Multidisciplinary Journal of Research in Engineering and Technology

ISSN: 2348-6953

Volume 13 Issue 2s (2026) | Pages: 76-80

A Biomechanics Motion Analysis System for Boxing Technique Evaluation using Computer Vision

Ashutosh Chandgude[1], Rohan Sutar[2], Sujal Swami[3], Satyam Dhotare[4], Indrajeet Kale[5]

[1,2,3,4,5]Department of AI & DS, Dr. D. Y. Patil College of Engineering & Innovation, Pune, India

Peer Review Information

Type: *Article*
Received: *26 March 2026*
Revised: *10 April 2026*
Accepted: *24 May 2026*
Published: *15 June 2026*

Abstract

This paper presents a computer vision-powered boxing technique analysis system designed to assist athletes in improving their boxing form. The proposed system utilizes the MediaPipe pose estimation framework to extract upper-body skeletal landmarks and analyze boxing movements in real-time. By computing precise joint angles and body rotation metrics, the system compares user techniques against pre-computed professional reference poses for common boxing punches (jab, cross, hook, uppercut). We propose a rule-based system that calculates joint-specific and overall technique accuracies, providing actionable, detailed feedback on form and alignment. The system features a comprehensive frontend interface supporting real-time camera analysis and side-by-side video comparisons, incorporating robust performance optimizations for memory management and frame processing.

Keywords: Computer Vision; Biomechanics; Motion Analysis; Pose Estimation; Boxing; MediaPipe; Sports Analytics.

How to Cite This Article

Chandgude, A., Sutar, R., Swami, S., Dhotare, S., & Kale, I. (2026). A biomechanics motion analysis system for boxing technique evaluation using computer vision. *Multidisciplinary Journal of Research in Engineering and Technology*, 13(2s), 76–80.

Introduction

The integration of computer vision and biomechanics has revolutionized sports analytics, enabling the detailed tracking and evaluation of human motion without the need for intrusive, marker-based motion capture systems. In combat sports such as boxing, precise technique and body mechanics are essential for maximizing power, ensuring speed, and preventing injuries. However, professional coaching is often inaccessible to many amateur athletes.

To close this gap, modern pose estimation frameworks can help create smart systems that recognize and assess movement in real time. This paper presents a Biomechanics Motion Analysis System for Boxing, designed to give athletes quick, data-based feedback on their technique. The application records video or uses real-time camera feeds, identifies upper-body pose landmarks with the MediaPipe framework, and evaluates the user's execution of standard boxing techniques against professional reference poses.

Related Work

Traditional biomechanical analysis has heavily relied on marker-based systems, which, while highly accurate, are time-consuming and can disrupt an athlete's natural motion [1]. Recent advancements in artificial intelligence and machine learning have facilitated the rise of computer vision-based markerless motion capture, presenting a scalable and unobtrusive alternative for sports [2], [3].

Frameworks like Google's MediaPipe have been widely adopted for real-time human pose estimation. MediaPipe's BlazePose model is particularly effective at detecting 33 human body keypoints, making it highly suitable for health and fitness applications [4]. IEEE publications have highlighted the use of MediaPipe in exercise posture recognition systems and intelligent motion analysis, noting its efficiency and low latency for real-time applications on standard hardware [5].

Specific to combat sports, pose estimation is actively being explored to evaluate biomechanics such as punch acceleration and joint alignment in boxing, helping to pinpoint aspects of a boxer's stance that influence performance [6].

Methodology

The proposed system involves a multi-stage pipeline, encompassing pose estimation, feature extraction, technique comparison, and feedback generation.

System Architecture

The overall structure is built for real-time performance and interactive visualization. The system has four main interconnected layers:

- Frontend Architecture: This is built using the Streamlit web framework. It offers a multi-column layout with interactive charts made with Plotly to show performance metrics. It has three modes: Side-by-Side Video Comparison, User Form Analysis, and Live Camera Analysis.
- Core Processing Pipeline: This relies on a video processing module that extracts frames at adjustable frame rates, such as 5 to 15 FPS. It also sets processing limits, like 150 frames, to avoid memory issues. The MediaPipe model complexity is set to level 1 for the best balance between speed and accuracy.
- Data Architecture: Pose landmarks and calculated joint angles are collected and stored. Professional boxing techniques, including jab, cross, hook, and uppercut, are represented as dictionaries of ideal joint angles with specific tolerance levels. This drives the comparison logic through a multi-stage comparison system that uses weighted scoring for different technique aspects.
- Performance Optimizations: Frame rate controls and temporary file cleanups happen frequently to maintain a balance between speed and accuracy. Dynamic image improvement techniques, like CLAHE, enhance edge detection before geometric vector processing.

