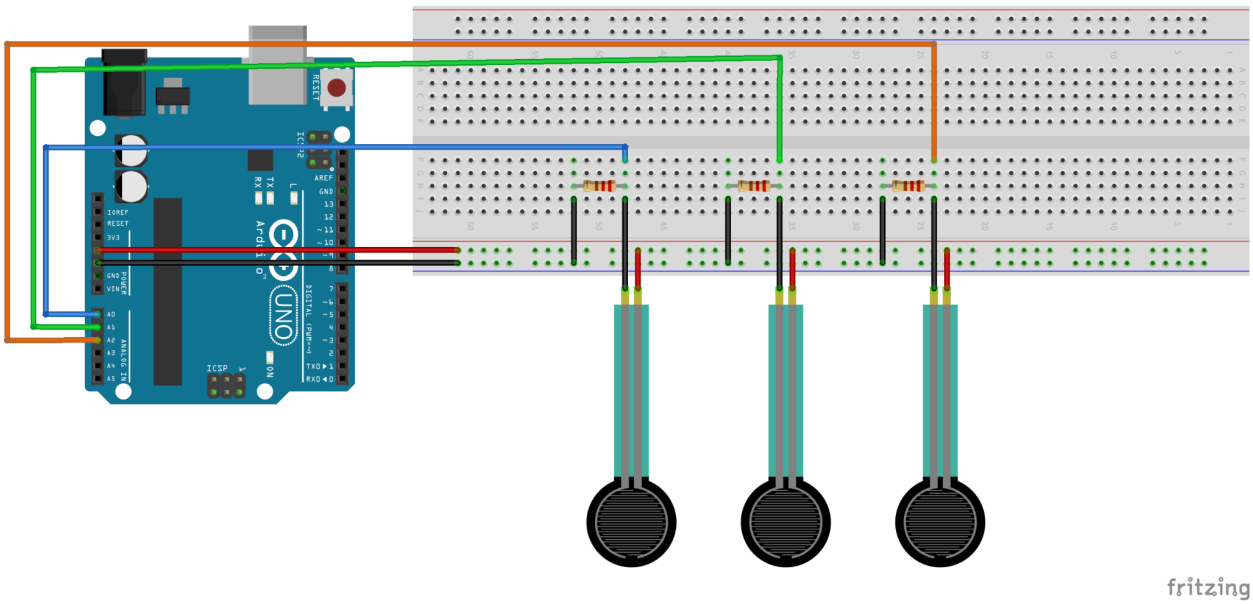

Figure 24. Wiring schematic of the Arduino Uno and FSR Sensor

6.2.3 Obstacles

Obstacles are an integral part of the game, designed to test the player's accuracy and precision. These are positioned within the goal area and each obstacle is fitted with a Force Sensitive Resistor (FSR) sensor.

The primary consideration in the selection of obstacle materials is their ability to absorb the impact from a soccer ball and effectively trigger the FSR sensor. The material needs to be sufficiently soft to cushion the ball's impact, yet responsive enough to transfer the force to the sensor. This balance is essential to ensure accurate detection when the soccer ball strikes the obstacle.

A suitable choice for this requirement would be a foam material (***Figure 25***). Foam is lightweight, easy to shape, and has excellent shock-absorbing properties. It is also relatively easy to attach to the walls of the goal and can be safely and securely mounted without causing damage.

Figure 25. Foam material

6.2.4 laptop

The laptop plays a crucial role in the system, acting as the central processing unit. It runs the game application in Unity. The laptop receives data from the Arduino Uno which signifies when the player's soccer ball hits an obstacle. This data is then processed within the Unity application to give points and provide real-time feedback to the user.

6.3 Software

This section provides a brief overview of the software components utilized in this project.

6.3.1 Unity

Unity is a powerful game development engine used to create interactive 3D and 2D experiences.The versatility combined with powerful tools makes it ideal for beginners and professionals alike. In this project, Unity is used to design and implement the game interface and programmed using C# language to control the game mechanics, provide visual feedback to the user, and get data from Arduino.

6.3.2 Arduino

The Arduino software (IDE) allows the user to compose programs and upload them to Arduino boards. In this project, the Arduino IDE is employed to program the Arduino Uno board. This code enables the microcontroller to interpret the inputs from the FSR sensor and transmit the relevant data to the laptop.

6.5 Final Prototype

The final prototype reflects a developmental progression from the initial game concept established in section 4.3, augmented by improvements identified through discussions and implications arising in sections 5.1, 5.2, and 5.4. The basic setup for the prototype is introduced first, followed by a demonstration of the game screen. Lastly, the practical issues associated with this high-fidelity prototype will be addressed.

6.5.1 Set up

Figure 26 displays the implementation of the Arduino circuit explained in section 6.1.1.3. This circuit is connected to the three obstacles shown in ***Figure 27***, each containing an attached FSR sensor.

