Real-Time Table Tennis Scoring and Player Position Tracking System Using Computer Vision

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Abstract

This study focuses on developing a system that uses state-of-the-art computer vision techniques to improve the accuracy and efficiency of table tennis tracking. The table tennis ball's trajectory and movement are tracked automatically by the system using a mobile camera array, allowing for real-time score updates without the need for human participation. This method guarantees precise and seamless scoring, freeing players from worrying about maintaining score and allowing them to concentrate fully on the game. The system uses player pose estimation technologies in addition to real-time scoring to track and record player positions and motions during the match. The system may provide a thorough study of player motions, including tracking posture and finding important motion patterns, by gathering and analyzing skeletal data.

Keywords: Computer vision paper, Table Tennis Scoring Player, Pose Estimation,Real-Time Tracking, Human Posture Analysis, Machine Learning, Sports Technology

1. Introduction

This project focuses on the development of a real-time scoring system for table tennis in particular, using advanced computer vision techniques to monitor the movement of the ball on the table. The system is designed to provide accurate and fast scoring , enabling players to fully focus on their game. It provides an essential tool for both training and tournament environments, ensuring that the scores are accurate and reliable. Two-ball tracking algorithms are used , both relying on color-based imaging techniques to detect orange ping-pong balls. Calibrate these algorithms to accommodate different lighting conditions, ensuring a stable performance in various places. Mobile cameras are often used for tracking as they are more accessible and easier to use.

The significance of this system is its ability to maintain the integrity of the game by providing a simple and accurate method of scoring. Traditionally, table tennis scoring is based on hand tracking, prone to human error, especially in fast-paced games where the ball moves quickly and unpredictably. By integrating computer vision, the system mitigates these errors, ensuring that every point is accurately recorded. This innovation is particularly beneficial in training scenarios, where consistent scoring can help players focus on improving their techniques without the distraction of monitoring scores.

Additionally, the project addresses the challenges posed by different performance spaces, such as varying lighting and camera placement .The algorithms used in this system are designed to be flexible, allowing for adjustments to color detection limits during the calibration process. This flexibility ensures that the system can maintain high accuracy in a variety of situations, be it professional environments or random learning. The flexibility of the system makes it a versatile tool, suitable for a wide range of activities from amateur leagues to professional competitions.

Besides the primary focus which is on ball tracking and real-time scoring, the system integrates a second valuable feature: player pose estimation. This feature enhances analysis by tracking skeletal points such as the head, shoulders and limbs, and providing insight into player techniques allowing coaches and athletes to identify areas for improvement, making the system a comprehensive tool for teaching. The potential future enhancements, such as real-time feedback and comprehensive performance metrics, position this project as more than just an automated scoring solution; it's a platform in order to provide sports technology that has advanced.

This project combines real-time ball tracking, accurate scoring, and player position estimates, driving innovation in sports technology and increasing scoring accuracy and player performance analysis.

2. Methodology

This work focuses on the integration of real-time ball tracking and pose statistics to develop a comprehensive table tennis game tracking system. The methodology is divided into four main parts: video input and preprocessing, ball tracking, pose estimation, and game state tracking and scoring.

I). Video compression and preprocessing:

Hardware Configuration: Video input is recorded using an Android device camera connected to a PC via USB. The Android device is mounted on a tripod, ensuring that it captures the view from the top of the table tennis table. This setup ensures that the entire pitch is covered and both players are in the camera's field of view.

Software and Tools: The DroidCam application transfers a video feed from an Android device to a PC, where it is processed using OpenCV. The video images are converted from RGB to YCbCr color space to improve the visibility of the orange ping-pong ball and to facilitate the extraction of player bones for identity estimation.It recognizes the head, shoulders, wrists, elbows, hips, knees and ankles. The extracted keypoints are processed to filter out the noise, project missing data, and normalize the key points according to the player's position on the table.

II). Ball tracking:

This system uses two algorithms to track the table tennis ball:

Contour search settings: This algorithm detects the contour of the orange ball in each video frame. Color separation of the ball from the background is used, followed by edge detection to determine the boundaries of the ball. The known contours are then analyzed to determine the position of the ball. The system is designed to provide optimal color boundaries based on ambient lighting conditions.

