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Project Synopsis Template (2024-25) - Sem VII

AI-Driven Table Tennis Scoring and Ball Speed Tracking

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Abstract :-

This project aims to develop an advanced table tennis detection and scoring system using computer vision techniques with OpenCV. The system is designed to track the table tennis ball in real-time, calculate its speed, and update the scores for both players[3]. It employs template matching for table and net detection, edge and corner detection for line identification, and background subtraction for ball tracking[2]. These techniques enable precise ball path analysis and bounce detection, creating a comprehensive and efficient sports analysis tool that integrates multiple computer vision algorithms[4].

Introduction :-

In the realm of sports analytics, accurate and real-time tracking systems play a critical role in enhancing both the player experience and spectator engagement. Table tennis, a fast-paced and dynamic sport, presents unique challenges for tracking due to the small size and high speed of the ball[3]. Traditional scoring systems rely heavily on human judgment, which can be prone to error[3]. This project leverages the power of computer vision to automate the detection, tracking, and scoring processes in table tennis, aiming to improve accuracy and reliability while reducing human error[2].

Problem Statement :-

The primary challenge in developing an advanced table tennis detection and scoring system lies in the complexities of accurately detecting and tracking a small, fast-moving ball in real-time. Table tennis balls can reach speeds exceeding 31m/s, making manual tracking difficult and error-prone. Additionally, the small size of the ball and its rapid movement pose significant challenges for computer vision systems, which must distinguish the ball from various backgrounds and track its trajectory accurately. The system must be able to differentiate between ball bounces on the table and other interactions, such as collisions with the net or paddle, and false positives from background noise. This requires robust detection algorithms that can maintain high accuracy even under varying lighting conditions and different camera angles.

Moreover, the system must correctly identify the table boundaries, net position, and player areas to ensure accurate scoring. Misidentification of these elements can lead to incorrect scoring, which undermines the reliability and usefulness of the system. Real-time processing is crucial, as delays in detection and scoring can disrupt the flow of the game and degrade the user experience. The

system must also be resistant to obstacles, where the ball might be temporarily obscured by players or equipment, and be capable of recovering quickly to continue accurate tracking. These combined challenges necessitate a sophisticated integration of multiple computer vision techniques to create a comprehensive and efficient solution that can operate reliably in a dynamic and fast-paced environment.

The primary challenges in developing a table tennis detection and scoring system include:

- Accurately detecting and tracking a small, fast-moving ball.
- Differentiating between ball bounces on the table and other interactions.
- Correctly identifying table boundaries, net position, and player areas.
- Real-time processing to ensure immediate scoring updates.

Proposed Solution :-

To address the complex challenges of detecting and tracking a fast-moving table tennis ball, the proposed solution integrates several advanced computer vision techniques using OpenCV. Each of these techniques contributes to a specific aspect of the system, ensuring high accuracy and real-time performance.