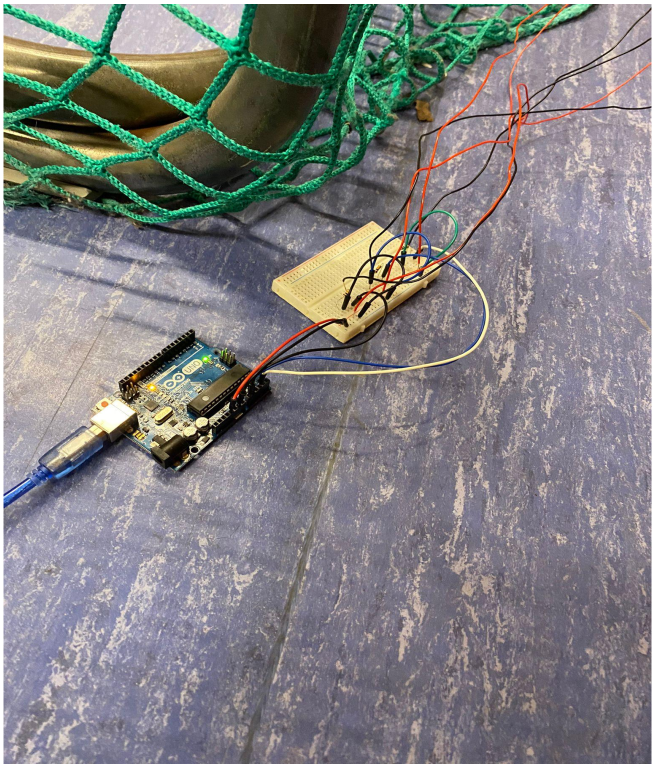

Figure 26. Breadboard- Arduino connection

Figure 27. Three obstacles in goal post

Figure 28. Ground setup

The complete setup is viewable in ***Figure 28***, where tapes at 15, 30,45,60 and 75 degrees are placed 4.5 meters from the ball. The white tape marks intervals of 0.5 meters.

6.5.2 Start and Tutorial Screen

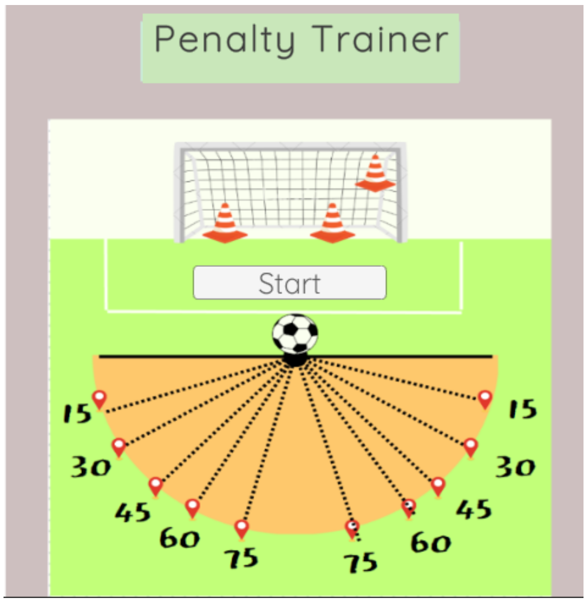

Figure 29. Start Screen of hi-fi prototype

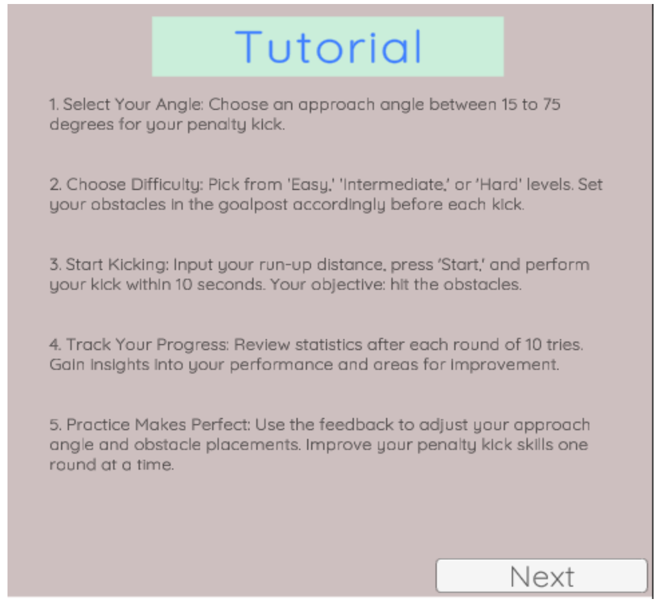

Figure 30. Tutorial Screen of hi-fi prototype

Once the setup is complete, users initiate the game. ***Figure 29*** shows the start screen of the application, and ***Figure 30*** represents the tutorial screen, guiding users to understand the overall game rules before beginning play. The tutorial explanation is much more concise than the game screen provided in the section 5.1.

6.5.3 Level Selection and Angle Selection

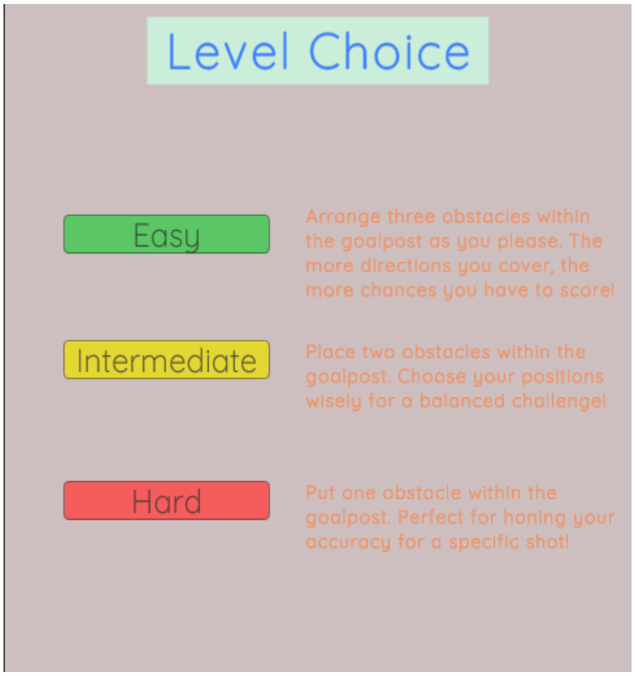

Figure 31. Level choice Screen of hi-fi prototype ***Figure 32.*** Angle select Screen of hi-fi prototype

Figure 31 exhibits the level selection phase. Users choose among easy, intermediate, or hard levels based on their penalty kick skills. Subsequently, they place obstacles within the goal post in the desired positions, with the number of obstacles varying according to the selected level. Users then select the approach angle they wish to practice. ***Figure 32*** displays the angle selection screen, where users can practice five different angles, moving to the statistics page to view feedback after sufficient practice.

