Analysis of Archery Posture and Technique Through Human Activity Recognition Utilizing MediaPipe

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ABSTRAK

Panahan merupakan olahraga yang menuntut postur dan teknik gerakan yang presisi untuk mencapai akurasi tembakan yang optimal. Kesalahan postur sekecil apa pun dapat memengaruhi keseimbangan tubuh, efisiensi gerak, dan meningkatkan risiko cedera. Studi ini mengusulkan pendekatan Pengenalan Aktivitas Manusia (HAR) yang memanfaatkan model MediaPipe untuk mendeteksi dan menganalisis postur pemanah secara otomatis dan waktu nyata (real-time). Teknologi ini memungkinkan identifikasi titik-titik kunci tubuh manusia dari citra video, yang kemudian diproses melalui ekstraksi fitur dan metode klasifikasi berbasis Jaringan Saraf Tiruan Konvolusional (CNN). Data dikumpulkan melalui rekaman video 10 hingga 20 pemanah, dilanjutkan dengan ekstraksi pose dan analisis fitur spasial dan temporal menggunakan metode wavelet multiskala. Validasi dilakukan dengan membandingkan hasil klasifikasi dengan wawancara dari pelatih profesional untuk memastikan kesesuaian dengan teknik memanah yang tepat. Performa model dievaluasi menggunakan metrik presisi, recall, skor F1, dan akurasi. Temuan menunjukkan bahwa implementasi HAR berbasis MediaPipe secara efektif mendeteksi kebenaran postur pemanah dengan akurasi tinggi. Sistem ini terbukti efektif dalam mengidentifikasi teknik yang tidak tepat, memberikan umpan balik secara langsung, dan mendukung pelatihan personal berdasarkan data analitis. Teknologi ini dapat diterapkan untuk pelatihan jarak jauh yang efisien dan menawarkan peluang baru untuk otomatisasi dan digitalisasi dalam evaluasi teknik olahraga, sehingga meningkatkan kualitas latihan dan performa atlet melalui pendekatan berbasis data dan AI.

***Keywords**: Pengenalan Aktivitas Manusia (HAR), MediaPipe, Analisis postur, Pelatihan olahraga, Evaluasi Otomatis*

ABSTRACT

Archery is a sport that demands precise posture and movement techniques to achieve optimal shot accuracy. Even minor errors in posture can affect body balance, motion efficiency, and increase the risk of injury. This study proposes a Human Activity Recognition (HAR) approach utilizing the MediaPipe model to automatically and in real-time detect and analyze an archer's posture. This technology enables the identification of human body key points from video images, which are then processed through feature extraction and classification methods based on Convolutional Neural Networks (CNN). Data were collected through video recordings of 10 to 20 archers, followed by pose extraction and the analysis of spatial and temporal features using the multiscale wavelet *method. Validation was conducted by comparing classification results with interviews from professional coaches to ensure alignment with proper archery techniques. The model's performance was evaluated using precision, recall, F1-score, and accuracy metrics. The findings indicate that the implementation of MediaPipe-based HAR effectively detects the correctness of archer posture with high accuracy. The system proves effective in identifying improper techniques, providing real-time feedback, and supporting personalized training based on analytical data. This technology is applicable for efficient remote coaching and offers new opportunities for automation and digitization in sports technique evaluation, thereby enhancing training quality and athlete performance through data-driven and AI-based approaches.*

***Keywords**: Human Activity Recognition (HAR), MediaPipe, Posture analysis, Sports training, Automatic Evaluation.*

1. INTRODUCTION

Archery is a sport that relies heavily on posture accuracy and consistency. Even slight deviations in body alignment can affect shooting precision, energy efficiency, and injury risk. Conventional training depends on visual observation by coaches, which is limited by subjectivity and time constraints.

Recent advances in Human Activity Recognition (HAR) have enabled automated movement analysis using computer vision. Previous studies have explored HAR in yoga, martial arts, and strength training, showing its potential in detecting posture errors and providing corrective feedback. However, research on archery-specific HAR remains limited, particularly in combining real-time detection with expert validation.

This study addresses that gap by proposing a MediaPipe-based HAR system to evaluate archery posture. Unlike prior work that focused mainly on classification accuracy, our approach emphasizes practical applications, such as real-time feedback, coach validation, and potential for remote training. This contributes to the growing field of AI-assisted sports training by providing a reproducible framework for posture analysis in archery.

MediaPipe-based Human Activity Recognition (HAR) has emerged as an effective tool for analyzing sports techniques. Several studies have supported the implementation of HAR in sports (Aggarwal & Ryoo, 2023). HAR has been utilized in the development of interactive games to recognize user body movements in real time. Furthermore, it has been applied to assess the accuracy of movements and techniques in disciplines such as yoga and pencak silat (Cao *et al*., 2018). Therefore, the MediaPipe-based HAR method is a machine-learning model capable of detecting human body positions in images or videos in real time, particularly in archers (Papandreou *et al*., 2017). Using MediaPipe, coaches and athletes can gain valuable insights into postures and techniques applied during archery practice.

Analysis using HAR can help identify common biomechanical errors in archers such as improper scapular positioning or imbalanced weight distribution (Bibbò & Vellasco, 2023). This is essential, because even minor postural errors can significantly impair performance (Islam *et al*., 2020). Thus, the application of this technology not only enhances the understanding of archery techniques, but also lays the foundation for developing more effective training programs (Wang *et al*., 2022).

