VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY

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Department of Computer Engineering

Project Report on

AI-Driven Table Tennis Scoring and Ball Speed Tracking

In partial fulfillment of the Fourth Year (Semester–VII), Bachelor of Engineering (B.E.) Degree in Computer Engineering at the University of Mumbai

Academic Year 2024-2025

Project Mentor

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Submitted by

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CERTIFICATE of Approval

This is to certify that **SONNAL KATARA** of Fourth Year Computer Engineering studying under the University of Mumbai has satisfactorily presented the project on "**AI-Driven Table Tennis Scoring and Ball Speed Tracking**" as a part of the coursework of PROJECT-I for Semester-VII under the guidance of **Mrs. Vidya Zope** in the year 2024-2025.

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Dr. Nupur Giri **Dr. J. M. Nair**

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COURSE OUTCOMES FOR B.E PROJECT

Course Outcome	Description of the Course Outcome
CO 1	Do literature survey/industrial visit and identify the problem of the selected project topic.
CO2	Apply basic engineering fundamental in the domain of practical applications FORproblem identification, formulation and solution
CO 3	Attempt & Design a problem solution in a right approach to complex problems
CO 4	Cultivate the habit of working in a team
CO 5	Correlate the theoretical and experimental/simulations results and draw the proper inferences
CO 6	Demonstrate the knowledge, skills and attitudes of a professional engineer & Prepare report as per the standard guidelines.

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Chapter 1: Introduction

1.1 Introduction

Table tennis is a sport that requires precision, speed, and reflexes. Given the rapid movement of the ball, accurate tracking of its motion and scoring is vital for both professional and recreational players. Traditional scoring and ball tracking methods rely heavily on human judgment, which can be prone to errors, especially in fast-paced scenarios. This project focuses on the development of an AI-driven system for table tennis scoring and ball speed tracking using advanced computer vision techniques. By integrating OpenCV with template matching, edge detection, and background subtraction, the system will automate real-time ball tracking, calculate speed, and accurately update scores.

1.2 Motivation

With the growing influence of artificial intelligence and computer vision in sports analytics, automating processes like scoring and ball tracking in table tennis presents an exciting challenge. Manual methods are often subjective and error-prone, and the lack of real-time feedback can diminish the player experience. This project aims to bridge this gap by leveraging the power of AI to deliver more accurate and reliable outcomes in table tennis matches. The motivation stems from the need to reduce human error, enhance accuracy, and promote the application of AI in sports.

1.3 Problem Definition

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.

1.4 Relevance of the Project

In the highly competitive world of sports, data plays an increasingly crucial role in decision-making and performance enhancement. Accurate, real-time data allows athletes, coaches, and analysts to make informed judgments about game strategies, player performance, and areas for improvement. This project, focused on table tennis, contributes to the evolving field of sports analytics by automating the process of ball tracking, speed calculation, and scoring. Traditionally, scoring in table tennis has been manual, requiring human intervention, which is prone to error, especially in fast-paced games. By integrating artificial intelligence (AI) and computer vision techniques, this project removes the element of human error and provides a more precise, objective, and consistent scoring system. This leads to a more transparent and fair competition environment, where both players and spectators can rely on the data being recorded accurately.

Beyond its implications for live matches, this project offers substantial benefits in training environments. Automated ball tracking and performance data allow athletes to monitor their

playing habits, such as the speed of their shots, ball placement, and reaction times, with unparalleled precision. This real-time feedback can enhance coaching strategies, as coaches can tailor training regimens based on detailed, data-driven insights rather than just observation. Additionally, the system allows players to analyze specific movements and refine their techniques, ultimately improving their skills more effectively. The combination of automated tracking and real-time analytics provides players and teams with a competitive edge, making this project highly relevant in the modern landscape of sports technology and analytics.