6.5.4 Game play

Figure 33. Player on 15 degrees of approach angle and 2.5m run-up distance

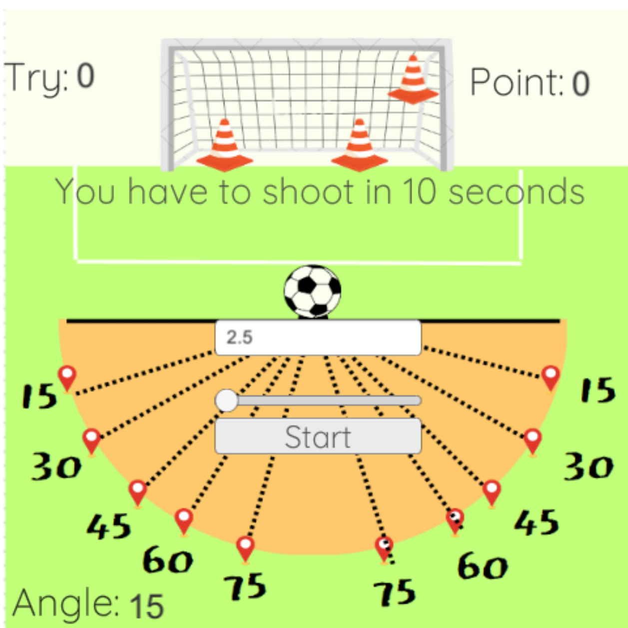

Figure 34. Gameplay Screen of hi-fi prototype

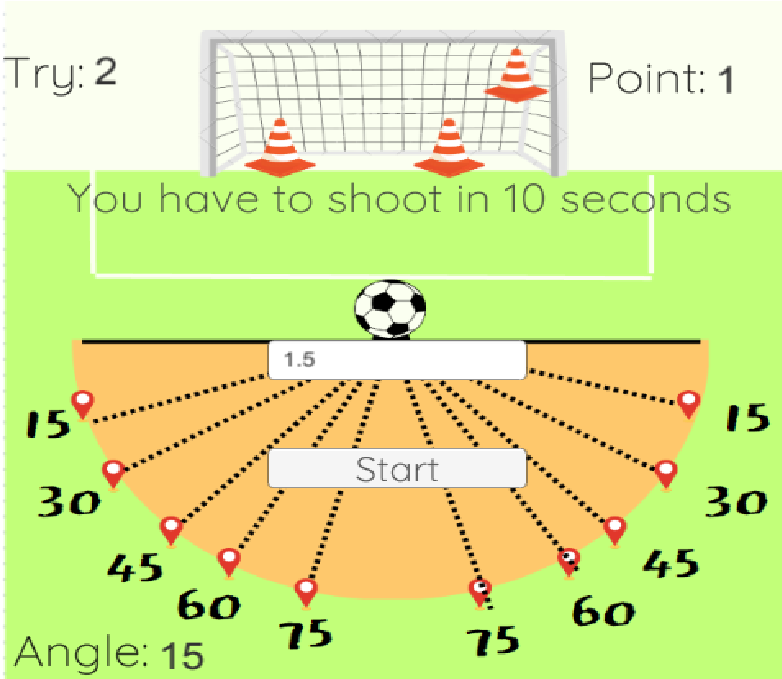

Figure 35. Gameplay Screen of hi-fi prototype after second attempt

Figure 33 displays a player preparing to kick the ball from a 2.5-meter distance at a 15-degree angle. Now the player is ready to press the start button and take a penalty.

Figure 34 presents the gameplay screen, with a centrally positioned input field for entering the approach distance. The selected angle is displayed on the bottom left of the screen, with the count of kicks on the top left and current points on the top right. After users kick the ball and press the start button, they are given a 10-second time slider to kick the ball. As seen in ***Figure 35***, points increase when users hit obstacles within the goal post. Users have five attempts in total. After five attempts, the start button is deactivated and the finish button is activated.

6.5.5 Result and Statistic

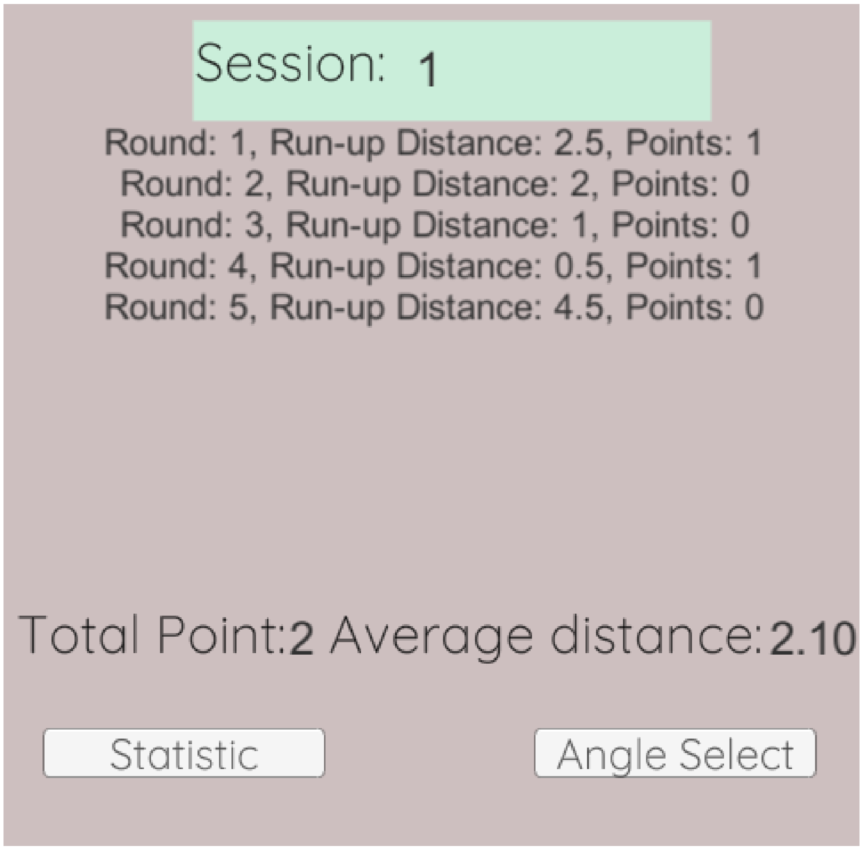

Figure 36. Result Screen of hi-fi prototype

Figure 36 illustrates the results screen that appears after completing a 15-degree session, offering users immediate feedback on their approach distance and corresponding points.

