Yolo v-8 Based AI System for In-depth Tennis Match Analysis

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***Abstract*—It uses the real-time object detection features of the You Only Look Once (YOLO) v8 architecture to track players and the ball in a match. The system computes key performance metrics such as the speed of the hitting ball and the speed of the players to measure efficiency, reaction time, and the player's performance in the match. These include, specifically, hitting speed of the ball, using the trajectory and time intervals of the key frames for detection, while players' speed may be derived from movements across the court. With these two, detailed player performance profiles can be generated, and these could be used in post-match analysis, strategic decision-making, and enhancing performance. This study demonstrates the potential of YOLO v8 as a high-performance tool in sports analytics to build an efficient and scalable solution for the evaluation of professional tennis performance.**

Keywords— YOLO v8, AI system, tennis match analysis, player performance, ball hitting speed, player speed, object detection, sports analytics, real-time tracking, performance evaluation, video analysis, tennis analytics, machine learning, computer vision, tactical analysis.

I. Introduction

Tennis is a dynamic sport that demands quick reflexes, accurate shot-making, and strategic movement on the court. Traditionally, performance analysis in tennis relied on subjective observations or basic statistical methods such as win rates, types of shots, or point outcomes. These methods do not, however, deliver a detailed data-driven evaluation of the player's true capabilities in the course of a match. With the advancement of machine learning and computer vision technology, there has indeed been a real opportunity to amplify performance analysis during live matches because both player and ball movement can be easily tracked with maximum accuracy. As part of this work, we designed an innovative, AI-based framework for real-time tennis match analysis using the You Only Look Once version 8 architecture. YOLOv8 is the latest technology in the object detectionframework, offering high accuracy and high-speed detection and localization of objects within videos. Using this technology, we will extractperformance metrics, such as the hitting speed of the ball and themovement speed of the player, which will help in evaluating the efficiency, agility, and reaction time of a player during a game. The system processes high-definition video footage of the movement of the ball and the player, with all velocity details at contact points and captures the player movements in the court. The speed of the ball at contact is computed by measuring the time taken for the ball to travel between key points in the court based on a track of its trajectory. Player speed is calculated by observing his or her positional data at different stages of the match. These two metrics-ball hitting speed and player speed-are the essential parameters to define the physical ability and performance of a player under competitive conditions.

Here, the goal is to design a real-time solution that scales and provides such insight to the players, coaches, and analysts to make better decisions in terms of improving performance, developing a strategy for the match, and preparing training plans. YOLOv8 delivers accurate, high-quality data on how players move, react, and shoot during the match. We thus demonstrate the feasibility and effectiveness of using advanced object detection algorithms, such as YOLOv8, in sports analytics, particularly in tennis, for enhancing performance analysis and informed decision-making in competitive sports.

II. Importance of Technology

Advanced technologies are increasingly being integrated into sports analytics, which is becoming more crucial for changing performance evaluation, training methodologies, and competitive advantage. For sports like tennis, where precision, agility, and strategic execution lead to successes, assessing the accuracy of player performance using technology can greatly impact training or competition results. This project and its technology, especially YOLO v8-based AI system, will occupy a pivotal position in altering the analysis of tennis matches and player development.Real-time Analysis and Precision: The object detection algorithm, YOLO v8, is able to track and analyze the players and ball in real-time with high precision. Traditional performance analysis methods are based on manualinput and are subjective, thus their scalability and precision are limited.

The system based on YOLOv8 can track everything that happens in a tennis match continuously-from fast movement to high-speed ball trajectories-so that objective data-driven analysis may be performed that cannot or is impractical with traditional techniques. This implies that the system provides a much more holistic and comprehensive evaluation of player performance because it focuses on key metrics such as ball hitting speed and player speed. Such metrics go beyond the basic statistics like points won or shot types and may be able to offer deeper insight into a player's physical and technical abilities. Understanding how fast the players move and how fast they hit the ball can tell much about their fitness level, reaction time, and skill proficiency, which can be used for performance optimization.

Informed Decision-Making for Coaches and Players: The insights generated from this technology can empower coaches and players to make data-driven decisions about training regimens and match strategies. Coaches can identify areas where players need improvement, while players can adjust their tactics based on the insights from real-time data. This level of detail enables personalized feedback and training plans that target specific aspects of a player’s game, enhancing their chances of success in future matches.