1.5 Methodology Used

The methodology for this project leverages several computer vision techniques to create an automated, real-time system for table tennis ball detection, tracking, and scoring. One of the foundational methods used is **template matching**, which helps detect and locate the table and net positions within each frame of the video. By matching predefined images (templates) of the table and net with the incoming video feed, the system can identify the playing area, ensuring that all ball movements are tracked within the correct context. This is crucial for determining whether the ball bounces are valid or if the ball crosses the net during gameplay. Additionally, **edge and corner detection** techniques, such as the Canny and Harris detectors, are used to identify the lines and boundaries on the table, which are essential for tracking ball interactions and ensuring accurate scoring decisions.

Another important step in the methodology is **background subtraction**, which isolates the ball from other elements in the video, including players and background noise. This technique involves continuously updating a model of the static background and subtracting it from each frame, leaving only moving objects, such as the ball, to be tracked. Background subtraction is particularly effective in ensuring that the ball's movements are captured consistently, even in dynamic environments with changing lighting or player interference. The system then utilizes a **speed calculation** algorithm by analyzing the ball's position across consecutive frames, allowing it to compute the ball's velocity. This information is valuable not only for real-time tracking but also for providing performance insights into player dynamics, such as shot speed and response times.

Finally, the system incorporates **bounce detection**, a critical aspect of accurate scoring. By monitoring sudden changes in the ball's trajectory and speed, the system can determine when and where the ball bounces on the table. Since the rules of table tennis heavily rely on valid bounces for scoring, this method ensures precision in determining which shots are valid, which hit the net, or which bounce outside the table’s boundaries. Together, these techniques create a comprehensive and reliable solution for real-time ball tracking, speed analysis, and automated scoring, addressing the challenges presented by the fast-paced nature of table tennis.

Chapter 2: Literature Survey

2.1 Research Papers referred

Paper : Small Object Detection of Table Tennis Based on Deep Learning Network

- **Abstract Summary**: This paper addresses the challenge of detecting small, fast-moving objects in real-time, particularly focusing on table tennis. The authors propose a deep learning network optimized for small object detection by balancing detection speed and accuracy. They constructed a dataset of 20,000 table tennis images and utilized a convolutional neural network (CNN) with residual connections. By combining layers with rich semantic information and object position information, the proposed system enhances detection accuracy. A novel data augmentation technique was introduced, significantly improving the model's learning capability for small targets. Experimental results confirmed the model's superior accuracy and speed in table tennis ball detection, making it suitable for real-time applications.
- **Inference:** This research is highly relevant to our project as it directly tackles the issue of small object detection in fast-paced environments like table tennis. The use of CNN and residual connections, along with feature pyramids, provides valuable insight into how we can enhance our own ball tracking model. The idea of data augmentation can also be applied to our dataset to improve model accuracy

2.2 Exiting Systems

Currently, there are no dedicated AI-driven systems specifically designed for table tennis scoring and ball speed tracking. While technologies such as **Hawk-Eye** in tennis and **SwingVision** in table tennis and other sports provide advanced ball tracking and analytics, these solutions either focus on different sports or offer limited functionality that doesn't fully align with the objectives of this project.

Most existing systems in table tennis rely on manual methods for scoring and lack real-time, automated speed tracking or bounce detection. The current solutions either use basic video

analysis for training purposes or are limited to rudimentary tracking, without integrating advanced AI and computer vision techniques for comprehensive game analysis.

This absence of a fully automated AI-based system for real-time scoring and ball speed tracking in table tennis highlights the need and relevance of this project.

2.3. Lacuna in the existing systems

1. **Accuracy in Varied Conditions**: The system may face difficulties in maintaining consistent accuracy during ball detection and tracking under different lighting conditions or varying backgrounds. Proper calibration might be required to handle these changes effectively.
2. **Limited Generalization Across Sports**: While the system is designed for table tennis, it may not perform optimally for other sports like badminton or squash, which have different ball dynamics and court dimensions, thus requiring sport-specific tuning.
3. **High-Speed Ball Detection**: Detecting and accurately tracking fast-moving balls in table tennis, which can reach speeds of up to 31m/s, could pose a challenge, potentially leading to miscalculations in speed and trajectory.
4. **Obstacles and Occlusion**: The presence of players or equipment can block the camera's view, temporarily halting ball detection and leading to inaccurate tracking, especially in fast-paced matches.
5. **Net and Boundary Violations**: The system might struggle with detecting boundary and net violations accurately during high-speed rallies, especially when the ball barely grazes the net or lands near the edge of the table.