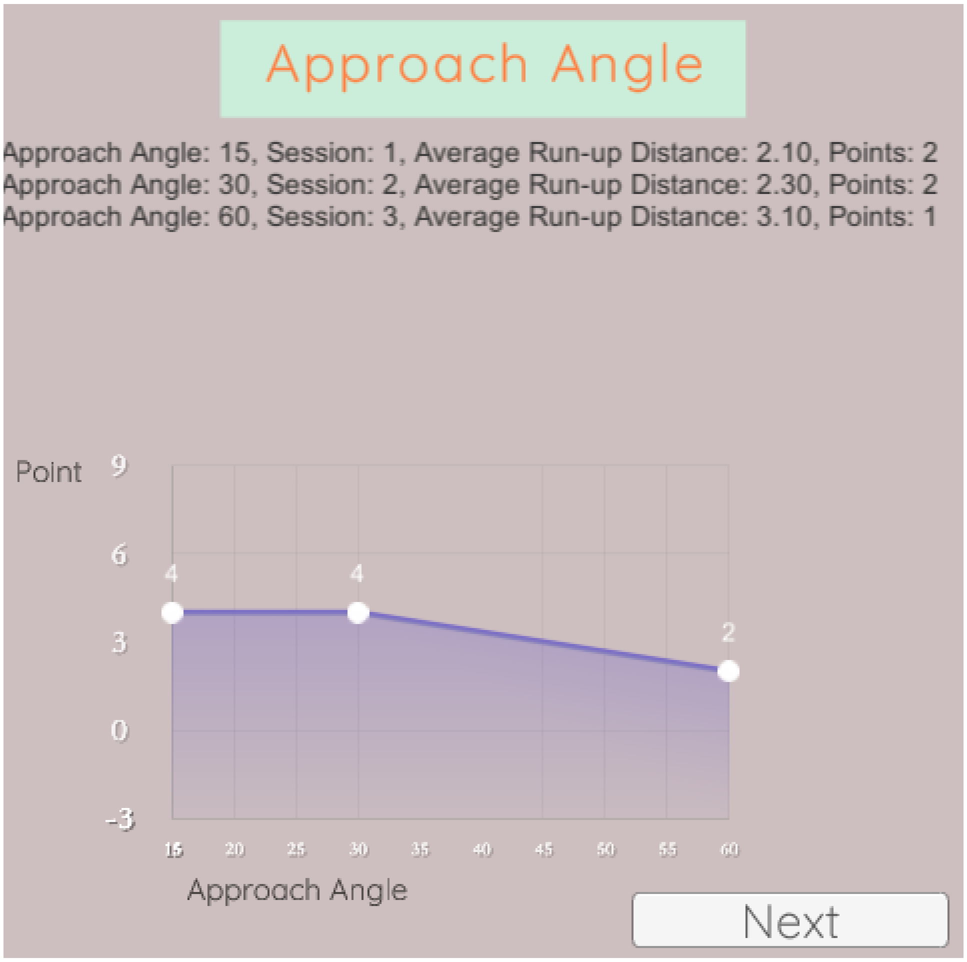

Figure 37. First Feedback Screen of hi-fi prototype

Figure 37 provides feedback about the chosen approach angle, including the selected angle for each session, average run-up distance, and points earned. A graph at the bottom of the screen plots points against approach angle, enabling users to find their most effective angle. More attempts lead to increasingly refined and accurate feedback.