Hotbox search engine: This algorithm divides each video frame into a grid of boxes. The system calculates the number of pixels in each box that correspond to the color of the ping-pong ball. The box with the highest count is supposed to be the "hotbox," which is supposed to contain the ball. This approach ensures proper and consistent follow-up.

Calibration Process: During the calibration process, the system adjusts the color thresholds for the orange ball using a calibration script. The user places ping-pong balls on the table and runs the script to determine the optimal color range for detecting the ball in the given environment. The resulting color thresholds are then applied to the ball tracking algorithms to ensure accurate detection.

III). Pose Estimation:

While the current iteration of the project focuses primarily on ball tracking, the system is designed with the further integration of player pose estimation in mind.

The Lightweight OpenPose Model: This model is used to extract skeletal highlights of players from the video feed. This model is optimized for performance, making it suitable for real-time applications.

The flowchart below shows the steps in the pose estimation and player action analysis process, from capturing player poses to analyzing actions and providing real-time feedback & which describes how the system processes skeletal data. Joint positions are normalized, and it classifies player actions using machine learning models , ultimately providing methods that can be used to improve performance while playing.

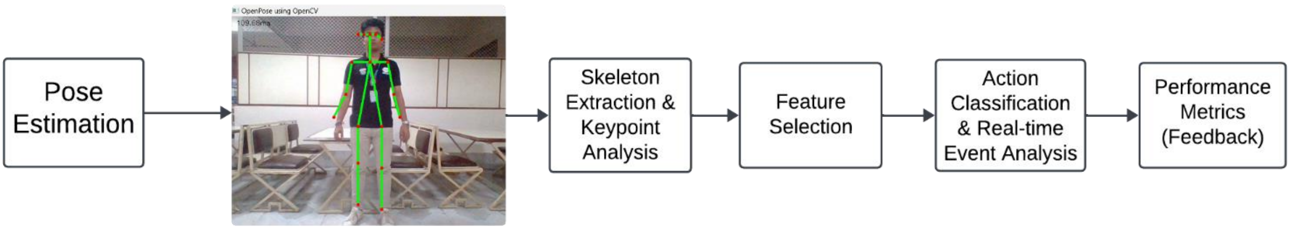

Fig 2.3.1:-Pose Estimation and Analysis Pipeline for Table Tennis Tracking.

Key Point Feature Selection: After obtaining the skeleton points, the system performs feature extraction to identify and classify player actions. The system normalizes joint positions relative to the bounding box, ensuring that the feature data is accurate despite changes in camera angle, player position and movement speed.

Action Recognition and Classification: The system uses a support vector machine (SVM) classification model to learn specific table tennis actions based on the extracted skeletal elements. The SVM model is trained on a data set of table tennis actions to accurately classify actions such as forehand strokes, backhand shots and serves.

Real-time event analysis: In order to evaluate player performance the system uses the Dynamic Time Warping (DTW) algorithm, which compares player's current actions to predefined action templates. DTW algorithm calculates the similarity of player action sequences and standard sequences, and provides real-time analysis of player mechanics. Low action scores are flagged for further analysis where the player's can improve.

IV). Game state tracking and scoring:

Finite State Machine (FSM) Theory: The state of the game is controlled by the Finite State Machine (FSM) which controls the transitions between different states of the game, such as "Pre-Serve", "Serve", "In-Play", "Game Over". Then the FSM back starts in "Pre-Serve" mode, after the server has settled the ball waits for it to be lifted up, which means he is ready to serve. Once the serve is detected, the FSM switches to "In-Play" mode, where it monitors ball movement, looking for bounces, hits and side switches. The flowchart below shows the structure of the FSM, showing the different states and the conditions that trigger transitions between them. This visual representation helps to clarify the ongoing understanding of game environment management.