Scalability and Accessibility: While traditional methods may require much human resource or a lot of manual effort, the YOLOv8 system is scalable to be applied on different match types, from live-streamed events to practice sessions and training camps. It provides an efficient, cost-effective alternative for video analysis and is accessible to a broader scope of players from amateur to professional levels, independent of access to advanced analytics teams or facilities.

The capture and analysis of movement dynamics, ball speed, and player speed are all contributions to the growing field of sports science. It provides new avenues for research on player performance, injury prevention, and game strategy. As AI continues to evolve, it will introduce even more sophisticated methods for analyzing player behavior and match tactics, pushing the science of sports analytics even further.

III. LITERATURE REVIEW

Object detection and object tracking is a fundamental problem in the field of computer vision and pattern recognition,which has been widely studied over the past few decades.

P. Zhao, T. Luo, and P. Bi, [1] "Athlete Performance Analysis: Machine Learning for Predicting Tennis Player Scores" (2024) Explores the application of machine learning techniques to predict the performance and scores of tennis players. The study aims to analyze various factors that influence player performance using data-driven approaches and develop predictive models that can help forecast match outcomes. The research highlights the potential of machine learning in enhancing athlete performance analysis in competitive sports. (Peizhe, Tianyu, & Pengfei, 2024)

J. Guo, J. Zhu, S. Lin, and F. Shi, [2] "Momentum Prediction for Tennis Matches Based on Counter-Factual Analysis and Multi-LGBM" (2024) This study focuses on predicting momentum shifts in tennis matches by combining counter-factual analysis with Multi LGBM models. By simulating different match scenarios, the paper seeks to evaluate how specific events impact player momentum, using advanced machine learning techniques to forecast match dynamics and improve predictive accuracy. (Jingxiang, Jianhua, Sheng, & Feng, 2024)

A. Cao, X. Xie, M. Zhou, H. Zhang, M. Xu, and Y. Wu, [3] "Action-Evaluator: A Visualization Approach for Player Action Evaluation in Soccer" (2024). The research offers "Action-Evaluator," which is a visual analytics-based approach to assess and quantify player action during the matches, providing support for coaches and analysts to make sense of what players decide upon and perform on the field. The paper has highlighted intuitive visualization as crucial in improving the process of evaluation and strategic analysis of soccer. (Anqi, Xiao, Mingxu, Hui, Mingliang, & Yingcai, 2024)

R. M, R. B, L. R, and S. K, [4] "Player Performance Prediction in Sports Using Machine Learning" (2024) Researches the ability of machine learning techniques to predict player performance across different sports. The study involves analyzing player data to identify the various factors that can influence performance using predictive models in real-time forecasts. The research shows how machine learning can improve decision-making processes in sports by providing accurate performance predictions, which can help coaches and analysts in strategy formulation. (Rajeswari, Renukadevi, Lokesh, & Sabarish, 2024)

K. Jeong et al., [5] "A Monitoring System for Cattle Behavior Detection using YOLO-v8 in IoT Environments" (2024) This paper describes a monitoring system that uses YOLO-v8 for detecting and analyzing cattle behavior in IoT settings. The study aims to improve livestock management and welfare by providing accurate, real-time detection and classification of cattle behavior patterns through advanced object detection techniques. (Kyungchang, et al., 2024)

Z. Liu, K. Jiang, Z. Hou, Y. Lin, and J. S. Dong, [6] "Insight Analysis for Tennis Strategy and Tactics" (2023) This paper presents an in-depth analysis of tennis strategies and tactics through data-driven insights. The research is aimed at understanding strategic patterns and tactical choices to support the optimization of player performance and improve strategic planning in tennis matches. (Zhaoyu, Kan, Zhe, Yun, & Jin, 2023)

C. Rohra, M. Mangla, S. Asher, N. Agarwal and S. Desai, [7] "Footy Forecast – Measuring Performance in Football" (2023) Performance analysis in football by using advanced computing techniques. Data analytics and machine learning have been used in the study to evaluate player and team performance to predict game outcome and contributing players for their performance. The study throws light on important performance metrics in football that will help teams and analysts in strategy development and decision-making with a data-driven approach. (Shlok, Monika, Chirag, Soham, & Neha, 2023)