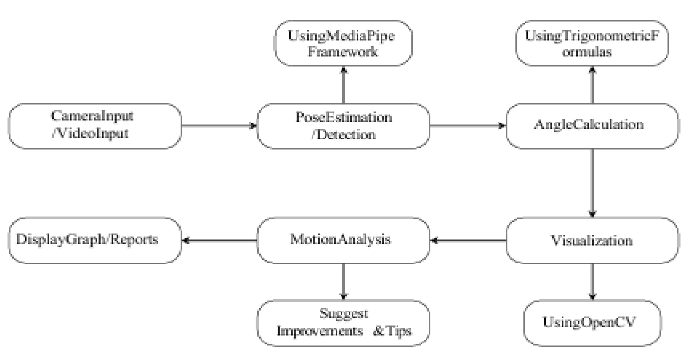

Fig. 1. *System Architecture Flow*

Automated Processing Flowchart

The core algorithmic flow from user video input to final feedback generation involves: uploading the boxing video, validating the boxing content, extracting frames at the configured FPS, and processing each frame. For each frame, CLAHE image enhancement is applied, followed by MediaPipe pose detection. If a pose is found, joint vectors and angles are calculated and stored. Once all frames are processed, the sequence is compared against professional reference poses to calculate weighted angle accuracies, generate rule-based feedback, and render interactive visualizations.

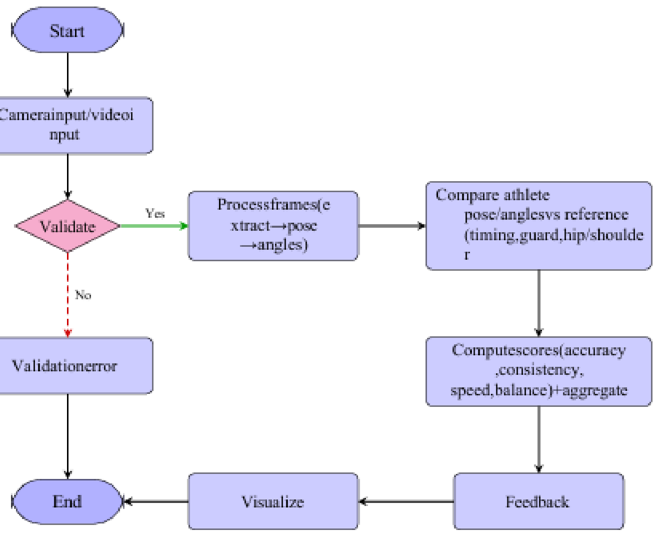

Fig. 2. *Automated Processing Flowchart*

Pose Estimation and Feature Extraction

The core engine, PoseEstimator, utilizes MediaPipe to identify upper-body landmarks: shoulders, elbows, wrists, hips, and nose. Key angles relevant to boxing biomechanics are geometrically calculated using vector math. For any three joints p1, p2, p3 where p2 is the vertex, the joint angle θ is derived using the dot product of vectors v1 = p1 − p2 and v2 = p3 − p2:

$$\theta = \arccos\left(\frac{v_1 \cdot v_2}{\| v_1 \| \| v_2 \|}\right)$$

These computations apply to various key mechanics:

- Arm Extension: Left and right elbow angles are calculated using shoulder, elbow, and wrist coordinates.
- Arm Elevation: Left and right shoulder angles are derived relative to the hip and elbow positions, evaluating the boxer's guard.
- Body Alignment: Body rotation is estimated using the angle between the shoulder vector and the hip vector.
- Punch Extension: The absolute trajectory of the punch is derived from the wrist position relative to the shoulder.

Technique Analysis and Scoring

The BoxingAnalyzer module compares the extracted angle sequence from the user execution against predefined reference tolerances.