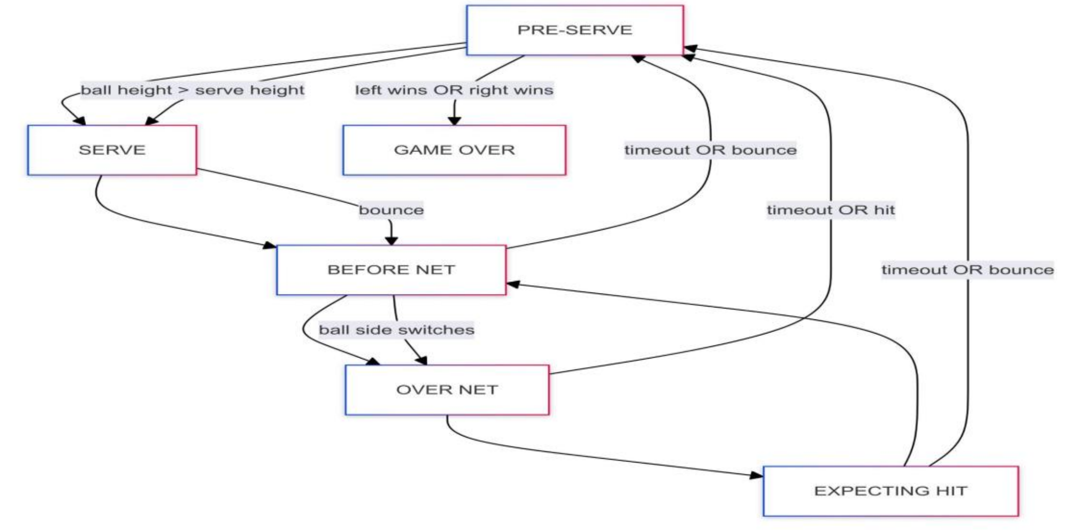

Fig 2.4.1:- State transition diagram of table tennis playing platforms.

Scoring Mechanism:- The FSM provides points based on the ball trajectory and actions detected by the ball tracking and position prediction systems. For example, if the ball bounces twice on the same side of the table, the opponent is awarded a point. The system uses audio cues to notify players of state changes, such as when a point has been scored or when it's the server's turn to serve.

Display and User Interface:- Real-time scores are displayed via a VGA output on a monitor connected to the PC, superimposed on the game's live video feed. The admin page allows the administrator to manually adjust scores, start or end games, and access other game management features.

3. Results

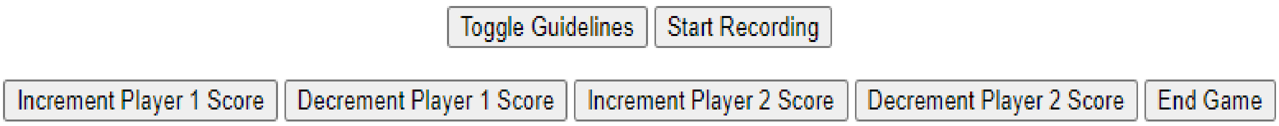

Fig 3.1:- This image displays the Desk Tennis Tracker administrator access interface, where the administrator can input credentials to benefit and get admission to the remaining controls.

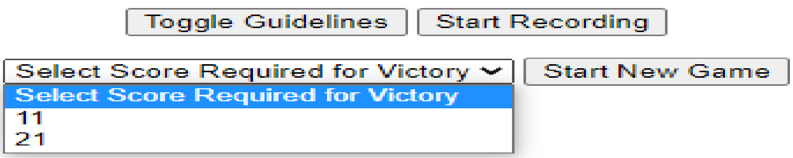

Fig 3.2:- This image provides admin procedures for setting up new games, selecting the points needed to win, and additional controls for starting new games, toggling and recording suggestions.

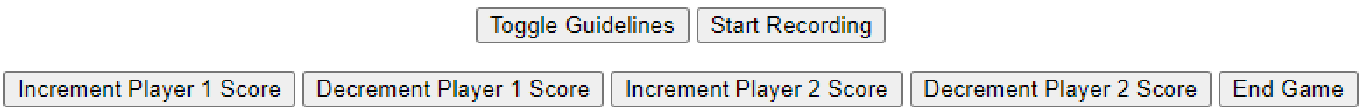

Fig 3.3:- This image shows the admin controls for dealing with the rating at some stage in table tennis, along with options to increment or decrement the players' rankings, begin recording, and stop the sport.