H. Yu, [8] "The Design Method of Intelligent Sports Information Management System" (2023) Intelligent sports information management system design and development. This research explores the use of sophisticated algorithms and soft computing techniques to develop an effective, automated management system for sports-related data. The system seeks to organize, retrieve, and analyze sports information more effectively in order to aid in decision-making and ultimately enhance the process of managing sports. (Hongtao, 2023)

Y. Zheng, W. Zhou, T. Zou, and H. Zhang, [9] "A Method for Table Tennis Bat Trajectories Reconstruction with the Fusion of Human Keypoint Information" (2023) The paper describes a reconstruction method for table tennis bat trajectories by integrating human keypoint detection data with trajectory analysis. With the accurate modeling of bat movements, the research study aims to improve insights into player techniques in order to better train and analyze performance in table tennis. (Yida, Wei, Tianyi, & Hui, 2023)

R. A et al., [10] "Deep Learning-Based Tennis Shot Type Prediction Using Gait Analysis" (2023) This study explores the deep learning method of predicting tennis shot types by observing the gait patterns of the players. Based on the players' movements, the study enhances the accuracy of shot prediction while providing insight into the decision and action of players during a game. (Rashmi, Brindha, Sandhya, Lakshmi, & Myvizhi, 2023)

S. Vancurik and D. W. Callahan, [11] "Detection and Identification of Choking Under Pressure in College Tennis Based Upon Physiological Parameters, Performance Patterns, and Game Statistics" (2023) This research paper focuses on the detection of choking under pressure in college tennis players by using physiological parameters, performance patterns, and game statistics. It tries to identify indicators of performance anxiety, thus providing a better understanding of how pressure affects the performance of a player in the critical moments of a match. (Stepan & Dale, 2023)

J.-R. Chang, C.-J. Wang, Z.-K. Wei, C.-J. Lu, and H.-Y. Lin, [12] "A Research Structure of Big Data Analysis and Application for Table Tennis Match Tactics Based on Computer Vision" 2023: This paper establishes a research structure using big data analytics and computer vision to analyze table tennis match tactics. It shows the capability of computer vision to record detailed match data, which aids in improving player strategy and match decision-making processes. The article highlights the role of visual big data in augmenting tactical planning. (Jui-Ren, Chia-Ju, Zhi-Kai, Chih-Jen, & Hsin-Yi, 2023)

S. Jhawar, [13] "Predicting Tennis Match Outcomes" (2022)This article presents the transition from traditional statistical methods to advanced machine learning in the prediction of tennis match outcomes. It uses different data sources such as player performance and betting odds for better prediction accuracy while considering data quality issues and model adaptability. (Shrihari, 2022)

S.K. Liang, J.Y. Chiang, and K. Wang, [14] "Feasibility Study of Using Hybrid Artificial Intelligence Architecture for Recognizing and Analyzing the Execution Styles of Tennis Players in Match" (2022) This paper explores the feasibility of hybrid AI architecture for recognizing and analyzing the execution styles of tennis players. The research will combine different AI techniques to improve the accuracy of player style detection, which is valuable for performance analysis and coaching strategies. (Shu-Kai, Jinn-Yen, & Kerwin, 2022)

M. Skublewska-Pa szkowska, P. Powroznik, and E. Lukasik, [15] "Attention Temporal Graph Convolutional Network for Tennis Groundstrokes" (2022) The paper introduces an attention-based temporal graph convolutional network (GCN) to classify phases of tennis groundstrokes. Utilizing advanced graph convolutional techniques, the work aims to enhance the accuracy of groundstroke phase classification and support performance analysis. (Maria, Paweł, & Edyta, 2022)

IV. Research methodology

The project "YOLO v-8 Based AI System for In-Depth Tennis Match Analysis" is structured in nature and incorporates computer vision techniques and performance metrics to evaluate the capabilities of tennis players. The overall aim of the research is to design an AI system using YOLOv8 (You Only Look Once version 8) for real-time tracking of tennis players and the ball. This allows for key performance metrics-whether it be player speed or shot speed-that would then determine overall player performance to be calculated. This analysis hopes to provide a more objective and data-based approach for determining selection committee choices regarding performance on the court.

