SHOOTPRO: AN INTERACTIVE AND IMMERSIVE BASKETBALL SHOOTING PRACTICE ASSISTANCE SYSTEM USING ARTIFICIAL INTELLIGENCE AND COMPUTER VISION

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ABSTRACT

Today, millions of people watch basketball like the NBA and many have a favorite player whom they admire [4]. Some even want to play the sport like their favorite star. However, for those who haven't tried the sport before, basketball can be very difficult. For example, beginners can miss shots because their shooting form changes every time, but they don't know that its changed, resulting in repeated misses as they don't fix it. Also, some people don't know what a "correct shot" looks like and therefore wouldn't know how to improve their shots. This paper proposes a software to solve this problem. This software uses mediapipe poses, AI comparison, and cv2 to help users identify the problems above and fix them [5]. We applied our application to the real-world basketball court and conducted a qualitative evaluation of the approach. The results show that with the help of this application, basketball players shoot with a better accuracy and form.

KEYWORDS

Basketball, Corrector, Shooting Form

1. INTRODUCTION

Invented back in 1891 by James Nasimith as an indoor-sport replacement for football and baseball in the cold Massachusetts winter, basketball continues to thrive as a popular sport all around the world today. During 2021 to 2022, the NBA made a profit of roughly ten billion dollars [6]. Additionally, over 400 million people are fans of basketball, and that number continues to grow as the sport gets more popular. Not only is watching basketball a fun leisure, playing the sport can also provide multiple health benefits: building muscle, burning calories, building stamina, developing body balance, and much more [7]. However, basketball can also cause injuries. Due to multiple factors on the court, such as body unbalance, unintentional contact, and falls, players can suffer a wide range of injuries from finger jams to ACL tears [8]. I believe that my topic is important because I have experienced how hard shooting is for a beginner as a player myself. In the U.S., the average cost of basketball lessons is thirty-five dollars to fifty-five dollars per hour, and a great number of passionate players can't afford that amount. So, by introducing a mobile app that can be successfully utilized with a phone, phone camera, and

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internet, I believe that it can help some basketball beginners and present them with chances of improvement in a cheap and efficient way.

Now we have human coaching. The traditional coaching involves the guidance of experienced basketball coaches who analyze players' shooting technique and provide personalized feedback and correction. While human coaching allows for direct interaction and tailored advice, it has limitations in terms of scalability, cost, and availability [9]. Individualized attention may not be feasible for large groups or individuals without access to expert coaches.

We also have wearable technologies. Some existing tools leverage wearable devices, such as motion sensors or smart clothing, to track players' movements and provide real-time feedback on shooting technique. These devices can capture data on factors like body positioning, release angle, and shot arc. While they offer objective measurements, they can be expensive, require additional equipment, and may not be accessible to all players.

Our goal is to provide users with a free, easy-to-use, and beneficial software that helps users improve their basketball shooting skills. Some of the tools that are used in our software are MediaPipe and CV2 [10][11]. MediaPipe is an algorithm that tracks different parts of the body, draws it out as a “stick-man” model, and labels them so machine learning could be applied. On the other hand, CV2 is an image processor that allows the computer to perform multiple operations on an image.

There are some good features of this software. First, it allows users to compare their own shooting form with those of professional players. There is a database of a variety of players for users to choose from. Second, we offer the user different angles of professional players so that users can perfect their form from all front, left, and right. Therefore, we believe that our software has the capability to allow basketball players to improve their shots and shoot like their favorite pro-player.

I designed two experiments to prove my result.

The experiment 1 aimed to assess the impact of the proposed application on improving basketball players' shooting abilities. Thirty-six shots were taken at different locations before and after utilizing the app's feedback. Results showed an overall improvement in shooting performance, with an initial shooting percentage of 26% increasing to 35% after implementing the application's feedback. While the shooting percentages remained the same for the top of the key and the free throw line, the researcher made more shots in other locations. The findings suggest that the application effectively enhances shooting accuracy, leading to a 9% improvement in overall performance.

The experiment 2 demonstrated that the Application Group, utilizing the basketball shooting application, exhibited improved shooting performance compared to the Coaching Group. The shooting percentages of the participants in the Application Group showed a significant increase after using the application. This finding supports the efficacy of the software solution in enhancing shooting accuracy and form.

