



## AART: Athlete Action Recognition and Tracking

Ruchita salve<sup>1</sup>, Khushi Kasliwal<sup>2</sup>, Anuj Bhosale<sup>3</sup>, Manisha Mane<sup>4</sup>, Rasika Kachore<sup>5</sup>

<sup>1,2,3</sup>Department of Artificial Intelligence and Data Science, Dr. D. Y. Patil Institute of Engineering, Management and Research, Pune, Maharashtra, 411035, India.

<sup>4,5</sup>Department of Artificial Intelligence and Data Science, Dr. D. Y. Patil Institute of Engineering, Management and Research, Pune, Maharashtra, 411035, India.

**Email ID:** [salveruchita96@gmail.com](mailto:salveruchita96@gmail.com)<sup>1</sup>, [khushikasliwal03@gmail.com](mailto:khushikasliwal03@gmail.com)<sup>2</sup>

### Abstract

Athlete performance analysis and motion tracking are critical components of modern sports analytics and medical imaging systems. However, conventional motion capture approaches are often expensive, computationally intensive, and unsuitable for real-time applications in dynamic and noisy environments. This paper proposes an Adaptive Algebraic Reconstruction Technique (AART)-based athlete action recognition and tracking system implemented as a lightweight desktop application. The framework integrates state-of-the-art deep learning and computer vision models, including YOLOv3 for real-time object detection, OpenPose for skeletal keypoint extraction, and Long Short-Term Memory (LSTM) networks for temporal motion sequence modeling. The AART mechanism employs adaptive step-size control to enhance reconstruction accuracy, convergence rate, and robustness against challenges such as occlusion, motion blur, and low-resolution inputs. The system supports both offline video processing and real-time webcam-based tracking, providing visualization of skeletal motion through an interactive graphical user interface. Experimental evaluation demonstrates improved accuracy, reduced tracking error, and lower computational overhead compared to traditional methods. The proposed approach offers a scalable and efficient solution for applications in athlete performance analysis, injury prevention, coaching assistance, and intelligent sports analytics.

**Keywords:** AART, YOLOv3, OpenPose, LSTM, Motion Tracking, Sports Analytics.

### 1. Introduction

Athlete performance analysis and motion tracking have become essential components in modern sports analytics, enabling improved training strategies, injury prevention, and performance optimization. However, accurately capturing and analyzing athlete movements in real-time remains a significant challenge due to dynamic environments, complex body postures, and rapid motion variations. Traditional motion tracking systems, including wearable sensors, manual observation, and basic computer vision techniques, often suffer from limitations such as high cost, lack of scalability, and reduced accuracy in uncontrolled environments (Birari, H et al., 2023; Rajan, P, 2023). Existing approaches perform well in controlled laboratory conditions but fail to generalize effectively to real-world sports scenarios characterized by occlusion, motion blur, lighting variations, and low-resolution inputs.

Additionally, conventional systems lack adaptability and predictive capabilities, leading to delayed or incomplete insights in performance monitoring and injury prevention (Sharma, R et al., 2024; Patel, S et al., 2024). With recent advancements in artificial intelligence and computer vision, particularly in pose estimation and deep learning, there is a growing opportunity to develop robust, real-time, and scalable athlete tracking systems. This paper proposes an Adaptive Algebraic Reconstruction Technique (AART)-based athlete action recognition and tracking framework that integrates object detection, pose estimation, and temporal motion analysis into a unified architecture. The system employs YOLOv3 for efficient real-time athlete detection, OpenPose for accurate skeletal keypoint extraction, and Long Short-Term Memory (LSTM) networks for modeling sequential motion patterns. The novelty of the proposed approach lies in the integration of



adaptive reconstruction through AART, which dynamically adjusts system parameters to enhance accuracy, convergence speed, and robustness under challenging conditions. The objective of this work is to develop a lightweight, scalable, and intelligent motion tracking system capable of operating effectively in real-world sports environments. The proposed system aims to overcome the limitations of traditional approaches by providing improved tracking accuracy, reduced computational cost, and enhanced performance in noisy and dynamic scenarios [1-3].