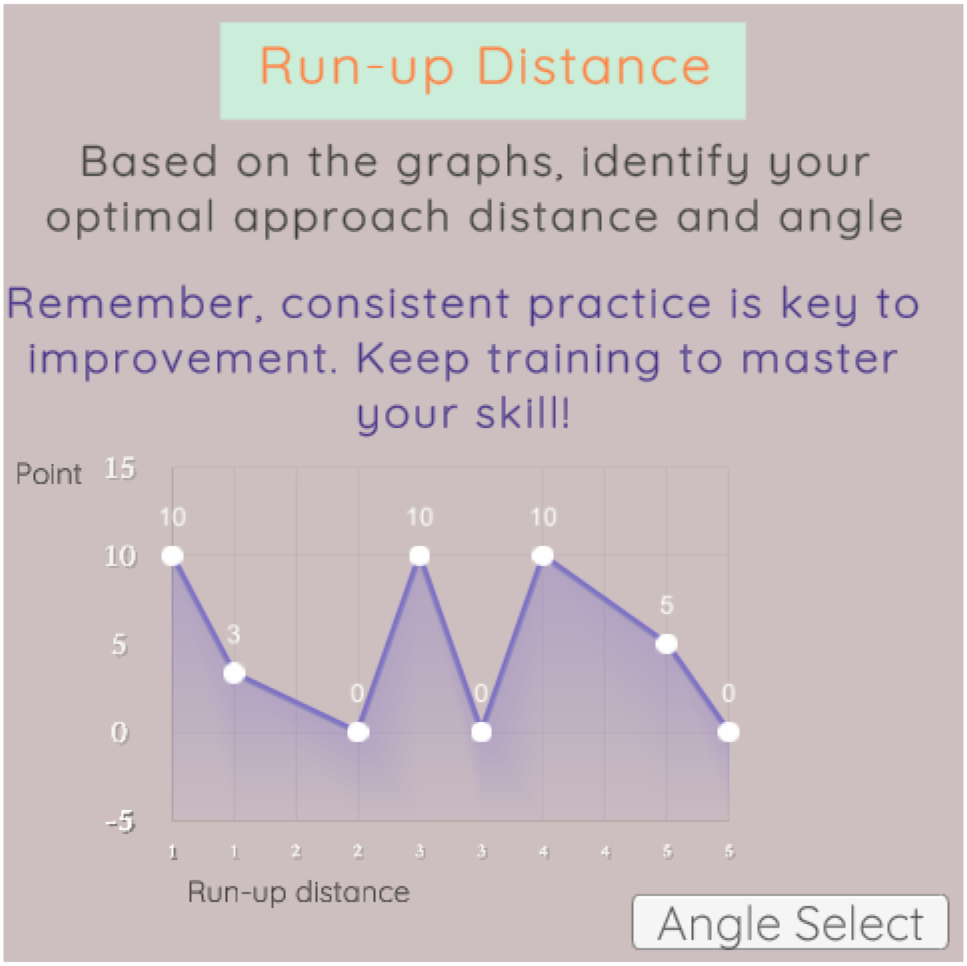

Figure 38. Second Feedback Screen of hi-fi prototype

Figure 38 represents the feedback regarding approach distance, offering a graph of points against approach distance. Through this, users can ascertain the approach distance that yields their best performance.

6.5.6 Practical problem

This hi-fi prototype has some practical problems. Due to the requirement to place obstacles within the goal post, both the Arduino, linked to the obstacles, and the laptop must be located near to the goal post. This necessitates a back-and-forth movement between the kicking area and the laptop, which could be inconvenient, particularly if the user is operating the system alone.

Moreover, the FSR sensor operates by detecting pressure, implying that the obstacles equipped with these sensors must be installed within a solid boundary, such as a wall. This limits the system's feasibility for outdoor usage, as the absence of a solid boundary to contain the obstacles could impede the function of the FSR sensors.

Possible solutions to address these practical problems could involve creating a portable or foldable wall that can be used as a solid boundary for outdoor usage. Additionally, the use of a wireless system such as a bluetooth module and mobile application could eliminate the necessity of the back-and-forth movement between the laptop and the kicking area.

6.6 Functional requirements Review

Table 7 shows the fulfillment of functional requirements.

Category	Requirement	Status	Reason for Status
Must	Measure approaching angle and run-up distance	O	The current setup includes an FSR sensor and a system that accurately measures both parameters
Must	The app must sense the ball hitting the object with 100% accuracy	△	The app has high accuracy but can still miss if the ball hits the edges of the obstacle

Must	The Arduino must start a 10-second timer when the start button is pressed and deactivate the button during this period	O	The prototype includes a timer function that works as intended
Must	Provide real-time feedback	O	The app provides immediate feedback upon ball impact
Must	The app must store the result of all rounds and show feedback for approaching angle and run-up distance using these data	O	The app currently stores data and displays the graph for approaching angle and run-up distance as feedback.
Should	The app should give various types of feedback ex) graph, chart, advice	△	The app currently provides only graph feedback types but could expand to include bar charts or other types of visual feedback.

Should	Provide progress tracking over time	O	The app does track progress as it shows all statistical records of each session.
Could	Multiple difficulty levels	△	Currently, the game has multiple difficulty levels, but the criteria for each level are vague and could be improved

Table 7. Functional requirements Review

In ***Table 7***, 'O' signifies that the requirement is entirely fulfilled, '△' means it is partially fulfilled, and 'X' indicates the requirement is currently unfulfilled.
This table not only shows the functional requirements but also assesses the current state of the prototype and the aspects that need further improvements.

7. Evaluation

This chapter explains the results of the evaluation test.

7.1 User Evaluation Method

7.1.1 Setup

The user group for this prototype is amateur soccer players who are willing to improve their penalty kick skills. UT Sport centrum is a suitable place for the prototype test setup since the prototype needs a goalpost and ground to show approaching angles and run-up distance. UT Sports Centrum is a public space that other students can use, so there was a limitation that many people could not be invited to the test. Therefore, 5 people who can participate in user group were selected. As only one participant could engage with the prototype at a time, each participant was allocated a separate time slot in a row.

Figure 39 shows the completed setup and ***Figure 40*** shows a simple diagram of the setup. The experiment environment required a pre-test arrangement. First, wires connected to the FSR sensor were attached to the obstacle and linked to the Arduino and laptop. The obstacles were attached to walls randomly differing the location. Next, tapes were set up at 15, 30, 45, 60, and 75 degrees from the penalty kick point, all 4m in length. The laptop is located near the goalpost since the laptop is connected with an arduino and obstacles. It takes a lot of time to go back and forth to the laptop before each kick, as participants always have to input the run-up distance in the game before kicking the ball. Considering the time constraints of using the sport centrum, for the acceleration of the test, the researcher put the approach distance into the app instead of the participant. Thus, the researcher was next to the laptop to protect the laptop from the soccer ball as well as input the run-up distance in the game whenever players take a penalty.