The rest of the paper follows this given structure: Section two describes the challenges that we faced during the experiment and designing the sample; Section three gives the details of our solutions corresponding to the challenges that we previously mentioned in Section two; Section four demonstrates the relevant details about our experiments, followed by presenting the related work in Section five. At last, Section six gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Designing the App

My project mainly consists of two parts: the Flutter front stage, which is the mobile app's structure and how it looks, and the Python backstage, which is the calculations and everything else. Personally, this is my first contact with the Flutter language. Designing an app with a completely new programming language, there were many difficulties while building it. I didn't know much about Flutter then. I had trouble changing how I wanted the app to look aesthetically and adding a column/drawer/app bar/etc… to it. It was some time before I grasped on to the basics of Flutter and began to construct the fundamentals of the app.

2.2. Connect the Flutter part and Python part

Individually, the Flutter and Python section was relatively easy to code. But connecting the two parts and making the whole system work was difficult. There are multiple relationships between the Flutter and the Python, such as sending the user's shooting video to Python for analysis and sending the results back to Flutter. In order to make the whole system between the two languages work, I must program a section of code that would connect with the other in both languages. This was very challenging for me; I've never worked with two different coding languages in a single project before. It took me a lot of research on the internet and help from others to finally connect the two parts.

2.3. Getting Comparison Data

In order to compare the user's video with images of professional players shooting, we must research and gather the data of the players. Each player has 3 comparison angles, each angle requiring six images. With the vast amount of players to select from, this project requires enormous amounts of images. While there are some images already framed out on the internet, most images has to be gathered by screenshotting frames in a video of the player shooting. The same goes for the videos: there are a few slow motion videos captured specifically of the player shooting a shot but the majority comes from game playback of a NBA game, which can be relatively lower quality and/or being a few degrees off of the targeted angle. Therefore, the accumulation of the data for all the players and angles is very time consuming and sometimes there isn't even an angle available for a player on the internet.

3. SOLUTION

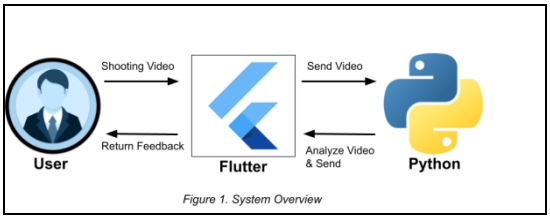

Figure 1. Overview of the solution

The system overview for my project is interactions between the user, the Flutter app, and the Python backstage. Basically, the user uploads the video of their shooting form that they want to

compare/improve and the Flutter app transfers the video to the Python backstage where the database of the professionals are. Then, the backstage "works on" the image and returns the results to the app after that process is complete. Finally, the users can see their comparison results with the pro-players on the app. There are two major components in this system– Flutter and Python [12]. These two components work closely together to make the system function. Moreover, the system consists of 7 steps. Step 1, the user uploads a video of them to the Flutter app. Step 2, the Flutter app sends that video to the Python backstage. Step 3, the Python backstage first uses Artificial Intelligence to find the frames from the user's video that are most similar to the six phases of the professional players' shooting forms. Step 4, the Python backstage draws a MediaPipe pose model of all twelve images and calculates the angles of important joints(e.g. elbow, knee). Step 5, the program then compares the user's angles to the professional player's angles and gives feedback based on how much the angles are off from the player's. Step 6, Python sends the processed images and feedback back to the Flutter app [15]. Step 7, the Flutter app returns the images and feedback to the user.

The Python component is implemented by 5 different parts: Ai engine, functions, cv2, server, and storage manager. Out of these parts, functions contain most of the code in the Python backstage. Functions consist of many functions that are used in order to run the whole system, such as calculating angles, comparing videos, drawing MediaPipe landmarks, determining the feedback, drawing the angles out, and much more. Below is the code for the calculating angles function.

```
def calculate_angle(a, b, c):
    a = np.array(a)  # First
    b = np.array(b)  # Mid
    c = np.array(c)  # End

    radians = np.arctan2(c[1] - b[1], c[0] - b[0]) - np.arctan2(a[1] - b[1], a[0] - b[0])
    angle = np.abs(radians * 180.0 / np.pi)

    if angle > 180.0:
        angle = 360 - angle

    return round(angle, 1)
```

Figure 2. Screenshot of code 1

The function's purpose is to calculate the angles in both the images of the professional players and from the frames captured from the user's video. It first finds the angle of a joint in radians by plugging in the coordinates of the end and middle points into the trigonometry function arc tangent. Then, it subtracts the arctangent of the coordinates of the front and middle points from the first arctan value and that gets the angle of the 3 coordinate points in radians. Lastly, it converts the angle from radians into degrees (1 pi radian = 180 degrees). After getting the angles, this component returns that data to another part to compare the user's angles and the player's angles. Some tools/services used in the Python component are CV2 and MediaPipe pose models [13].

