International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 03 | Mar 2026 www.irjet.net p-ISSN: 2395-0072

Video Based Sports Performance Assessment Using Pose Estimation and Machine Learning

Dr. Sandeep Kulkarni[1], Mahak Sayyad[2], Adith Elavathoor[3], Manu Krishna[4]

[1]*Assistant Professor, Department of Computer Science, Ajeenkya DY Patil University, Lohegon, Pune-412105*
[2]*Student, School of Engineering, Ajeenkya DY Patil University, Lohegon, Pune-412105,*
[3]*Student, School of Engineering, Ajeenkya DY Patil University, Lohegon, Pune-412105,*
[4]*Student, School of Engineering, Ajeenkya DY Patil University, Lohegon, Pune-412105,*

Abstract — *Historically, sports perfoance measurement has been based on human judgment by coaches and experts and thus it can be highly deficient in terms of human bias, limited view angles as well as the lack of accurate quantitative measurements. As the need to make data-driven decisions with respect to sports training and talent identification grows, intelligent systems providing objective, consistent, and scalable performance evaluation are required. This study describes an AI-Based Sports Performance Assessment System capable of analyzing the movements, posture of the athletes and performance indicators using video-based data through the application of Computer Vision and Machine Learning methods. The project is created based on the problem statement of Smart India Hackathon (SIH) 2025, which is AI Sports Assessment Application. The suggested system will manipulate recorded or live video footage of a sport to identify important biomechanical indicators of joint angles, limb motions, posture accuracy, and consistency of motion. A pose estimation framework is utilized to estimate and track human skeletal keypoints in video frames, which allows the spatiotemporal analysis of the movements of athletes in detail. These features are then fed through machine learning models that determine the quality of performance, detecting when movement is not following a perfect pattern, and giving feedback that can be taken as action. The system has the capability of accommodating several sporting situations and can be expanded to incorporate sensor-based information to achieve improved accuracy. The research design is a prototype-based experimental research, where standardized datasets and controlled assessment conditions are used. Quantitative measures of performance are provided including accuracy, precision and error rates in movement detection and consistency in assessment. The system focuses on reliability and reproducibility via pre-processing of data in structured format, model validation and testing of multiple samples. The findings prove that AI-based sports evaluation may dramatically decrease subjectivity and offer reliable and meaningful feedback to both athletes and coaches. This study identifies the opportunities of artificial intelligence to revolutionize sports analytics by providing scalable, real-time, and objective evaluation of performances.*

Key Words: Sports Performance Assessment, Pose Estimation, Machine Learning, Computer Vision, MediaPipe

I. INTRODUCTION

Sports performance assessment plays an important role in improving athlete skills, training effectiveness, and injury prevention. Coaches traditionally evaluate athlete performance by observing movements and identifying errors manually. Although this method is widely used, it depends heavily on human judgment and may lead to inconsistent or subjective results. Manual analysis is also time-consuming, especially when analyzing multiple athletes or long training sessions.

With the advancement of computer vision, it has become possible to analyze human movement using video data. Computer vision allows computers to extract meaningful information from images and videos and has been widely applied in motion analysis and sports performance evaluation [1]. One of the key techniques used in motion analysis is pose estimation, which detects and tracks important body joints such as shoulders, elbows, hips, and knees. These detected points help in understanding posture, alignment, and movement patterns [2].

Pose estimation frameworks such as MediaPipe Pose provide accurate detection of body landmarks in real time. These landmarks can be used to calculate biomechanical features such as joint angles and posture alignment. This allows objective analysis of athlete movements without the need for expensive motion capture systems [2].

Machine learning techniques can further enhance performance assessment by analyzing extracted features and identifying patterns in athlete movements. Machine learning algorithms can learn from data and classify movements based on performance quality [3]. This enables automated performance evaluation and reduces reliance on manual observation.

This study aims to develop a video-based sports performance assessment system using pose estimation and machine learning. The system detects body landmarks from video data, extracts important movement features, and classifies performance. This approach provides a

reliable, objective, and cost-effective solution for sports performance analysis.

II. LITERATURE REVIEW

Computer vision has been widely used in sports performance analysis due to its ability to analyze human movement using video data. It provides accurate and automated evaluation compared to manual observation methods [1]. Video-based analysis allows continuous monitoring of athlete performance without requiring specialized hardware.

Pose estimation is an important technique used to detect body landmarks and analyze posture. MediaPipe Pose is a widely used pose estimation framework that detects 33 body landmarks and provides reliable performance in real-time applications [2]. Similarly, OpenPose is another pose estimation model that detects multiple body joints and enables accurate motion tracking [4]. These systems allow biomechanical analysis by calculating joint angles and movement patterns.

Machine learning algorithms such as Random Forest, Support Vector Machines, and Neural Networks have been used to classify sports movements based on extracted features [3]. Random Forest is commonly used because of its high accuracy and ability to handle complex datasets. Machine learning models can identify patterns in movement data and classify performance effectively.

