Computer Vision for Volleyball Serve Classification

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Abstract

In this paper we investigated building a machine-learning based computer vision application to identify and classify volleyball serves based on player movement. This project was written in an OpenCV environment. Given a single camera angle of a given serve video, we used a Hough transform to translate the end line of a volleyball court to identify foot faults, and a pre-trained R-CNN to identify the player. By analyzing the relative positioning of different joints of the player's body — including hips, shoulders, elbows, and wrists — and their changes, we hoped to provide an accurate differentiation of serves.

[primary findings]

[results and conclusion]

1 Introduction

Sports are an integral part of many of our lives. Whether commiserating over a Super Bowl loss, competing in a volleyball tournament, or just playing pickup, these experiences with sports serve as a crucial avenue for community bonding — especially given the dearth of walkable cities and third spaces in states like Ohio.

1.1 Background on Technology Advancements in Sports

As the interest, engagement, and market capitalization of sports leagues such as the NFL and NBA has skyrocketed, so too has the attention given towards the training athletes receive. Technological advancement has benefited training techniques across the board. Sports medicine, film study, and coaching schemes have all evolved in tandem with strides in medical science, computer vision, and statistical analysis.

1.2 Background on Computer Vision

Computer vision is, as the name suggests, a field of artificial intelligence dedicated to enabling computers to derive visual information. It involves developing algorithms and techniques to extract meaningful insights from images or videos. This encompasses a wide range of tasks, such as object detection, image classification, facial recognition, and scene understanding. Convolutional Neural Network (CNN) and derivative neural networks have become dominant in computer vision. CNN is optimized for processing data with a grid patterns, such as images, and has adaptive learning properties that lend well towards pattern analysis.

2 Active Computer Vision Implementations in Sports

Computer Vision in particular has seen some of the greatest advances in importance and usage in sports with the growth of sports analytics — with plenty of room for future innovation.

2.1 Computer Vision in the NFL

In the NFL, film study is a cornerstone of game preparation. Coaches and players analyze game footage to understand opponent tendencies, strategize plays, and improve individual and team performance. Computer vision plays a crucial role in this process, allowing for automated player tracking, play recognition, and statistical analysis. Computer vision can also benefit teams and players in more subtle ways, such as injury prevention. Modern NFL uniforms are equipped with RFID sensors and receivers allowing the league to track and analyze player movement. The league uses this information in conjunction with high-resolution, high-frame-rate cameras to gain insights into how different plays and movements impact player safety. [3]

2.2 Computer Vision in the NBA

Similar to the NFL, the NBA relies heavily on film study for game analysis and player development. Computer vision technologies enable coaches and analysts to track player movements, identify offensive and defensive patterns, and provide valuable insights into optimizing game strategies.

2.3 Film Study for Volleyball

While not as widely adopted as in major professional sports leagues, volleyball teams have also started using computer vision for film study. Systems have been developed to track player movements, analyze ball trajectories, and provide performance feedback to players and coaches. A stellar example of this has been the startup Balltime, which within a few years has expanded into a host of teams from youth clubs to top collegiate teams such as Long Beach State. [1]

2.4 Project Goals

My project aims to build on existing technological advancements in player training. In this project, I will implement a machine-learning based computer vision application to identify

different kinds of volleyball serves. My hope is this application will allow experienced players to analyze and tweak their serve performance without a coach, through providing descriptive statistics on their technique.

3 Components of Volleyball Computer Vision Project

Implementing computer vision involves a number of iterative steps. The work by Cheshire, Halasz, and Perin provides a relatively strong template for 2d image processing with object detection, which is most relevant for analyzing single angle videos of volleyball serves. This project used position tracking and 2d court reconstruction to represent basketball players and their on-court movements based off clips pulled from YouTube, identifying five total steps 1. Court Detection 2. Pedestrian Detection 3. Color Classification 4. Player Tracking and 5. Mapping. [2] While not all 5 steps are relevant to this program, this approach provides a solid framework to tackle this project with.

3.1 Court Detection

Timothy Lee's project Automating NFL Film Study: Using Computer Vision to Analyze All-22 NFL Film, while using similar methods as other sports video analysis papers, is differentiated by the extraction of relevant information about football plays using only recorded video from one camera. [4] This is useful as many beach volleyball clips, even at the highest level, may only cover one or two camera angles (and usually never simultaneously. Timothy Lee used vertical yardlines and horizontal hashmarks from the NFL field to identify and subsequent reconstruct the field from one shot, utilizing a Hough transform (see figure 1 on page 7).

3.1.1 Pedestrian Detection, Color Classification, Player Tracking, and Mapping

Object detection is often the most important component and the biggest challenge, with a variety of environmental factors impacting the algorithms efficacy. Each sport has unique challenges and as such requires tweaked models. Most sports-based papers referenced in this project, including Cheshire et al. and Timothy Lee, work hand in hand with color

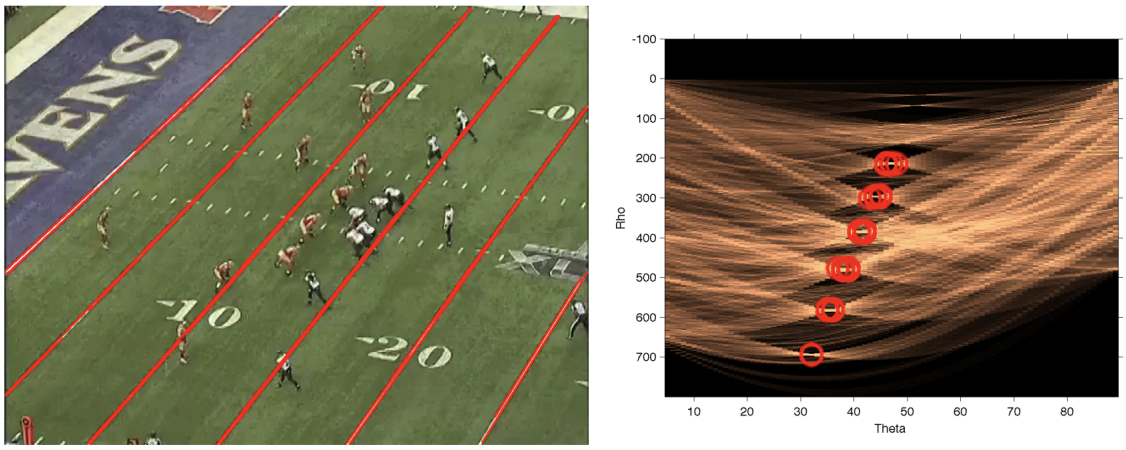

Figure 1: Timothy Lee: Automatic detection of yardlines on a football field (left) using the Hough transform (right).

classification for object detection to identify teams. This approach is largely irrelevant in analyzing a single clip of a volleyball server.

For the sake of this project, I am aiming to identify a server and the different joints of their body — including hips, shoulders, elbows, and wrists as the primary components to identify types of serves. Previous literature exists examining serve type detection based on ball movements and trajectories. [5] However, no publicly available research has covered serve type detection based on player movement itself. Effective player movement analysis has positive implications not only for serve types but also to provide feedback on body mechanics, training, and player safety.

As such, the program is built around the detailed identification of a single server with little consideration to differentiating them from other players not included in the shot. An effective approach to achieve this task would be to utilize a pre-trained detection model based on the R-CNN (Region-based Convolutional Neural Network) architecture.

4 Results and Analysis

5 Conclusion

6 Acknowledgement

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