2.4 Comparison of existing systems and proposed area of work

Several technologies exist for ball tracking and automated scoring in sports, but most are designed for sports like tennis, cricket, or soccer. In contrast, there is a lack of systems dedicated to **table tennis**, which involves unique challenges such as faster ball speeds, smaller playing areas, and more frequent bounces. Below is a comparison between existing systems in similar sports and the proposed system:

Feature	Existing Systems (e.g., Hawk-Eye, SwingVision)	Proposed AI-Driven Table Tennis System
Sport-Specific Focus	Systems like Hawk-Eye and SwingVision are optimized for sports like tennis, cricket, and soccer.	Specifically designed for table tennis, addressing the fast-paced nature, small ball size, and unique game dynamics.
Ball Speed and Trajectory Tracking	Existing systems trackball speed and trajectory effectively in slower sports like tennis and cricket.	The proposed system is tailored to track the smaller, faster-moving table tennis ball with high accuracy.
Boundary and Net Violation Detection	Current systems detect net and boundary violations in tennis and soccer, but may be inconsistent in faster sports.	The proposed system integrates AI for accurate detection of net touches and boundary violations, even in fast rallies.
Cost and Scalability	Systems like Hawk-Eye are expensive, requiring multiple high-speed cameras and sensors.	The proposed system uses cost-effective hardware (e.g., a single high-speed camera) and readily available software libraries like OpenCV.

Table 2.4.1: Comparison of existing system & proposed area of work

While existing systems in other sports provide general ball tracking and scoring, they are not optimized for the unique requirements of table tennis. The proposed AI-driven system fills this gap by offering a solution that is sport-specific, real-time, and capable of handling the rapid dynamics of table tennis.

2.5. Focus Area

The focus of this project is on the development and optimization of a real-time, AI-driven system for tracking and scoring table tennis matches. The system leverages computer vision techniques to detect, track, and analyze ball movement, speed, and player interactions in a fast-paced environment. Key areas of focus include:

1. **Real-Time Ball Detection and Tracking**:
   The primary focus is on achieving accurate and continuous tracking of the ball throughout the match, even under varying lighting conditions, player movements, and temporary occlusions. The system will utilize advanced computer vision techniques such as **template matching**, **background subtraction**, and **edge detection** to ensure precise and reliable detection of the ball's position and trajectory.
2. **Ball Speed Calculation**:
   The system will calculate the speed of the ball in real-time by analyzing consecutive frames of video. This will involve optimizing algorithms to handle rapid changes in ball speed, which is critical for providing accurate feedback to players and coaches. The speed calculation will also be used for performance metrics and training insights.
3. **Scoring Automation**:
   Automating the scoring process by detecting valid bounces and player interactions is a key focus area. The system will use bounce detection algorithms to distinguish between valid and invalid shots, such as balls hitting the net or bouncing outside the table boundaries. This will eliminate human error in scoring and provide an objective way to track match results.
4. **Net and Boundary Violation Detection**:
   Another focus is the accurate identification of net touches and boundary violations, which are common in table tennis but challenging to detect in real time due to the speed of the game. The system will integrate specific detection algorithms to ensure that net violations and boundary events are accurately recorded.
5. **Performance in Varied Conditions**:
   The system must perform reliably across different playing environments, whether indoors or outdoors, and under different lighting conditions. This focus area involves optimizing

the system to adapt to changes in camera angles, lighting, and background noise to ensure consistent performance and high accuracy.

6. **Cost-Effective and Scalable Design**:

   Unlike more expensive multi-camera systems, this project aims to develop a cost-effective solution using a single high-speed camera and open-source libraries like OpenCV. Ensuring that the system remains scalable and easy to deploy in both amateur and professional settings is a key priority.