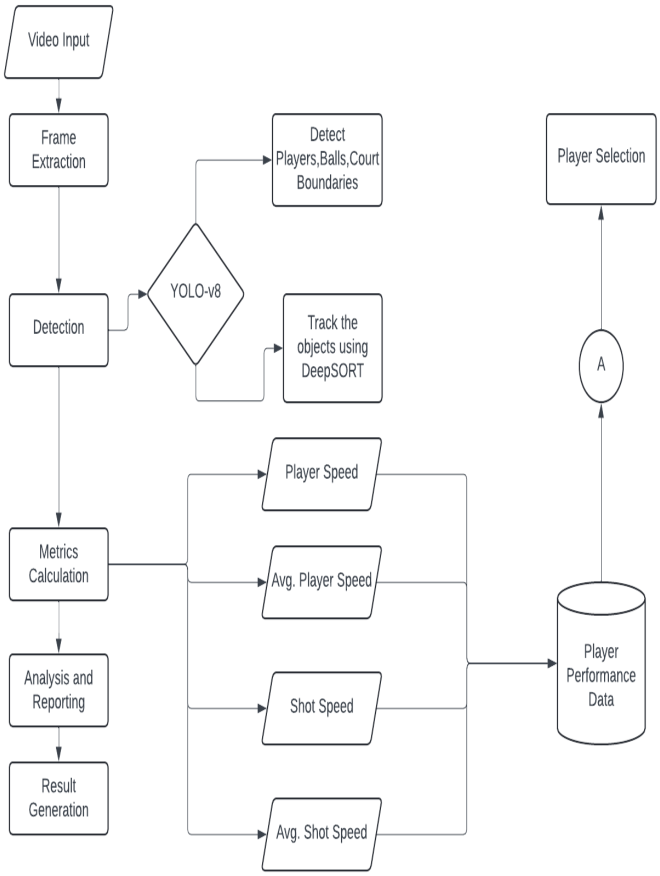
The research employs a quantitative approach and uses video data from tennis matches. It will collect a large dataset of videos of different types of tennis matches and of different players: professional and amateur levels. Such videos will be annotated with key information such as locations of players, the trajectory of the ball, and the type of shots. This data is the basis of the model training process.

Real-time object detection to track and recognize the players and the ball will be implemented by YOLOv8 during model development. Video frames will be preprocessed and resized according to the YOLOv8 model's requirements so that the high-quality data consistently fed to train is used for consistent and efficient data output. In each frame, YOLOv8 will output bounding boxes around the players and the ball. A tracking algorithm such as SORT, Deep SORT, or a Kalman filter will be used to keep track of the identity of players and the ball in multiple frames. This would then allow for accurate tracking of the movement of the players and the trajectory of the ball throughout the game.

The system will then calculate the speed of the players and the shot speed of the ball. The player's speed will be calculated by taking into account the change in position over time, estimating the velocity by taking into account the frame rate and distance between frames. Shot speed will be estimated by tracking the movement of the ball after being hit by the player, calculating its velocity by taking into account the distance traveled and the time taken.

Finally, player performance will be rated based on a few parameters such as player speed and shot speed. The faster the player, the better is the court coverage, and the higher the shot speed, the stronger the offense. These parameters, in combination, will help evaluate a player's performance during the match. This AI-based analysis aims to provide a more objective method for choosing top-performing players, which can be of great value to selection committees in sports organizations.

V. FLOW DIAGRAM OF PROPOSED WORK



VI. ALGORITHM

Step	Description
1	**Video Preprocessing:** Convert videos into frames and resize them to the required dimensions for YOLOv8 input.
2	**Object Detection with YOLOv8:** Use the YOLOv8 model to detect players, tennis balls, and other relevant objects in each frame.
3	**Tracking Players and Ball:** Implement a tracking algorithm (e.g., SORT, Deep SORT) to track the players and ball consistently across frames.
4	**Calculate Player Speed:** Track player movements and calculate their speed by analyzing position changes over time.
5	**Calculate Shot Speed:** Track the ball after it is hit and calculate the shot speed based on the ball's movement over time.
6	**Performance Evaluation:** Combine player speed and shot speed to evaluate overall performance.
7	**Result Interpretation:** Interpret the analysis results and provide insights for selection committees to aid player evaluation.