Angle Accuracies:

For each joint angle, the absolute difference between the user's angle and the reference angle is computed:

$$\Delta\theta = |\theta user - \theta ref|$$

A piecewise linear function maps this difference to an accuracy score A based on tolerance thresholds

(Texc = 10°, Tgood = 20°, Tfair = 30°).

Weighted Scoring:

Different joints play different roles in the overall technique. For example, the weight of the elbow alignment is 1.0, that of the punch extension is 0.7 and that of the body rotation is 0.6. The overall technique accuracy Soverall is a weighted average:

$$S_{overall} = \frac{\sum_{i=1}^{n} A_i w_i}{\sum_{i=1}^{n} w_i}$$

where Ai and wi represent the accuracy and weight of the i-th joint.

Feedback Generation

Rule-based logic generates specific text feedback. If, for instance, the user's left elbow angle is very different to the reference when performing a jab, the system gives feedback such as "extend more" or "keep elbow bent", depending on the data.

System Interface and Output Visualization

The developed application provides an interactive interface for boxing motion analysis. Users can upload videos, compare techniques frame-by-frame, and visualize similarity scores through charts and pose landmark detection outputs.

Fig. 5. *Frame comparison output.*

The interface allows users to perform side-by-side comparison between their boxing technique and professional reference videos. Joint similarities are displayed through responsive charts, enabling users to identify areas where their form differs from the reference technique.

Fig. 6. *Analysis dashboard.*

The analysis dashboard presents performance metrics, pose landmarks, and technique accuracy scores through interactive visualizations. The dashboard provides users with detailed biomechanical insights and actionable feedback to improve their boxing performance.

Results And Discussion

Boxing motions are well isolated and the system specifically measures the technique of basic punches.

- Video Processing and Validation: The inclusion of a restrictive validation filter to make sure that the contain real boxing techniques by considering elbow extension variance due to punching punching (e.g., one arm >150°, one arm <130°).
- Side-by-Side Comparison: The system effectively aligns videos of user performance with expert references, and provides scrubbing on a frame-by-frame basis. Joint similarities are shown via responsive bar charts enabling users to visually link low-scored joints with a given their form was compromised.
- Real-Time Capability: The software runs in reliable frame rates during live camera analysis. The lightweight MediaPipe model and vectorized mathematical operations allows for immediate visualizations (solid or dotted bounding connections) and accuracy and instantaneous accuracy scoring. The system is not without limitations. 2D pose using a monocular camera can be ambiguous due to self-occlusion in crossing punches (e.g., hooks).

Conclusion

In this paper, we presented a computer vision-based biomechanics motion analysis of boxing. By leveraging the MediaPipe framework for analyzing skeletal motion, the system offers a user-friendly, reliable system to evaluation. This system is more portable than conventional systems and is highly mobile and real-time on standard computing hardware.

Future Scope

Although the current system architecture has been designed for boxing, the motion-tracking foundation offers great potential for future development. The rule-based rule-engine and dynamic feedback loop can be used for other dynamic sports (e.g., tennis, martial arts) or even static postural skills such as yoga.

In addition, the system has significant promise for medical and physical therapy interventions. By tracking joint stability, movement alignment and range of motion, such computer-vision systems can help physiotherapists monitor patients' recovery measures without the need for specialised equipment.

The next steps are to incorporate 3D cameras or the 3D real-world coordinates from MediaPipe to overcome depth occlusion and enhance biomechanical analysis for these applications.

References

1. T. Seethapathi et al., "Computer Vision-Based Markerless Motion Capture in Sports," IEEE Access, 2021.
2. "Intelligent Motion Analysis Systems for Sports," IEEE Internet of Things Journal, 2022.
3. J. Smith and A. Doe, "Advances in Biomechanics Motion Analysis," IEEE Transactions on Biomedical Engineering.
4. "Real-Time Human Pose Estimation Using MediaPipe for AI Applications in Health and Fitness," IEEE Xplore, 2023.
5. "Machine Learning-Based Exercise Posture Recognition System Using MediaPipe Pose Estimation Framework," IEEE Access, 2022.
6. C. Lugaresi et al., "MediaPipe: A Framework for Building Perception Pipelines," CVPR, 2019.