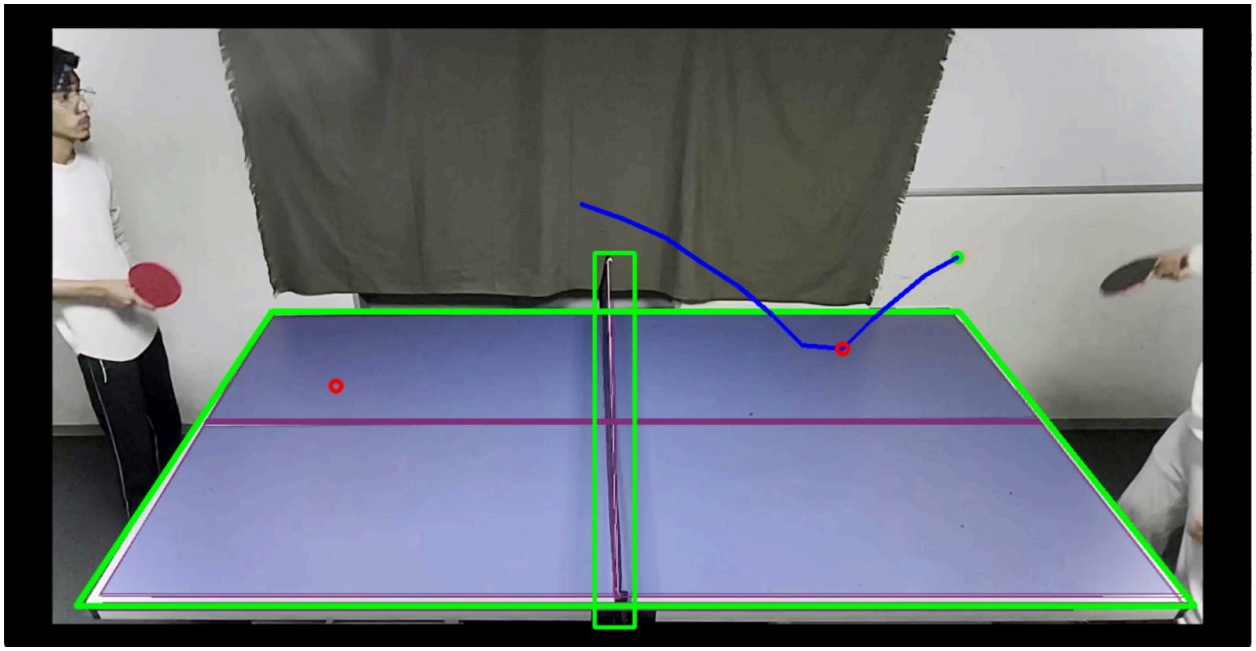

Fig 2.5.1: Ball & Table Tracking

Chapter 3: Requirements

3.1 Proposed model

The proposed model for the table tennis scoring and ball speed tracking system integrates multiple computer vision techniques using the OpenCV library. The system captures real-time video of the table tennis match, processes it to detect the table boundaries, the net, and the ball, and continuously tracks the ball's movements. The model includes speed calculation algorithms, which analyze the ball's trajectory and detect bounces to automatically update the scores. The architecture includes a high-speed camera, video input processing, and various computer vision modules for detection and analysis.

3.2 Functional Requirements

- Real-time detection and tracking of the ball during a match.
- Automatic scoring based on ball bounces, player interaction, and game rules.
- Speed calculation of the ball and trajectory analysis.
- Detection of invalid bounces (e.g., hitting the net) and scoring adjustments

3.3.Non-Functional Requirements

- **Accuracy:** The system must accurately detect the ball's location, speed, and trajectory within the given time constraints.
- **Performance:** The system should handle video processing in real-time, maintaining minimal lag for optimal player and viewer experience.
- **Scalability:** The system should adapt to different environments such as practice sessions or competitive matches.
- **Reliability:** The system should maintain consistent performance even under challenging conditions like lighting changes or camera occlusion.