Previous studies have shown that combining pose estimation and machine learning provides reliable sports performance assessment. These systems help in improving athlete training and performance evaluation. However, pose estimation accuracy can be affected by lighting conditions, camera angle, and video quality [4]. Despite these limitations, video-based assessment remains an effective solution.

Fig. 1: *Pose Estimation of Athlete during Jump Movement for Motion Analysis*

III. METHODOLOGY

This study used an experimental research design to develop and evaluate a sports performance assessment system using pose estimation and machine learning. The system was implemented using Python programming language (version 3.10), which is widely used for machine learning and computer vision applications [1].

The dataset consisted of 120 video samples collected from publicly available sources and recorded practice sessions with participant consent. Participants included male and female individuals between 18 and 25 years of age. A convenience sampling method was used. Videos included movements such as squats, jumping, and running. Videos with clear body visibility were included, while videos with poor lighting or incomplete body visibility were excluded.

Video preprocessing was performed using OpenCV library (version 4.8), which is commonly used for video processing tasks [5]. Each video was converted into frames, and resolution was standardized to 1280 × 720 pixels to ensure consistency.

Pose estimation was performed using MediaPipe Pose, which detects 33 body landmarks including shoulders, hips, knees, and elbows [2]. These landmarks were used to analyze posture and movement.

Biomechanical features such as joint angles and posture alignment were calculated from landmark coordinates. These features were used because they provide important information about movement quality [4].

Machine learning classification was performed using the Random Forest algorithm implemented in Scikit-learn library [3]. The dataset was divided into training and testing sets using an 80:20 ratio. System performance was evaluated using accuracy, precision, recall, and F1-score metrics.

Standardized pre-processing and feature extraction methods were used to ensure accuracy and consistency.

Fig. 2: *Pose Estimation of Athlete During Squat Movement Using MediaPipe*

IV. RESULTS AND DISCUSSION

The system successfully detected body landmarks using MediaPipe Pose. Landmark detection was accurate in most video samples and allowed effective movement analysis [2].

The Random Forest classifier achieved an accuracy of approximately 88%. The model was able to classify athlete movements based on extracted features [3].

The results show that pose estimation and machine learning provide reliable sports performance assessment. The system provides objective evaluation and reduces dependence on manual observation.

Some limitations were observed due to lighting and camera angle variation. However, overall system performance was effective.

Fig. 3: *Machine learning-based performance classification system interface*

V. CONCLUSION

This study presented the design and implementation of a video-based sports performance assessment system using pose estimation and machine learning techniques. The proposed system successfully demonstrated that athlete movements can be analyzed automatically using computer vision methods, eliminating the need for manual observation and subjective evaluation. By utilizing pose estimation algorithms, the system was able to detect key anatomical landmarks and extract meaningful biomechanical features such as joint angles, posture alignment, and movement consistency. These features provided valuable quantitative data that could be used to evaluate performance objectively and consistently.

The results of this study showed that pose estimation frameworks such as MediaPipe provide reliable and accurate detection of human body landmarks under normal environmental conditions. The extracted landmark coordinates enabled precise calculation of joint angles, which are essential indicators of movement quality and technique [3]. Furthermore, the integration of machine learning algorithms allowed the system to classify athlete performance based on extracted biomechanical features. The Random Forest classifier was selected due to its robustness, ability to handle complex datasets, and effectiveness in classification tasks [5]. The model demonstrated satisfactory performance in distinguishing between correct and incorrect movement patterns, indicating that machine learning can be effectively applied to sports performance assessment.

One of the major advantages of the proposed system is its non-invasive and cost-effective nature. Unlike traditional motion capture systems, which require specialized sensors and expensive equipment, the proposed method only requires a standard video camera and a computer system. This makes the system accessible and practical for use in real-world environments such as sports training centers, educational institutions, and rehabilitation facilities. Additionally, the automated analysis reduces human error and ensures consistent evaluation across multiple sessions, improving reliability and repeatability [4].

Despite its advantages, the system has certain limitations. The accuracy of pose estimation may be affected by factors such as poor lighting conditions, occlusion of body parts, and improper camera positioning. These environmental factors can influence landmark detection accuracy and, consequently, performance evaluation results. Additionally, the system was tested on a limited dataset, and further testing on larger and more diverse datasets is necessary to improve generalization and robustness.

Future work can focus on improving the system by incorporating deep learning-based classification models, which may provide higher accuracy and better performance in complex scenarios. Expanding the dataset to include more participants, different sports activities, and various environmental conditions can further enhance system reliability. Additionally, real-time feedback systems can be developed to assist athletes and coaches in correcting movement errors immediately during training sessions. Integration with mobile devices and wearable systems can also improve accessibility and usability in practical sports environments.

In conclusion, this research demonstrated that video-based pose estimation combined with machine learning provides an effective and practical solution for automated sports performance assessment. The proposed system has significant potential to improve athlete training, performance evaluation, and injury prevention by providing objective, accurate, and efficient movement analysis. With further development and improvement, such systems can play an important role in the future of sports science and intelligent performance monitoring.

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