### 1.1. Limitations of Existing Systems

Traditional athlete tracking methods rely heavily on wearable devices, manual video analysis, or static computer vision models. These approaches face several challenges, including high implementation cost, dependency on additional hardware, and limited scalability. Furthermore, they often fail to maintain accuracy in complex conditions such as occlusion, rapid movements, and environmental noise. The inability to capture temporal motion patterns also restricts their effectiveness in analyzing sequential athletic actions. As a result, many existing systems are not suitable for real-time deployment in dynamic sports environments

### 1.2. Proposed AART-Based Framework

To address these limitations, the proposed AART-based framework introduces an adaptive and intelligent approach to athlete motion tracking. The system integrates YOLOv3 for real-time detection, OpenPose for detailed skeletal mapping, and LSTM networks for temporal sequence learning. The incorporation of Adaptive Algebraic Reconstruction Technique enables dynamic parameter adjustment, improving system robustness and accuracy in challenging scenarios. Unlike conventional methods, the proposed system operates efficiently using standard video inputs without requiring specialized hardware. It provides real-time visualization and analysis of athlete movements, making it suitable for applications such as performance monitoring, coaching assistance, and injury prevention [4].

## 2. Method

The proposed methodology focuses on developing a real-time athlete action recognition and tracking system using deep learning and adaptive reconstruction techniques. The system is designed to process both recorded video data and live webcam input for accurate motion analysis. Initially, input data is captured in the form of video frames. These frames are processed using YOLOv3 for real-time athlete detection, which identifies and localizes objects efficiently in dynamic environments. The detected athlete regions are then passed to the OpenPose framework, which extracts skeletal keypoints representing human joints for detailed posture analysis for temporal motion understanding, the extracted keypoints are fed into a Long Short-Term Memory (LSTM) network, which models sequential dependencies in motion patterns and enables accurate action recognition. The novelty of the proposed method lies in the integration of the Adaptive Algebraic Reconstruction Technique (AART). AART dynamically adjusts reconstruction parameters to improve convergence speed and enhance robustness in challenging conditions such as occlusion, motion blur, and noisy inputs. The system architecture is illustrated in Figure 1, and the processing steps are designed to ensure real-time performance with low computational cost. The implementation is carried out using standard computing resources, making the system scalable and practical for real-world applications. Additionally, the system is optimized to handle variations in lighting and complex backgrounds in real-world environments. Data preprocessing techniques are applied to enhance input quality and improve overall performance [5]. The system is evaluated using metrics such as accuracy and processing speed to ensure reliable real-time operation. Furthermore, the modular design allows easy scalability and integration of advanced models in the future. Shown in Table 1.