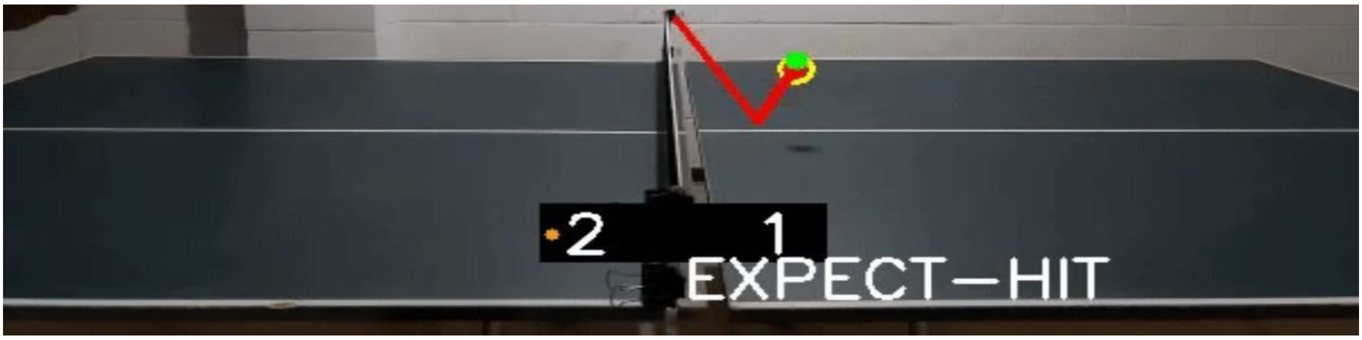

Fig 3.4:- This image illustrates the functioning of the ball tracking system, in the "Expect Hit" mode showcasing its path and the score display that emerges during gameplay.

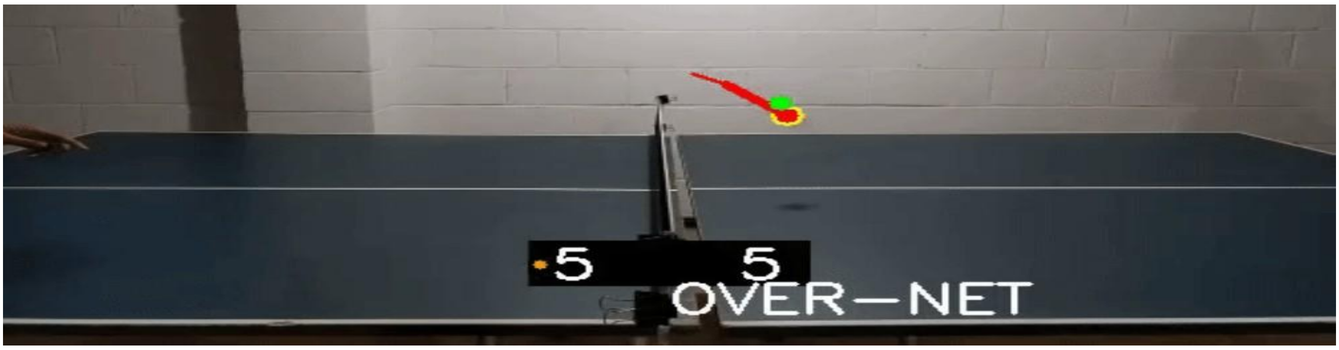

Fig 3.5:- This Figure shows the system for tracking the ball as it moves towards the net where the score has been updated and the status is labeled "Over Net".