VII. ADVANTAGE OF PROPSED MODEL OVER EXISTING MODEL

The proposed AI system based on YOLO v8 for the in-depth analysis of tennis matches possesses several significant benefits over traditional models and existing AI-based systems. Such benefits arise from the integration of advanced object detection, real-time performance, and accurate player and ball speed calculations, which are crucial for player performance evaluation and match dynamics analysis. Below are the key benefits of the proposed model over existing solutions:

1. High Detection Accuracy with YOLO v8 :

Improved Object Detection: The YOLO v8 model is a state-of-the-art object detection framework offering superior accuracy and speed in comparison to its previous versions and the traditional method. YOLO v8 is able to identify multiple objects in each frame, including the players and the ball, even when played at their normal pace in the game of tennis. This was not the case with the previous models as it would struggle tracking multiple fast-moving objects in real-time.

Faster Detection: The architecture of YOLO v8 is optimized for processing faster, thereby enabling real-time analysis. This gives coaches and analysts the ability to track live matches with minimal lag time, immediately feeding back comments on key ball hits, player movements, and key match moments. Latency usually characterizes such existing systems and thus makes it hard to implement real-time analysis.

2. Real-Time Calculation of Ball and Player Speed :

Accurate Speed Estimation: The proposed model makes use of sophisticated tracking techniques that calculate the speed of the ball and players with high accuracy. With the aid of

YOLO v8's accurate object detection, it can measure the trajectory of the ball and the movement of the player, hence yielding reliable speed calculations. This gives it a huge advantage over the traditional systems that often depend on manual tracking or less accurate methods, which might introduce errors or delay.

It shows real-time performance tracking, while previous systems did just provide post-match analysis or simply used slower speed tracking methods, so our model calculates player and ball speeds at real-time processing. This creates instant insights useful during the game in improving training and tactical decision making.

3. Enhanced Usability :

User-friendly interface. The system, being developed is friendly, in terms of easy usability by the coaches and analysts. The improvement on existing models that may need highly technical knowledge or configurations, in which it cannot be understood for the immediate extraction of information by a non-technical person for fast insights and action.

4. Scalability and Adaptability :

Multiple Camera Support: The proposed model can handle inputs from multiple cameras, allowing for a more robust and detailed analysis of the match from various angles. This scalability is a major advantage over traditional systems that typically rely on a single camera or limited view of the court, potentially missing key details about player movements or ball trajectories.

Robustness against Different Conditions: The YOLO v8-based model has a high adaptation ability and good performance under environmental conditions, which include varying lights or court surfaces (hard, clay, grass). This becomes crucial in a real-world scenario in which external influences may affect the system's performance. Traditional models tend to lack such adaptability and, as a result, do not produce optimal performance in such conditions.

5. Cost-Effective Solution :

Lower Cost Compared to Traditional Systems: This model employs commercial hardware and very efficient algorithms, which means its performance will be high. The cost-effectiveness of the model is greater in comparison to certain traditional systems using expensive equipment or time-consuming methods such as manual data collection. Thus, the threshold for small teams or a lone player wanting to enhance their game through fine details is lower.

6. Reduced computational overhead and latency :

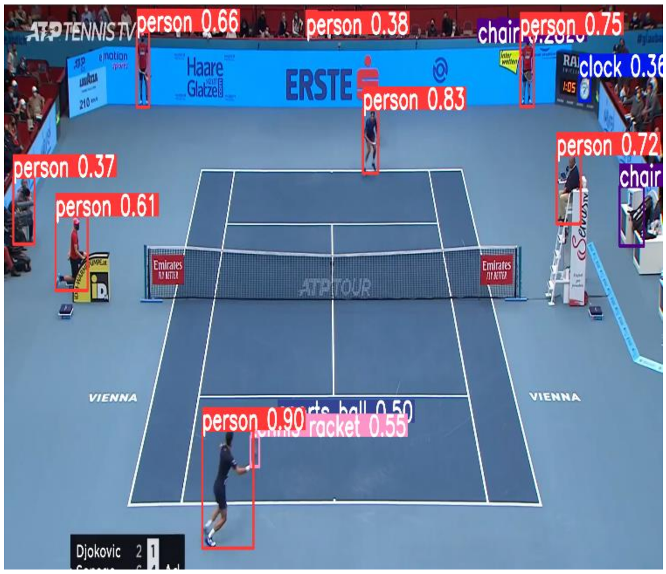
It has also optimized for YOLO v8 with more efficient processing yet maintaining a very high level of accuracy, which is supposed to have lesser computational overhead with low latency; hence, it could process video frames in real time. Former AI models or systems may be quite computationally extensive or even too slow, thereby not very viable for real-time analysis.