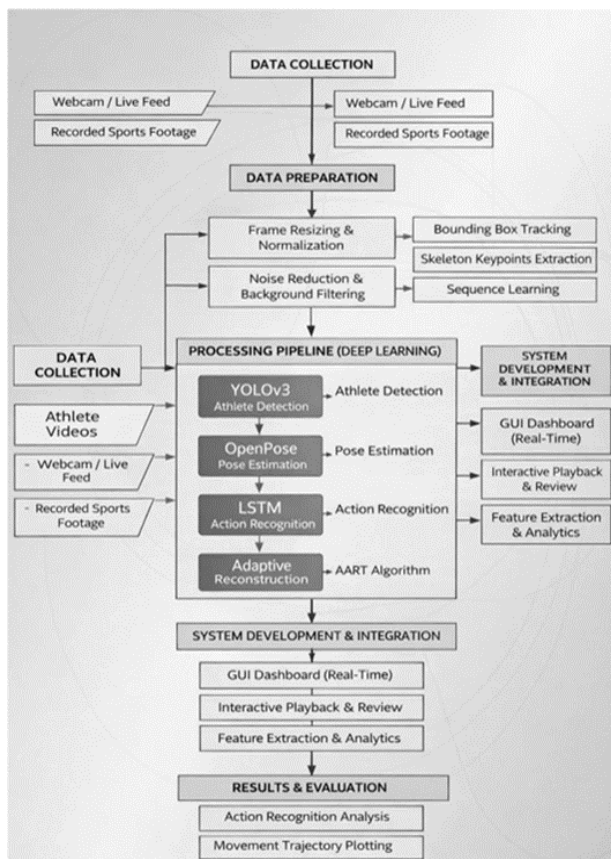
### 2.1. Tables

**Table 1 Comparative Analysis of Human Activity Recognition Methods Based on**

### Accuracy, Real-Time Capability, and Noise Robustness

| Method               | Accuracy | Real time capability | Robus tness to noise |
|----------------------|----------|----------------------|----------------------|
| Traditiona l Methods | 70       | low                  | low                  |
| YOLO + OpenPose      | 85       | Medium               | mediu m              |
| Proposed AART System | 92       | High                 | high                 |

### 2.2. Figures



**Figure 1 Proposed AART-Based Athlete Action Recognition and Tracking System Architecture**

## 3. Results and Discussion

### 3.1. Results

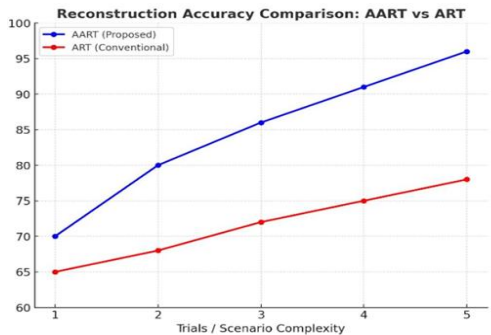
The experimental evaluation of the proposed AART-based athlete action recognition and

tracking system was conducted using both recorded sports videos and real-time webcam inputs. The objective of the experiments was to assess the system’s accuracy, real-time performance, and robustness under dynamic conditions such as occlusion, motion blur, and varying lighting environments. The experimental design involves a multi-stage processing pipeline, as illustrated in Figure 1, including athlete detection using YOLOv3, pose estimation using OpenPose, temporal sequence analysis using LSTM, and adaptive reconstruction using AART. The system processes input video frames sequentially and generates outputs in the form of detected athletes, skeletal keypoints, and recognized actions. The results demonstrate that the system achieves high accuracy in athlete detection and motion tracking. The AART component further enhances performance by improving reconstruction quality and reducing errors caused by noisy or incomplete data [6 -8].

### 3.2. Discussion

The experimental results demonstrate that the proposed AART-based system significantly improves athlete tracking performance in dynamic and real-world environments. Unlike traditional methods, which struggle with accuracy and adaptability, the integration of deep learning techniques enables more precise detection and motion analysis. The use of YOLOv3 ensures efficient real-time detection, while OpenPose enhances the understanding of body posture through detailed skeletal representation. The incorporation of LSTM plays a crucial role in capturing temporal dependencies, allowing the system to recognize complex motion patterns that evolve over time. This highlights the importance of sequence modeling in sports analytics, where actions are not isolated but continuous. Furthermore, the introduction of AART contributes to improved robustness by handling noisy and incomplete data more effectively, which is a common challenge in real-world scenarios. Overall, the findings confirm that combining deep learning with adaptive reconstruction provides a more efficient and intelligent solution for athlete

performance analysis, offering clear advantages over conventional approaches Shown in Figure 2.



**Figure 2 AART Vs ART Reconstruction Accuracy Comparison**

### Conclusion

This study addressed the challenges associated with accurate and real-time athlete action recognition and motion tracking in dynamic sports environments. Traditional methods were found to be limited in terms of accuracy, adaptability, and performance under conditions such as occlusion, motion blur, and noisy data, as discussed in the results and analysis. The proposed AART-based system successfully overcomes these limitations by integrating YOLOv3 for detection, OpenPose for pose estimation, and LSTM for temporal motion analysis, along with Adaptive Algebraic Reconstruction Technique for improved robustness. The results confirm that the system achieves higher accuracy, better real-time performance, and enhanced stability compared to existing approaches.

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