Figure 39. experiment environment

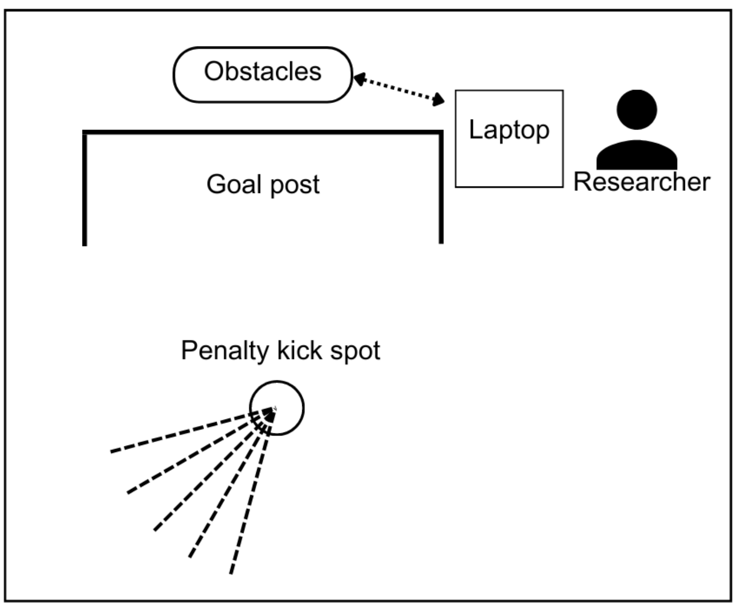

Figure 40. Simplified diagram of the experiment environment - Researcher should be next to the laptop for game play. Laptop should be next to the obstacles since they are connected.

7.1.2 Procedure and Evaluation technique

At first, participants received an information letter and then a consent form to sign. Then, they were informed about the test procedure.

The test consisted of two sessions, play testing and interview, each utilizing a different evaluation technique.
In the first session, participants were asked to play the game. Because of time constraints, participants were asked to choose 3 different approach angles and take 5 penalty kicks each with random run-up distance.

After taking all penalty kicks, participants could find the feedback about approach angle and run-up distance. With this feedback, participants were asked to take 10 times of penalty kicks **again** using the optimal approach angle and run-up distance gathered from the feedback graph. This is to check whether users show progress or not.

This session was evaluated using observation, with an additional touch of the Wizard of Oz technique. The Wizard of Oz technique was used because the obstacles do not have 100 percent accuracy of detecting. Thus, without the participants knowing, the researcher directly raised the score when the score did not rise even though the participants hit the obstacle.
The purpose of this session was to evaluate how users interact with the game and feedback, and their progress after receiving feedback. The researcher used a prepared checkbox and table to record how participants interact with the prototype. The checkbox questions and statistic table can be found in ***Figure 41*.** The checkbox questions were yes/no in nature. Through these checkbox questions, the researcher evaluated if participants had difficulty progressing in the game, if the difficulty of the obstacles was appropriate, and if the feedback was provided appropriately through gameplay. Furthermore, after completing the game, in-game statistics such as optimal approach angle, run-up distance, and average points before and after using these optimal angles and distances were recorded in a table. This was to evaluate whether participants could accurately find their optimal run-up distance and approaching angle, and whether their penalty kick skills improved when using this information. This session took approximately 20-30 minutes.

The second session consisted of a semi structured-interview. After the first session, participants were asked questions by the researcher in a semi-structured interview format. The questionnaire for the interview can be found in **appendix A**. The purpose of this interview is to understand players' experiences and perceptions about the penalty kick game. It's aimed at assessing the clarity and fairness of the game rules, the effectiveness of the feedback provided to players, the factors contributing to players' enjoyment, and how well players can improve their skills based on the feedback received.

Checkbox Questions:

1. Did participants have difficulty understanding the game rules while using the app?
2. Did the participants struggle to hit the obstacle?
3. Did participants understand the feedback?
4. Did participants want to practice after getting feedback?
5. Did participants show progress with optimal run-up distance and approaching angle?

Figure 41. Checkbox questionnaire

7.2 Results

7.2.1 Checkbox results and statistic table

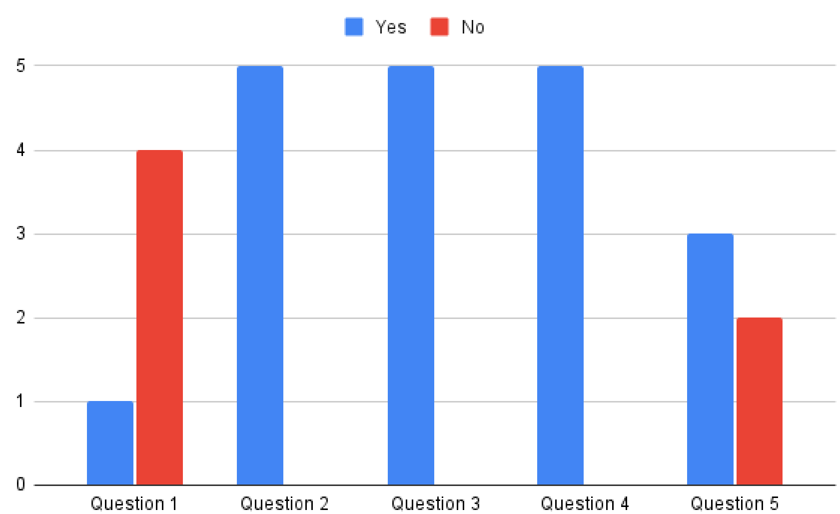

Figure 42. Checkbox results

Participant	Optimal Angle (degrees)	Optimal Distance (m)	AverageScore Before using optimal approach angle and run-up distance	Score After using optimal approach angle and run-up distance
1	30	2.5	2	2
2	45	3	1	1
3	60	2	0	1
4	45	2.5	1	1
5	30	3	1	2

***Figure 43*. Participants in-game statistic**

The checkbox survey and the statistic table results were analyzed to understand the user experience and the game performance.

In the checkbox survey, regarding the question of whether participants had difficulty understanding the game rules while using the app, 4 out of 5 participants reported no difficulties.

As to the question of whether the participants struggled to hit the obstacle, all five participants admitted having difficulty.
When queried on their understanding of the feedback, all participants affirmed their comprehension, implying that the feedback provided was clear and meaningful.

In terms of the willingness to practice after receiving feedback, all participants expressed a desire to practice more.