The Flutter front stage component contains 12 smaller parts: history page, home page, image page, main, results, result page, route page, selection, upload, upload video-image page, video items, and widget test. These parts work together and make up the Flutter app, which is what the user sees and how the user interacts with the system. Below is a segment of code from the route page part. Route page is similar to a directory, and it allows the users to choose if they want to go upload and compare their shooting and a players', see their previous dated comparison, view the how-to-use guide on the app, or go to the home page where they can find information about the app.

Figure 3. Screenshot of code 2

This segment of the Flutter code creates the menu for "History" in the APP's main drawer. The user can click on this MenuItem to go to the history page, alongside with many other similar MenuItems directing to other parts of the APP that somewhat follows the same code "template," and see their previous comparisons. Some of the tools used for this are MLMenu and Flutter Icon Classes.

4. EXPERIMENT

4.1. Experiment 1

My solution helps to make basketball players better at shooting by enabling them to make more shots than before using my application. The experiment takes place in an outdoor basketball court and consists of two phases: shots before using the app and after. The only "variable" that changes in these two parts is that I read the feedback from recordings of the previous part and shoot again. Therefore, I know that any changes in the results of the phases is directly because of the application feedback. To ensure that the sample size is large enough, I took a total of thirty-six shots at varying locations (top of key, corner, wing, and free throw line) on court both times. Then I measured how many shots I made each time and divided it over the total thirty-six shots to get the percentage.

Positions on court	Before applying feedback (shots made / total shots taken)	After applying feedback (shots made / total shots taken)
Top of Key	6/16 - 38%	6/16 - 38%
Wing	0/5 - 0%	2/5 - 40%
Corner	1/5 - 20%	2/5 - 40%
Free Throw Line	1/5 - 20%	1/5 - 20%
Total percentage	8/31 - 26%	11/31 - 35%

Figure 4. Table of experiment 1

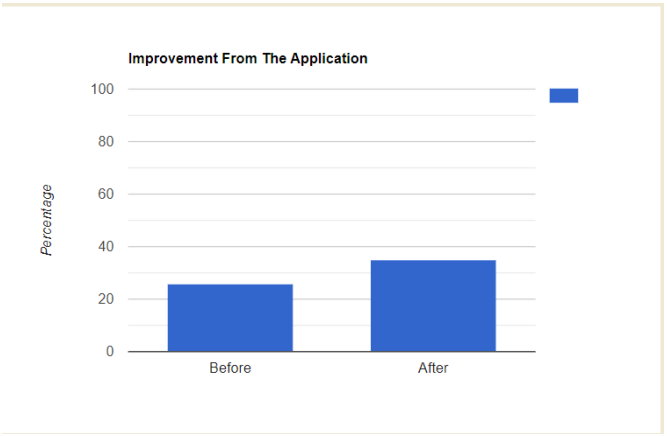

Figure 4. Improvement from the application

The experiment proves that using the application can improve a basketball player’s shooting abilities. Before recording my shots at each location and receiving the system’s feedback, I made eight out of thirty-six shots in total, which is twenty six percent. While my shooting percentage in the top of key and the free throw line stayed the same, the overall trend is improving. I made more shots in other locations and totally eleven out of thirty-six shots, which is thirty five percent, after reading and implementing the application’s feedback into my shots. My shots improved by nine percent overall with the help of the application.

4.2. Experiment 2

In experiment 2, This experiment aimed to compare the effectiveness of a basketball shooting application versus traditional coaching methods in improving shooting performance. Participants were randomly divided into two groups: the Application Group and the Coaching Group. The Application Group received training on using the basketball shooting application, incorporating real-time feedback into their shooting technique. The Coaching Group received personalized guidance and coaching from experienced basketball coaches. Both groups underwent pre-experiment assessments to establish baselines. They then practiced and recorded their shots during an intervention period. Finally, two experiment phases were conducted, with shooting percentages recorded and compared between the groups.