Real-Time Match Evaluation: The fast processing and low latency combination allows the system to evaluate player performance in real time during a match, while existing systems may take considerable time to process data, thus limiting their real-time application.

VIII. RESULT AND DISCUSSION

RESULT:

The YOLOv8-based AI system was able to identify and track players on the tennis court well, with confidence scores of active players reaching as high as 0.90. This shows it is robust enough in detecting objects necessary for performance evaluation, including player positions and movements. It has less consistent detection of smaller and faster-moving objects, like the tennis ball with a confidence score of 0.50 and racket at 0.55. These lower confidence levels indicate that though the system may be able to identify such objects, its precision is reduced when handling smaller or partially occluded objects. This means that the precision of derived metrics like ball speed and racket impact analysis could be adversely affected since their accuracy relies on detection that is constantly accurate.



DISCUSSION:

It enables the system to calculate some critical performance metrics such as speed, reaction time, and court coverage. The player's performance can be very well analyzed using this system with coaching support. By analyzing the relation between ball and racket position over time, it is also possible to estimate hitting speeds. The system thus becomes crucial in evaluating shot power and technique. However, relative low confidence toward the detection of smaller objects as the tennis ball calls for better refinement. Use of high resolution images, specialized datasets of images of tennis play, and processing techniques to accommodate occlusion or motion blur effects can improve results. Moreover, post-processing filtering algorithms can omit irrelevant detections or background objects as chairs or clock to enhance computer efficiency and focus completely on tennis relevant elements. The challenges addressed will make the system reliable for in-depth match analysis and practical use for coaching and performance evaluation.

IX. CONCLUSION

The YOLOv8-based AI system that does in-depth analysis of the tennis match can be regarded as a milestone in developing automated sports analytics. By correctly identifying the players along with key items such as the ball and racket, the system makes it easy to obtain some of the performance metrics such as the speed of the player, agility, and hitting power of the player. Though detection is tough for objects smaller and of fast motion, the system still proves robust. Further optimized with improved training on tennis-specific datasets and small object detection using advanced techniques, this system will transform tennis performance evaluation. It is going to offer powerful insights for coaches, players, and analysts to fine-tune strategies, enhance training, and elevate the general level of competition.

X. REFERENCES

1. P. Zhao, T. Luo and P. Bi, "Athlete Performance Analysis: Machine Learning for Predicting Tennis Player Scores," 2024 6th International Conference on Communications, Information System and Computer Engineering (CISCE), Guangzhou, China, https://ieeexplore .ieee.org/document/10653354, 2024, pp. 1158-1162, doi: 10.1109/CISCE62493.2024.10653354.

2. J. Guo, J. Zhu, S. Lin and F. Shi, "Momentum Prediction for Tennis Matches Based on Counter-Factual Analysis and Multi-LGBM," 2024 7th International Conference on Advanced Algorithms and Control Engineering (ICAACE), Shanghai,China,https://ieeexplore.ieee.org/document/10548 364,2024, pp.781-785, doi:10.1109/ICAACE61206.2024. 10548364.

3. A. Cao, X. Xie, M. Zhou, H. Zhang, M. Xu and Y. Wu, "Action-Evaluator: A Visualization Approach for Player Action Evaluation in Soccer," in IEEE Transactions on Visualization and Computer Graphics, vol.30, no.1, pp. 880-890,https://ieeexplore.ieee.org/document /10296094, Jan. 2024, doi: 10.1109/TVCG.2023.3326524.

