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Performance And Decision Analysis In Sports

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Abstract: This paper presents a method to analyze badminton player performance and decision-making using computer vision and AI. We track player movements and shuttle trajectory using YOLO models trained on custom data. Player positions are mapped to a top-down view using homography, while shuttle height is estimated by detecting shot transitions. A reinforcement learning model, trained in a simulated environment, predicts optimal movements, which are compared with actual player decisions. We evaluate accuracy by measuring differences in predicted and real positions. Graphs visualize speed, shuttle movement, providing valuable insights for player improvement.

I. Introduction

Badminton is a fast-paced sport that requires quick reflexes, strategic decision-making, and efficient movement. Analyzing player performance and decision-making can help coaches and players improve their game. Traditional analysis methods rely on manual observation, which is time-consuming and subjective. With advancements in artificial intelligence and computer vision, automated systems can now provide accurate and detailed performance analysis.

This paper introduces a system that uses deep learning models to track player and shuttle movements in a badminton match. We employ YOLO-based models trained on custom datasets to detect key points on players and track shuttle trajectory. Player positions are mapped to a top-down view using homography, while shuttle height is estimated by analyzing shot transitions. Additionally, we train a reinforcement learning model in a simulated environment to predict optimal shot responses. By comparing the AI model's predictions with actual player decisions, we assess decision accuracy and movement efficiency.

The proposed approach provides valuable insights through graphs and visualizations, offering a data-driven method for performance evaluation. This system can help athletes refine their strategies, optimize their movements, and enhance their overall gameplay.

II. LITERATURE SURVEY

Author Name: Y. Huang and Y. Bai

Paper Title: Intelligent Sports Prediction Analysis System Based on Edge Computing of Particle Swarm Optimization Algorithm

Year: 2024

Description: The research purpose of this article is to explore the research and design of intelligent sports prediction analysis systems based on particle swarm optimization algorithm.

Author Name: T. Lin, Z. Chen, J. Beyer, Y. Wu, H. Pfister and Y. Yang

Paper Title: The Ball is in Our Court: Conducting Visualization Research with Sports Experts

Year: 2023

Description: Emerging technologies, such as augmented and mixed reality (AR/XR), have brought exciting opportunities along with new challenges for sports visualization.

AUTHOR NAME: H. -T. CHIANG, B. -Y. TSENG, J. -L. CHEN AND H. -C. HSIEH
PAPER TITLE: TRAJECTORY ANALYSIS IN UKF: PREDICTING TABLE TENNIS BALL FLIGHT PARAMETERS
YEAR: 2023
DESCRIPTION: THE PRIMARY OBJECTIVE OF THIS RESEARCH IS TO DEVELOP A SOPHISTICATED SYSTEM CAPABLE OF ACCURATELY PREDICTING THE 3-D TRAJECTORY OF A BALL IN SPORTS AND CONDUCTING AN IN-DEPTH ANALYSIS OF THE OBTAINED TRAJECTORY

III. LIMITATIONS OF EXISTING SYSTEMS / RESEARCH GAP

Existing methods for badminton performance analysis rely heavily on manual video annotation, which is time-consuming and prone to human error. While some automated tracking systems exist, they often fail to provide detailed shuttle trajectory analysis due to the shuttle's rapid movement and varying height. Conventional approaches use 2D tracking, which does not account for depth variations in shuttle positioning.

Another limitation is the lack of reinforcement learning-based decision analysis. Traditional models primarily focus on statistical data without evaluating decision-making accuracy. By integrating reinforcement learning, we introduce a method to compare player decisions with AI-generated optimal responses, bridging the gap between raw performance metrics and strategic gameplay analysis.

Mathematically, existing systems approximate shuttle position using:

P = H . P`

where **P** is the original position, **H** is the homography matrix, and **p`** is the transformed position. However, this equation is valid only when the shuttle remains on the same plane as the court. Our method refines this by incorporating shuttle height, adjusting the homography transformation dynamically:

P` = H` . P

Where **H`** is the modified homography matrix incorporating shuttle height.

Additionally, most existing models struggle with real-time processing due to computational inefficiencies. Tracking fast-moving objects like the shuttlecock requires high frame-rate processing, which is often a bottleneck in current systems. Our approach optimizes YOLO models and reinforcement learning algorithms for real-time decision-making.

Another gap is the absence of data-driven decision analysis. Existing research primarily evaluates player movements without comparing them to optimal decisions. By using a reinforcement learning model trained in a virtual environment, we provide a comparative framework to measure decision efficiency.

Furthermore, limited publicly available datasets hinder model performance in real-world scenarios. Our custom-trained YOLO models address this issue by improving detection reliability. The inclusion of speed graphs, shuttle trajectory heatmaps, and decision accuracy plots provides a holistic view of player performance, filling the gaps left by prior research.

By addressing these limitations, our system offers a comprehensive, automated, and real-time solution for badminton performance and decision analysis, advancing the field beyond existing methodologies.