3.4.Hardware & Software 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)

3.5.Technology and Tools utilized

- **OpenCV:** This library is crucial for video analysis, template matching, and image processing.
- **NumPy:** For numerical computations involved in speed calculations and other mathematical functions.
- **Python:** The primary language used for developing the software modules.
  IDE: For code development and debugging.

3.6.Constraints of working

- **Processing Speed:** Real-time video processing demands high computational power. Delays in processing could result in inaccurate scoring or ball tracking lags.
- **Ball Color and Design:** Variations in the color or markings on the ball (e.g., logos or patterns) might affect the system's ability to consistently detect and track it, especially if it blends with the background.
- **Occlusion by Players:** Players' movements may occasionally block the camera's view of the ball, causing temporary tracking failure.
- **Varying Camera Angles:** Changes in the camera angle or positioning can affect the accuracy of the system's algorithms, requiring recalibration or adjustment.
- **Ball Speed Variability:** The system must accurately track balls at both high and low speeds. Rapid changes in speed during play could challenge the system's ability to maintain continuous detection.

Chapter 4: Proposed Design

4.1 Block Diagram

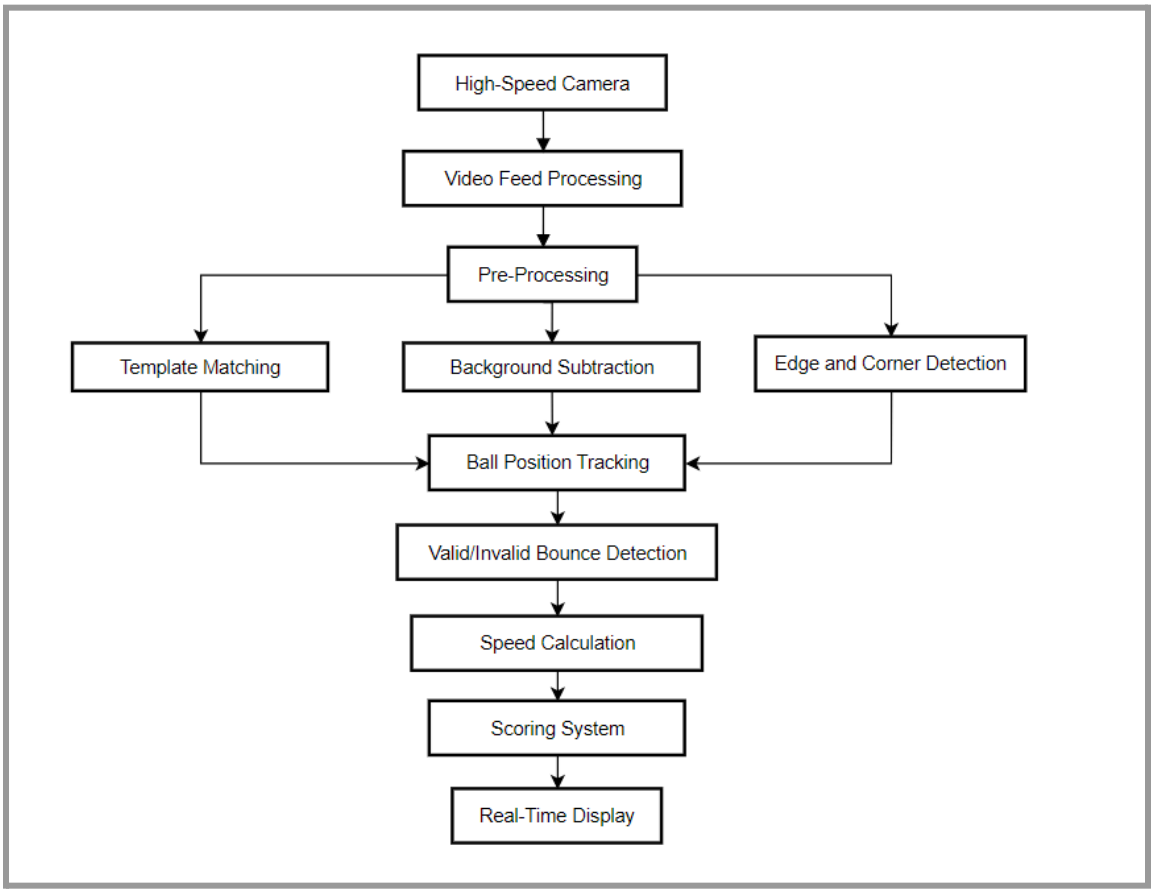

Fig 4.1.1: Block Diagram

4.2 Proposed algorithms

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.