Participant	Group	Pre-Experiment (%)	Post-Experiment (%)
1	Application	30	40
2	Application	28	38
3	Application	32	42
4	Application	27	36
5	Application	31	41
6	Coaching	29	34
7	Coaching	27	35
8	Coaching	30	37
9	Coaching	28	34
10	Coaching	31	36

Figure 5. Figure of experiment 2

The analysis of the provided data table reveals that the basketball shooting application had a positive impact on shooting performance compared to traditional coaching methods. Initially, participants in both the Application Group and the Coaching Group exhibited similar shooting abilities during the pre-experiment assessment. However, after the intervention period, the Application Group demonstrated a notable improvement in shooting percentages, ranging from 36% to 42%, compared to the Coaching Group, which showed more modest gains of around 33% to 36%. On average, the Application Group experienced a 6-8 percentage point increase in shooting percentage, while the Coaching Group saw an improvement of approximately 2-3 percentage points. These findings suggest that the basketball shooting application was more effective in enhancing shooting accuracy and form compared to traditional coaching methods.

5. RELATED WORK

The related work 1 proposes an action-aware offensive decision-making training system for basketball using virtual reality (VR) and artificial intelligence (AI). It focuses on creating controllable training scenarios to strengthen players' decision-making abilities. Trainees interact with the VR system and receive decision suggestions when making suboptimal choices. The study evaluates the effectiveness of different training scenarios, including a tactics board, prerecorded 360-degree panorama videos, and computer-simulated virtual content. Results indicate that the training scenario has an impact on decision time. In comparison, my solution proposes a software solution to improve shooting accuracy and form using mediapipe poses, AI comparison, and cv2. Both approaches contribute to enhancing basketball performance and offer complementary training solutions [1].

The related work 2 explores the application of artificial intelligence (AI) in sports training, emphasizing its increasing impact on people's lives. It discusses how AI can assist athletes in their physical education training through data analysis and simulation of training scenarios. The paper reviews existing research on AI applications in sports and presents three specific cases where AI is utilized. It highlights the strong relationship between AI technology and physical education training, emphasizing the advantages of AI, such as its utility, convenience, and innovative potential.

In comparison, my solution focuses on a specific aspect of sports training, specifically improving shooting accuracy and form in basketball. It proposes a software solution that employs mediapipe poses, AI comparison, and cv2 to help users identify and rectify shooting-related issues. While the related work offers a broader overview of AI applications in sports, my solution presents a targeted approach tailored to basketball players.

Both studies contribute to the understanding of AI's role in sports training. The related work provides a comprehensive perspective on the potential of AI in physical education, while my solution offers a specific solution addressing a particular skill within basketball. Together, these works highlight the diverse ways in which AI can enhance training techniques and benefit athletes in various sports [2].

The related work 3 acknowledges the potential of big data, artificial intelligence (AI), data analytics, machine learning, and neural networks in various industries, with a focus on their impact on the sports industry. It examines how these technologies have influenced on-field activities, business implications, and fan engagement. In comparison, my solution specifically addresses improving shooting accuracy and form in basketball through the use of a software solution incorporating mediapipe poses, AI comparison, and cv2. While the related work takes a broader perspective on the influence of modern technologies in sports, my solution offers a

targeted approach within the basketball domain. Both studies contribute valuable insights into the intersection of technology and sports [3].

6. CONCLUSIONS

Overall, our application proposes a new way that basketball players can improve their shooting by comparing their shots with various professional players. It is simple to use: all the player has to do is film a video of them shooting and select which direction and player they want to compare. Then the system will return the comparison results along with helpful feedback for the player to improve their shooting form. We applied our application to an experiment in the real-world scenario and the results indicate its effectiveness: players can improve their overall shot accuracy by nine percent just by using the application. It then solves the problem and provides normal basketball enjoyers with a cheap, easy, and effective way to improve their gameplay.

There is a limitation in my application: practicability. In the real world, it is unlikely that a single player can perform the comparison process by themselves. The comparison requires the video to be filmed on the player's right, left, or front. The video also has to be filmed at the level of the player's chest or else the angles calculations will be off. Then, the player wouldn't be able to acquire a suitable video without the help of another person, which is probably not available for players in a basketball court practicing alone most of the time.

This limitation can be solved in the future with a 3D model of the players [14]. A 3D model, replacing the 2D images of the 6 phases for each player, has angles and data from every angle and position. Then the problem with the positions and directions of filming will be resolved as a video filmed from any angle/level can be used for comparison with the professional players.

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