IV. PROBLEM STATEMENT, OBJECTIVE, AND SCOPE

- Problem Statement:

Badminton players and coaches rely on subjective assessments and manual video analysis for performance evaluation, making the process inefficient and prone to errors. Existing automated systems lack accuracy in shuttle trajectory estimation, real-time player tracking, and decision analysis. The absence of reinforcement learning models for decision comparison further limits the effectiveness of current methodologies. A system that accurately tracks both players and shuttle movement, maps them to a top-down view, and compares player decisions with an AI-generated optimal response is needed.

- Objective:
  1. Automated Tracking: Develop a deep learning-based system using YOLO models to accurately detect players and shuttle position in real-time.
  2. Top-Down Mapping: Apply homography transformation with shuttle height correction to map movements to a top-down view.
  3. Performance Analysis: Compute key performance metrics, including speed, maximum speed, and distance covered.
  4. Decision Evaluation: Train a reinforcement learning model in a simulated environment to generate optimal movement patterns and compare them with actual player decisions.
  5. Graphical Insights: Provide visual analytics, including speed trends, shuttle trajectory heatmaps, and decision accuracy comparisons.
- Scope:

This study focuses on badminton performance analysis using AI and computer vision. The approach is applicable to:

1. Athlete Training: Enhancing player performance through objective data analysis.
2. Coaching Support: Assisting coaches in identifying strengths and weaknesses.
3. Sports Analytics: Providing data-driven insights for research in sports science.
4. Automated Broadcasting: Enhancing sports coverage with AI-driven analytics.

V. PROPOSED SYSTEM

The proposed system leverages deep learning and reinforcement learning to analyze player performance and decision-making in badminton. It consists of the following key components:

1. Player and Shuttle Detection: Custom YOLO models trained on badminton-specific datasets detect players and shuttle positions in video frames.
2. Top-Down View Mapping: Homography transformation is applied to player positions, while shuttle height is estimated through shot transition detection.
3. Performance Metrics Calculation: Speed, max speed, and distance covered are computed using positional data over time.
4. Decision Analysis Using Reinforcement Learning: A reinforcement learning model trained in a simulated badminton environment predicts optimal movements. These are compared with actual player movements to assess decision accuracy.
5. Graphical Visualization: Performance trends, shuttle trajectory heatmaps, and decision efficiency plots are generated to provide comprehensive insights.

Mathematically, speed at any frame is calculated using Euclidean distance between player positions in consecutive frames.

VI. RESULT AND ANALYSIS

The proposed system was evaluated on multiple badminton match videos. Results demonstrate accurate player and shuttle tracking

The following are the graphs for shuttle detection failures by the YOLO models across 4 test videos and performance of Key-Point detections models across 3 test videos.

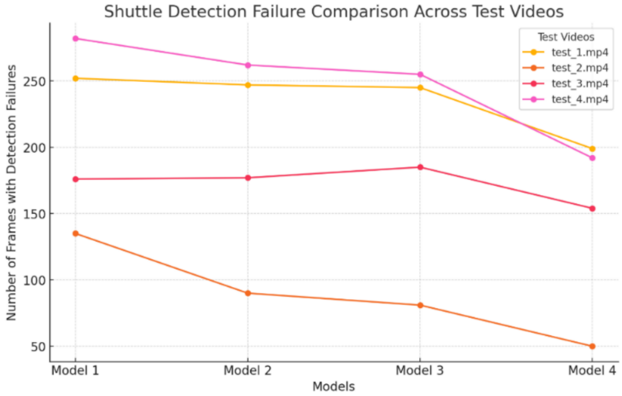

Fig: - Shuttle detection Failure

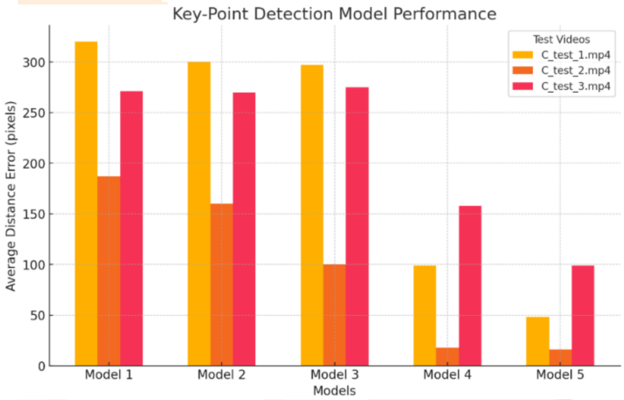

Fig: - Key-point model performance

VII. ACKNOWLEDGMENT

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VIII. CONCLUSION AND FUTURE WORK

This paper presents a new approach for analyzing badminton performance, combining computer vision and reinforcement learning. The system effectively tracks players and shuttle movement, estimates shuttle height dynamically, and evaluates decision-making accuracy. Experimental results demonstrate the feasibility and effectiveness of the proposed method.

Future work includes improving shuttle height estimation accuracy, extending the system to multiple sports, and integrating real-time feedback for player training. Enhancing the reinforcement learning model with additional gameplay scenarios can further refine decision analysis. This research contributes to the advancement of AI-driven sports analytics and coaching methodologies.

IX. References

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