Chapter 5: Plan of action for the next semester

To build on the initial successes and address the challenges identified, the following plan of action is proposed for the next semester:

1. **System Optimization**:
    - Conduct a thorough review of the existing algorithms to identify areas for improvement.
    - Optimize the ball detection and tracking algorithms to enhance performance in various lighting conditions and during player movement.
2. **Testing in Diverse Environments**:
    - Extend testing to different settings, including varied playing conditions and levels of play (amateur and professional).
    - Collect data to analyze system performance under different environmental variables, such as background noise and camera angles.
3. **Integration of more Features:**
    - Investigate the use of machine learning techniques to predict ball trajectories and enhance bounce detection.
4. **Documentation and Reporting:**
    - Document all findings, optimizations, and user feedback in a comprehensive report.
    - Prepare for a final presentation of the project, summarizing the entire process from development to results and future recommendations.

Chapter 6: Conclusions

This project successfully demonstrates the potential of integrating advanced computer vision techniques to create an automated table tennis scoring and ball-tracking system. By leveraging methods such as template matching, edge detection, and background subtraction, the system achieves real-time ball tracking and accurate scoring, minimizing the risk of human error. This offers a significant improvement over traditional manual methods, ensuring a more reliable, consistent, and objective approach to scoring in fast-paced games.

Beyond real-time gameplay, the system also provides valuable insights into player performance by tracking ball speed and bounce patterns. This data can be highly beneficial for players and coaches to analyze gameplay, optimize training regimens, and enhance skill development. The project demonstrates how AI and computer vision can elevate the precision and fairness of sports analytics, making it relevant not only for competitive matches but also for training environments. Overall, this innovation sets the stage for future applications of AI in sports, improving both the playing and viewing experience.

Chapter 7: References

i. Books Referred

[1] Merritt, H. E., 1971, *Gear Engineering*, Pitman, New York, pp. 82–83.

Journal Paper,

[2] Arakere, N. K., and Nataraj, C., 1998, "Vibration of High-Speed Spur Gear Webs," ASME Journal of Vibration Acoustics, 120(3), pp. 791–800.

Proceeding Paper,

[3] Stewart, R. M., 1977, "Some Useful Data Analysis Techniques for Gearbox Diagnostics," Proceedings of the Meeting on the Application of Time Series Analysis, ISVR, University of Southampton, Southampton, UK.

ii.Research Papers referred/ Journals/ Articles referred

1. Ericsson, A.; Prietula, M.; Cokely, E. The Making of an Expert Harvard Business Review (July–August 2007). *Expert Harv. Bus. Rev.* **2007**, *85*, 114. https://www.scirp.org/reference/referencespapers?referenceid=2977088

2. W. Li, X. Tan and Z. Wang, "Small Object Detection of Table Tennis Based on Deep Learning Network," *2020 International Conference on Computer Science and Management Technology (ICCSMT)*, Shanghai, China https://ieeexplore.ieee.org/document/9443773

3. H. Myint, P. Wong, L. Dooley and A. Hopgood, "Tracking a table tennis ball for umpiring purposes," *2015 14th IAPR International Conference on Machine Vision Applications (MVA)*, Tokyo, Japan, 2015 https://ieeexplore.ieee.org/document/7153160

4. R. Voeikov, N. Falaleev and R. Baikulov, "TTNet: Real-time temporal and spatial video analysis of table tennis," *2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*, Seattle, WA, USA, 2020 https://ieeexplore.ieee.org/abstract/document/9150877