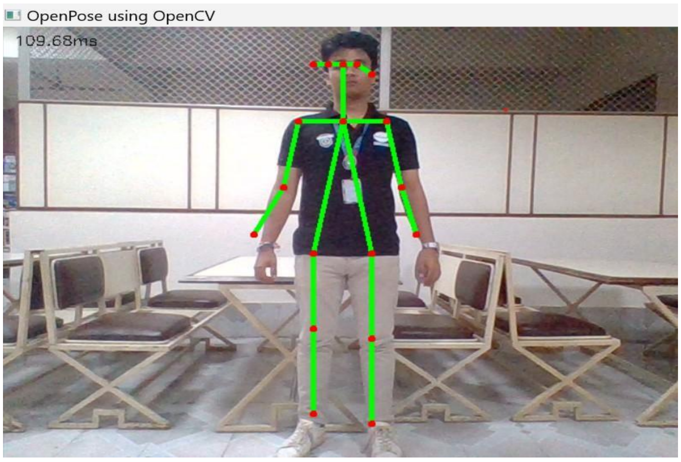

Fig 3.6:- This figure indicates the results of the pose estimation technique, where the skeletal points for the participant are detected using the OpenPose version, which demonstrates the device's capability to tune the participant's motion.

4. Conclusion

The "Real-Time Table Tennis Scoring and Player Position Tracking System Using Computer Vision" integrates ball tracking and human posture estimation technologies to create an all-in-one analysis system for table tennis games. This platform combines the precise ball localization capability of the Table Tennis Tracker with the advanced Human Table Tennis Actions Recognition and Evaluation model. As a result, the application not only tracks ball paths and provides live scores but also offers an in-depth analysis of player movements. The initial phase of player analysis has been achieved using the OpenPose-Lightweight model which effectively detects key body parts in players.

Furthermore, comparing against world class table tennis player postures can help "Real-Time Table Tennis Scoring and Player Position Tracking System Using Computer Vision". The system compares player postures against ideal standards, providing a percentage score that indicates how closely a player's position aligns with the ideal, offering actionable insights for immediate improvement.

While the paper has a solid foundation in combining ball tracking and position analysis innovatively, it could benefit from clearer language, more effective graphical integration, and more detailed conclusions to fully realize the depth of the research. In conclusion, the work not only meets the current needs of automated scoring in table tennis but also lays the foundation for future developments in player-performance research by going forward refining the system and exploring other features.

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6. Refrences

1. Tan, D. Y. W., H. Y. Ting, and S. B. Y. Lau. "A review on badminton motion analysis." In *2016 International Conference on Robotics, Automation and Sciences (ICORAS)*, pp. 1-4. IEEE, 2016.
2. Bonidia, Robson P., Luiz A. L. Rodrigues, Anderson P. Avila-Santos, Danilo S. Sanches, and Jacques D. Brancher. "Computational intelligence in sports: A systematic literature review." *Advances in Human-Computer Interaction* 2018 (2018).
3. Rahmad, Nur Azmina, Muhammad Amir As'Ari, Nurul Fathiah Ghazali, Norazman Shahar, and Nur Anis Jasmin Sufri. "A survey of video based action recognition in sports." *Indonesian Journal of Electrical Engineering and Computer Science* 11, no. 3 (2018): 987-993.
4. van der Kruk, Eline, and Marco M. Reijne. "Accuracy of human motion capture systems for sport applications; state-of-the-art review." *European journal of sport science* 18, no. 6 (2018): 806-819.
5. Manafifard, Mehrtash, Hamid Ebadi, and H. AbrishamiMoghaddam. "A survey on player tracking in soccer videos." *Computer Vision and Image Understanding* 159 (2017): 19-46.
6. Thomas, Graham, Rikke Gade, Thomas B. Moeslund, Peter Carr, and Adrian Hilton. "Computer vision for sports: Current applications and research topics." *Computer Vision and Image Understanding* 159 (2017): 3-18.
7. Cust, Emily E., Alice J. Sweeting, Kevin Ball, and Sam Robertson. "Machine and deep learning for sport-specific movement recognition: a systematic review of model development and performance." *Journal of sports sciences* 37, no. 5 (2019): 568-600.
8. Kamble, Paresh R., Avinash G. Keskar, and Kishor M. Bhurchandi. "Ball tracking in sports: a