Regarding progress with the optimal run-up distance and approaching angle, three participants demonstrated progress, while two did not, indicating a possible need for further refinement in the feedback or instructions related to these aspects.

Moving on to the statistical results, the participants showed diverse optimal angles and distances. The optimal angles varied from 30 to 60 degrees, and optimal distances ranged from 2 to 3 meters. In terms of score improvement, the participants showed mixed results. While some participants showed improved scores after using their optimal angles and distances, others did not show significant changes.

7.2.2 Interview Results

The interview results show participant responses for each theme.

Understanding Gameplay Difficulties: The interview responses showed a recurring theme of participants finding it challenging to hit the obstacles during the gameplay. There were some quotes like
“There was nothing I didn't understand, but I wish the angles were more diverse, and it was difficult to hit the obstacles.”

“It's harder than I thought to hit the obstacle, so I hope the size of the obstacle is a little bigger. One feedback is, I want you to make different points depending on the location of the obstacle. This is because the higher the obstacle, the harder it is to hit it, and the harder it is to hit it in the corner.”

“It was hard to hit the obstacle.”
This suggests potential areas for enhancing the game dynamics related to targeting and hitting the obstacles. A common solution suggested by participants was to increase the size of the obstacles.

Interpretation of Game Rules: The interview results indicated that participants found the game rules to be straightforward and understandable, echoing the checkbox results presented in section 7.2.2.1. However, some expressed concerns about the scoring system, suggesting that differentiating scores based on the position and size of obstacles could make the game more engaging and fair.

Some quotes from participants:

"The overall rules of the game are fine. Honestly, since this is for training purposes, when controlling the difficulty of the game, I hope the difficulty will vary depending on the size of the obstacle rather than the number of obstacles. Even if there are many targets, if the target is small, it will be difficult for beginners anyway, so the size of the obstacle will be better in controlling the difficulty level."

"The rule was okay to put it simply."

"The rules of the game were clear and concise. In particular, it was fun to try various things in the part where you have to adjust the approach angle and the distance of the kick. These challenging elements allowed me to focus more on the game and continue to play the game."

Feedback for Penalty Kick Improvement: Participants viewed the feedback system favorably, acknowledging its usefulness in identifying areas for improvement in their penalty kicks. Finding optimal approach angle and run-up distance was helpful to improve penalty kick skills as they can practice penalty kick using it. One participant argued that their perceived optimal run-up distance and approaching angle differed from what the feedback suggested.

Some quotes from participants:

"I could see which angle showed the best performance on the graph. But actually, the optimal approach angle that I think and the angle that the game gave as feedback were different."

"The feedback is through statistical data so it was helpful to know at which approach angle and run-up distance the success rate was high"

Factors Influencing Enjoyment and Interest: Participants noted that the game's varying approach distances and angles increased the game's intrigue and complexity, making it more

appealing. They found the act of hitting the obstacles itself enjoyable and it stimulated their competitive spirit. Furthermore, the competitive aspect of achieving higher scores than their peers added an element of excitement. These factors were commonly reported as the driving force behind continued engagement with the game.
Some quotes from participants:
“It was fun to hit the obstacle. It was fun to match at different angles because it felt like a mini game, and I think it helps me practice penalty kicks more continuously because I will try to match obstacles.”

“It was harder than I thought to hit the obstacle, but I was able to practice more because I was competitive.”

Improvement in Penalty Kick Skills: Responses regarding skill improvement after feedback were mixed among the participants. While some reported gaining confidence, this didn't consistently translate into a noticeable improvement in their game scores. Most participants reported that, though their scores did not significantly increase, their shots came closer to the obstacles when using feedback. They speculated that with more practice and accumulated data, their penalty kick skills would likely improve. This suggests that while feedback provides reassurance and promotes skill improvement, more time or additional gameplay opportunities might be necessary for players to fully integrate these insights into their performance.
Some quotes from participants:
“There was no improvement in points when practicing using feedback, but we found the ball closer to the target. Therefore, if I practice more, I think my penalty kick skills will improve.”

“However, if you practice from various angles and find the best angle and the best approach through feedback again, and practice from that angle, I think your penalty kick skills will improve.”

“I think it's improved. I kicked it repeatedly using the optimal approach distance and approach angle, so I was able to kick where I wanted to because I could position the stepping foot accurately.”

7.3 Conclusion evaluation phase

Overall, participants concluded that the product was easy to understand and could be used continuously. In addition, as shown in Section 7.2.2, the prototype allowed participants to find their optimal approach distance and approach angle, which helped them improve their penalty kick skills.As shown in 7.2.1 and 7.2.2, some changes are required in the size of the obstacle and the scoring system, and therefore some of the rules of the prototype must be changed in order to create a perfect penalty kick training.

7.4 Discussion evaluation phase

The results of the user evaluation process describe the performance of the prototype. It highlights the improvements, the effectiveness of the feedback system, and the usefulness of the prototype.

The evaluation results imply that the game dynamics were overall well-understood, suggesting that the instructions and game rules were clear and effective. However, players found it challenging to hit the obstacles, pointing to a potential area for improvement in the game design or player instruction. This aspect could be enhanced by increasing the size of the obstacles, as suggested by participants. Further, feedback from the participants indicates room for adjustment in the scoring system for a more engaging and fair experience, adding another dimension to the prototype's enhancement. The differentiation in points could be based on the size and location of each obstacle within the goal post

In relation to the feedback system, the participants positively acknowledged its usefulness in recognizing areas for improvement in their penalty kicks. They found the insights about the optimal approach angle and run-up distance helpful for modifying their gameplay strategies. Yet, the feedback related to the optimal run-up distance and approaching angle was not entirely reflected in the participants' game progress.