4. R. M, R. B, L. R and S. K, "Player Performance Prediction in Sports Using Machine Learning ," 2024 International Conference on Intelligent Systems for Cybersecurity(ISCS),India,https://ieeexplore.ieee.org/docu ment/10581086, 2024, pp. 1-6, doi: 10.1109/ISCS 61804 .2024.10581086.

5. R. K. Jeong et al., "A Monitoring System for Cattle Behavior Detection using YOLO-v8 in IoT Environments," 2024 IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, NV, USA, 2024, pp. 1-4, doi: 10.1109/ICCE59016.2024.10444145.

6. Z. Liu, K. Jiang, Z. Hou, Y. Lin and J. S. Dong, "Insight Analysis for Tennis Strategy and Tactics," 2023 IEEE International Conference on Data Mining (ICDM), Shanghai,China,https://ieeexplore.ieee.org/document/10415 706,2023, pp. 1169-1174, doi: 10.1109/ICDM58522 .2023.00143.

7. C. Rohra, M. Mangla, S. Asher, N. Agarwal and S. Desai, "Footy Forecast– Measuring Performance in Football," 2023 International Conference on Advanced Computing Technologies and Applications (ICACTA), Mumbai, India, https://ieeexplore.ieee .org /document /10393051, 2023, pp. 1-7, doi: 10.1109 /ICACTA 58201.2023.10393051.

8. H. Yu, "The Design Method of Intelligent Sports Information Management System," 2023 International Conference on Evolutionary Algorithms and Soft Computing Techniques Bengaluru, India, https://ieeexplore .ieee.org/document/10393528, 2023, pp. 1-5, doi: 10.1109/EASCT59475.2023.10393528.

9. Y. Zheng, W. Zhou, T. Zou and H. Zhang, "A Method for Table Tennis Bat Trajectories Reconstruction with the Fusion of Human Keypoint Information," 2023 8th IEEE International Conference on Network Intelligence and Digital Content (IC- NIDC), China, https://ieeexplore .ieee.org/document/10390665, 2023, pp. 71-75, doi: 10.1109/IC-NIDC59918.2023.10390665.

10. R. A et al., "Deep Learning-Based Tennis Shot Type Prediction Using Gait Analysis," 2023 Intelligent Computing and Control for Engineering and Business Systems India, https://ieeexplore.ieee.org/document /10449169, 2023, pp. 1-4, doi: 10.1109/ICCEBS 58601 .2023.10449169.

11. S. Vancurik and D. W. Callahan, "Detection and Identification of Choking Under Pressure in College Tennis Based Upon Physiological Parameters, Performance Patterns, and Game Statistics," in IEEE Transactions on Affective Computing, vol. 14, no. 3, pp. 1942-1953, 1 July-Sept.,https://ieeexplore.ieee.org/document/9750870, 2023, doi: 10.1109/TAFFC.2022.3165139.

12. J.-R. Chang, C.-J. Wang, Z.-K. Wei, C.-J. Lu and H.-Y. Lin, "A Research Structure of Big Data Analysis and Application for Table Tennis Match Tactics Based on Computer Vision," 2023 9th International Conference on Applied System Innovation Japan, https://ieeexplore .ieee.org/document/10179601,2023,pp.220-222, doi:10.1109 /ICASI5 7738.2023.10179601.

13. S. Jhawar, "Predicting Tennis Match Outcomes," 2022 International Conference on Futuristic Technologies India, https://ieeexplore.ieee.org/document/10094479, 2022, pp. 1-4, doi: 10.1109/INCOFT55651.2022.10094479.

14. S.-K. Liang, J.-Y. Chiang and K. Wang, "Feasibility Study of Using Hybrid Artificial Intelligence Architecture for Recognizing Execution Styles of Players in Tennis Match," 2022 IEEE 5th International Conference on Knowledge Innovation and Invention Taiwan, https://ieeexplore.ieee.org/document/9983570, 2022, pp. 128-132, doi: 10.1109/ICKII55100.2022.9983570.

15. M. Skublewska-Paszkowska, P. Powroznik and E. Lukasik, "Attention Temporal Graph Convolutional

Network for Tennis Groundstrokes Phases Classification," 2022 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), Padua, Italy, 2022, pp. 1-8, doi: 10.1109/FUZZ-IEEE55066.2022.9882822.