survey."*Artificial Intelligence Review* 52, no. 3 (2019): 1655-1705.
9. Shih, Huang-Chia. "A survey of content-aware video analysis for sports." *IEEE Transactions on Circuits and Systems for Video Technology* 28, no. 5 (2017): 1212-1231.
10. Beal, Ryan, Timothy J. Norman, and Sarvapali D. Ramchurn. "Artificial intelligence for team sports: a survey." *The Knowledge Engineering Review* 34 (2019).
11. Apostolidis, Evlampios, Eleni Adamantidou, Alexandros I. Metsai, Vasileios Mezaris, and Ioannis Patras. "Video Summarization Using Deep Neural Networks: A Survey." *arXiv preprint arXiv:2101.06072* (2021).
12. Kini, Sowmya. "Real Time Moving Vehicle Congestion Detection and Tracking using OpenCV." *Turkish Journal of Computer and Mathematics Education (TURCOMAT)* 12, no. 10 (2021): 273-279.
13. Davis, Michael. "Investigation into tracking football players from single viewpoint video sequences." *Bachelor of Science, in Computer Science, The University of Bath* (2008): 147.
14. Spagnolo, P., N. Mosca, M. Nitti, and A. Distante. "An unsupervised approach for segmentation and clustering of soccer players." In *International Machine Vision and Image Processing Conference (IMVIP 2007)*, pp. 133-142. IEEE, 2007.
15. Le Troter, Arnaud, Sebastien Mavromatis, and Jean Sequeira. "Soccer field detection in video images using color and spatial coherence." In *International Conference Image Analysis and Recognition*, pp. 265-272. Springer, Berlin, Heidelberg, 2004.
16. Heydari, Mohammad, and Amir Masoud Eftekhari Moghadam. "An MLP-based player detection and tracking in broadcast soccer video." In *2012 International Conference of Robotics and Artificial Intelligence*, pp. 195-199. IEEE, 2012.
17. Barnard, Mark, and J-M. Odobez. "Robust playfield segmentation using MAP adaptation." In *Proceedings of the 17th International Conference on Pattern Recognition, 2004. ICPR 2004.*, vol. 3, pp. 610-613. IEEE, 2004.
18. Pallavi, V., Jayanta Mukherjee, Arun K. Majumdar, and Shamik Sural. "Graph-based multiplayer detection and tracking in broadcast soccer videos." *IEEE Transactions on Multimedia* 10, no. 5 (2008): 794-805.
19. Ul Huda, Noor, Kasper H. Jensen, Rikke Gade, and Thomas B. Moeslund. "Estimating the number of soccer players using simulation-based occlusion handling." In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*,pp. 1824-1833. 2018.
20. Ohno, Yoshinori, Jun Miura, and Yoshiaki Shirai. "Tracking players and estimation of the 3D position of a ball in soccer games." In *Proceedings 15th International Conference on Pattern Recognition. ICPR-2000*, vol. 1, pp. 145-148. IEEE, 2000.
21. Santiago, Catarina B., Armando Sousa, Luís Paulo Reis, and Maria Luísa Estriga. "Real time colour based player tracking in indoor sports." In *Computational Vision and Medical Image Processing*, pp. 17-35. Springer, Dordrecht, 2011.
22. Ren, Jinchang, James Orwell, Graeme A. Jones, and Ming Xu. "Tracking the soccer ball using multiple fixed cameras." *Computer Vision and Image Understanding* 113, no. 5 (2009): 633-642.
23. Kasuya, Nozomu, Itaru Kitahara, Yoshinari Kameda, and Yuichi Ohta. "Real-time soccer player tracking method by utilizing shadow regions." In *Proceedings of the 18th ACM international conference on Multimedia*, pp. 1319-1322. 2010.
24. Homayounfar, Namdar, Sanja Fidler, and Raquel Urtasun. "Sports field localization via deep structured models." In *Proceedings of the IEEE Conference on Computer Vision and Pattern*

Recognition, pp. 5212-5220. 2017.
25. "Analyzing Table Tennis Tactics from Strokes Using Deep Reinforcement Learning" - J. Wu, H. Xu, IEEE Transactions on Neural Networks and Learning Systems, 2020.
26. Conaire, Ciarán Ó., Philip Kelly, Damien Connaghan, and Noel E. O'Connor. "Tennissense: A platform for extracting semantic information from multi-camera tennis data." In *2009 16th International Conference on Digital Signal Processing*, pp. 1-6. IEEE, 2009.