The usability of the prototype in terms of user experience and interaction was highly acclaimed. Notably, the gamification elements contributed significantly to the appeal of the game. The system of gaining points by hitting obstacles motivated users to engage with the game more consistently, and the point system induced competition among users. The varying approach distances and angles in the game added a level of interest and complexity, enhancing the attractiveness of the prototype. Furthermore, the feedback system made a positive contribution to the user experience, with all participants expressing a desire to practice more after receiving feedback. These findings underscore that the incorporation of gamification elements in the training system can effectively motivate and engage users during penalty kick training, providing an answer to research questions.

However, the improvement in penalty kick skills after using feedback was not uniform among participants. While some reported gaining confidence, it didn't consistently result in a noticeable improvement in their scores. Most participants agreed that with more practice and data accumulation, their penalty kick skills would likely improve. Therefore, future studies should consider providing more time or additional gameplay opportunities for users to fully integrate these insights into their performance.

Reflecting on the selected evaluation method and techniques, the combination of checkbox surveys and interviews provided a comprehensive understanding of user experience and game performance. The checkbox survey was effective in capturing immediate user responses to the game dynamics, feedback system, and game progress, while the interviews enabled a deeper understanding of participants' experiences and perceptions.

The Wizard of Oz technique, although not fully transparent to participants, ensured that the test results were not skewed by the prototype's technical limitations. However, its use introduce a source of bias and could affect the natural gameplay experience. For future studies, it would be beneficial to improve the obstacles' detection accuracy to eliminate the need for such interventions.

Overall, the user evaluation process has revealed valuable insights about the prototype's performance and usability. While certain aspects require improvement, the prototype has shown promise in aiding amateur soccer players in improving their penalty kick skills. These findings provide a solid foundation for refining the prototype and its feedback system in future iterations.

8. Limitation & Future Work

8.1 Limitation

Limited User Group

The evaluation was conducted with only five UT students, which did not fully represent the diverse skill and interest levels of potential players. The game dynamics, difficulty, and feedback could be perceived differently by different groups of people. This limitation potentially affects the results and observations.

Technical Limitations

While the technical aspects of the game function as intended, some obstacles were not correctly connected with the FSR sensor so that there was often no value after hitting obstacles. Furthermore, hardware limitations such as the size and positioning of obstacles could affect the game difficulty and player engagement.

UI Design

The user interface of the Unity application is functional, but it is not refined. It was designed with a focus on functionality rather than aesthetic appeal. As such, it might not provide an engaging visual experience to the users, potentially impacting user retention and game replayability.

Limited Gameplay Data

The current system only tracks a limited set of data, which may restrict the comprehensiveness of the feedback. It primarily focuses on the approach angle, run-up distance, and successful hits. However, it doesn't track other potentially valuable information such as the speed of the run-up, the kicking power, or the timing of the kick, which could add more depth to the feedback and help users improve their skills further.

8.2 Future Work

User Group Expansion

To address the limitation of a small user group, future evaluations should involve larger and more diverse groups of users. This will provide a broader range of feedback and potentially unveil areas for improvement that were not identified in this project. Moreover, it could allow for more comprehensive data analysis and statistical tests to confirm the findings.

Technical Improvements

To address the technical limitations, improvements could be made to enhance the responsiveness and accuracy of the FSR sensors. Additional measures could be put in place to ensure the correct connection of the sensors with the obstacles. The size and positioning of the obstacles could also be adjusted based on further user feedback to achieve the right balance of game difficulty and player engagement.

UI Enhancement

A more aesthetically pleasing and intuitive UI could be developed to increase user engagement and retention. This could involve graphics improvements, as well as a better layout and interaction design. The UI could also be designed to better cater to the specific needs and preferences of the target user group.

Expanded Data Tracking

To address the limitation of the tracked data, the system could be expanded to track more gameplay data. For example, it could include metrics such as the speed of the run-up, the kicking power, and the timing of the kick. These additional data points could provide users with more detailed feedback and further aid in skill development. A possible future direction could also be the implementation of machine learning algorithms to analyze the collected data and provide personalized feedback and suggestions for improvement.

Enhanced Scoring System

To increase game complexity and player engagement, the scoring system could be improved. Points could be awarded based on the difficulty of hitting specific obstacles, factoring in their size and positioning. This enhancement would add a strategic layer to the gameplay, making it more engaging and challenging.

9. Conclusion

Several problems have been identified with the current penalty kick training methods: they are repetitive, lack clear feedback, and bore the players. To address these issues, this research project aimed to develop a new penalty kick training method incorporating sensor technology and gamification elements. The project started with the generation of research questions aiming to understand the factors influencing penalty kicks, the methods of data collection, comprehensible feedback, and game elements for motivation.

A literature review was first conducted to understand the factors that influence penalty kicks, revealing that the approach angle and run-up distance are key factors affecting penalty kick accuracy. Brainstorming sessions helped identify that the most appropriate method of data collection would involve interactions between users and the game program, facilitated by sensors.

The use of persona and lo-fi prototypes allowed us to determine the type of feedback that was easiest to understand and most preferred by users. To investigate how users would perceive gamification elements, such as a challenge to hit obstacles and the introduction of a point system, a hi-fi prototype was created and tested with five users. The tests confirmed that these gamification elements enabled users to engage in continuous play.

Finally, through the discussion of evaluation test results, it was established that the prototype developed in this project does indeed help users improve their penalty kick skills and encourages continuous play. The system's effectiveness lies in its ability to break the monotony of traditional training, provide clear feedback, and keep players engaged through the strategic use of game dynamics.

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Appendix A. Interview questionnaire

Interview Questions:

1. Were there any difficulties or misunderstandings during gameplay?
2. What are your thoughts on the game rules?
3. What information could you find in the feedback to improve your penalty kicks?
4. How do you plan to use this feedback to improve your penalty kicks?
5. What factors contribute to your enjoyment or interest you?
6. After receiving the feedback, play the game once more using the optimal angle and approach distance obtained from the first session. Did your penalty kick skills improve after receiving the feedback?