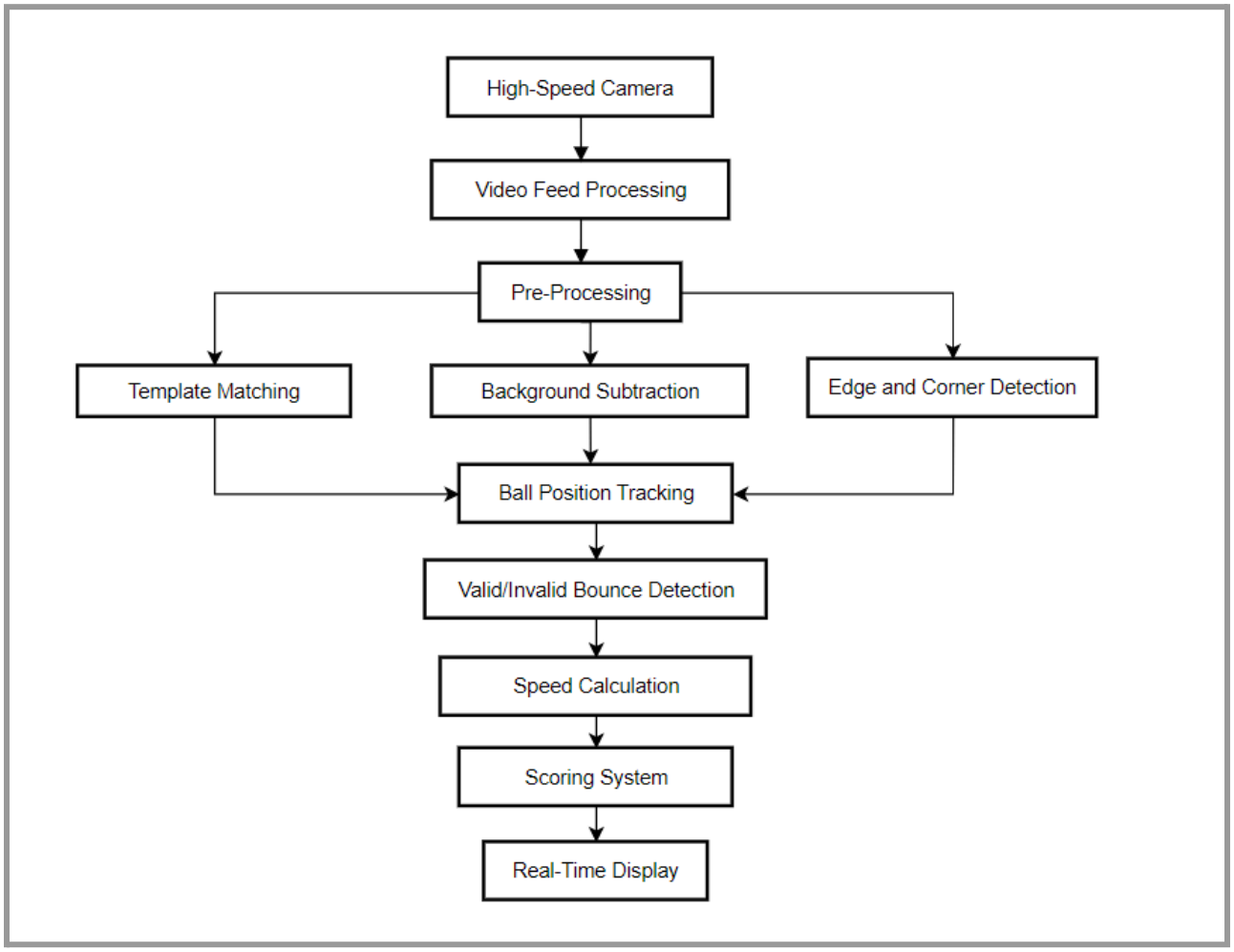
1. **Template Matching** : Template matching is employed to detect the position of the table and the net. This technique involves searching for small parts of an image, called templates, that match the corresponding portions in the larger image (video frame). By using pre-defined templates of the table and net, the system can locate these elements within each video frame. This is crucial for establishing the context and boundaries within which the ball is tracked. Accurate detection of the table and net ensures that the system can distinguish between valid and invalid bounces, which is essential for accurate scoring.
2. **Edge and Corner Detection** : Edge and corner detection algorithms, such as the Canny edge detector and Harris corner detector, are used to identify the boundaries of the table. These techniques highlight the edges and corners in the video frames, allowing the system to precisely define the table's perimeter. This is particularly important for recognizing the lines and boundaries that dictate whether a ball's bounce is in or out. Accurate boundary detection helps in ensuring that the system can make correct decisions about the legality of each play.
3. **Background Subtraction** : For tracking the ball, background subtraction is a fundamental technique. This method involves creating a model of the static background and then

subtracting it from each frame to isolate moving objects—in this case, the table tennis ball. By continuously updating the background model, the system can effectively differentiate the ball from other objects and background noise. This technique is essential for maintaining consistent and accurate tracking of the ball's movement across the playing area, regardless of variations in lighting and other environmental factors.

4. **Speed Calculation** : Calculating the ball's speed involves analyzing its position over time. By tracking the ball's coordinates across consecutive frames, the system can compute its velocity. This information is not only useful for providing insights into the game dynamics but also for identifying rapid changes in speed that may indicate bounces or other significant interactions. Accurate speed calculation helps in enhancing the analysis of player performance and the dynamics of the game.
5. **Bounce Detection** : Bounce detection is achieved by observing changes in the ball's trajectory. When the ball bounces, there is a sudden change in its vertical direction and velocity. By monitoring these changes, the system can accurately detect when and where the ball has bounced. This is crucial for scoring, as the rules of table tennis rely heavily on the ball's interactions with the table. Accurate bounce detection ensures that the scoring is precise and reflective of the actual game events.

By integrating these techniques, the proposed solution creates a robust and comprehensive system capable of accurately detecting and tracking the table tennis ball in real-time, calculating its speed, and updating the scoring for both players. This system leverages the strengths of OpenCV's powerful image processing capabilities, providing a reliable and efficient tool for sports analysis and enhancing the overall experience for players and spectators alike.

Methodology / Block Diagram:-

6. 

Hardware , Software and tools Requirements :-

Hardware:

- High-speed camera for real-time video capture.
- Computer with sufficient processing power

Software:

- OpenCV library for computer vision tasks.
- Python as the programming language.
- Integrated Development Environment (IDE)

Tools:

- OpenCV for image processing.
- NumPy for numerical calculations.

Proposed Evaluation Measures :-

To ensure the effectiveness and accuracy of the system, the following evaluation measures will be employed:

- **Accuracy of Ball Detection**: Measure the precision and recall of the ball tracking algorithm.
- **Speed Calculation Accuracy**: Compare the calculated speed with actual measured speed.
- **Trajectory Analysis Accuracy**: Validate the bounce detection algorithm against manually annotated data.
- **Real-Time Performance**: Assess the system's ability to process video in real-time without significant lag.
- **Scoring Accuracy**: Verify the scoring system against manual scoring by experts.

Conclusion :-

This project demonstrates the potential of integrating multiple computer vision techniques to create a comprehensive table tennis detection and scoring system. By leveraging template matching, edge and corner detection, and background subtraction, the system achieves accurate and real-time ball tracking and scoring. This innovation not only enhances the accuracy and reliability of scoring in table tennis but also showcases the broader applications of computer vision in sports analytics.

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