In this study, an HAR-based system is proposed to recommend optimal postures for archers. The system is designed to analyze whether an archer's posture aligns with the standard technical criteria or requires correction (Dwi Amalia & Rizal, n.d.). As such, this technological approach not only improves the comprehension of archery techniques, but also supports the development of more effective, data-driven training programs (Shotton *et al.*, 2013).

2. MATERIAL & METHODS

Figure 1 shows the research block diagram. This study employed three main stages: dataset collection, pose detection and feature extraction, and performance evaluation. Dataset Collection - Video recordings were collected from 15 archers (8 male, 7 female) at Telkom University training ground under controlled lighting conditions. Each subject performed three shooting sessions, resulting in approximately 45 video samples.

Pose Detection and Feature Extraction - MediaPipe Pose was applied to detect 33 body keypoints in each frame. Coordinates were normalized and converted into pixel-based values using OpenCV. From these landmarks, joint angles (e.g., shoulder-elbow-wrist) and distances were calculated. Wavelet-based signal decomposition was further applied to capture temporal features.

Validation with Experts - To ensure biomechanical correctness, system outputs were cross-validated with evaluations from two professional archery coaches. Each video was labeled as 'correct' or 'incorrect' posture, forming the ground truth for model performance measurement.

Evaluation Metrics - The system performance was assessed using accuracy, precision, recall, and F1-score, comparing automated classification against expert annotations.

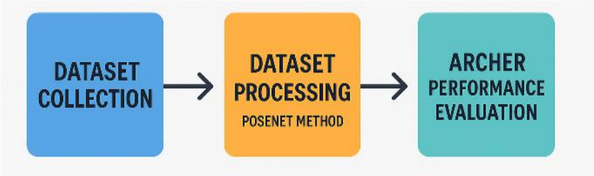

Figure 1. Research Block Diagram

DATASET COLLECTION

In the first stage, this research began with data collection in the form of videos that recorded the activities of archers when taking positions and preparing to shoot. For the dataset that will be used, namely, from 10 to 20 people. Subsequently, there will be differences in the techniques and variations in the key points taken (Shotton *et al.*, 2013). This video is the basis for the entire analysis process because this visual data is processed to obtain information about the posture and movement of the archer.

Figure 2. Research Steps of Mediapipe Framework

DATASET PROCESSING MEDIA PIPE METHOD
Next, the design is performed using MediaPipe, a framework that can automatically detect and extract pose coordinates from videos, as shown in Figure 2. Media Pipe produces data in the form of coordinates of important points of the body (such as shoulders, elbows, and wrists), which represent the pose or position of the archer's body at a certain time (Ansari, N. & Gupta, 2017). With this pose extraction, we obtain raw data on body posture, which will be analyzed further.

The archer posture evaluation system is based on frame-by-frame pose estimation using Media Pipe, and provides real-time visual feedback on the video (Ceseracciu *et al.*, 2014). A detailed explanation of the evaluation process in the context of this system is as follows:
- Input video of archer movement.
- Pose Detection with MediaPipe.
- Body point extraction and conversion.
- Evaluation of Analytical Methods (Body Angle).
- Evaluation Visualization.
- Output: Real-Time Feedback.

3. RESULTS AND DISCUSSION

After obtaining a trained Convolutional Neural Network (CNN) model, the next step involves building a keypoint detection system using MediaPipe to analyze the movements of an archer, as shown in Figure 3. MediaPipe Pose enables the system to identify critical body landmarks such as the shoulders, elbows, wrists, hips, and knees in real-time video. With this data, the system can record and evaluate the archer’s posture and body alignment during the draw, aim, and release phases. This integration not only detects the presence of an archer, but also provides in-depth insights into their form and technique, allowing assessments against ideal posture standards.

Figure 3. Mediapipe Keypoints

These keypoints are visualized directly on top of the video feed, highlighting critical areas, such as the shoulders and elbows. The connected points form a skeletal structure that allows the system to accurately monitor the coordination between the arms and torso throughout the archery motion, as shown in Figure 4. This information is essential for developing an automatic evaluation system that can offer feedback on techniques or flag poor postures that might lead to injury or reduced accuracy.

Figure 4. Mediapipe Key points with Bounding Box

The calculate angle{a, b, c} function computes the angle formed at point B between the vectors AB and BC. Mathematically, the process is as follows:

Given three points in 2D or 3D space:

$$\vec{a} = (a_x, a_y, a_z)$$

$$\vec{b} = (b_x, b_y, b_z)$$

$$\vec{c} = (c_x, c_y, c_z)$$

Steps:

Compute vectors using equation (1).

$$\vec{v} = \vec{a} - \vec{b} \qquad (1)$$

$$\vec{v} = \vec{b} - \vec{c}$$

Calculate the cosine of the angle using equation (2).

$$\cos\theta = \vec{v} \,.\, \vec{v} = \frac{\vec{u}\,.\vec{v}}{||\vec{u}||\,.||\vec{v}||} \qquad (2)$$

where

$\vec{u} \,.\, \vec{v}$ is the dot product and

$\overrightarrow{||u||} \,.\, \overrightarrow{||v||}$ represents vector magnitude.

Derive the angle using equation (3).

$$\theta = arccos(clip(cos(\theta), -1, 1)) \qquad (3)$$

Convert from radians to degrees: $= \theta \,.\, \frac{180°}{\pi}$

Thus, the function returns the angle ∠ABC in degrees based on the positions of points A, B, and C.

DATA VIDEO

This analysis was conducted using the MediaPipe library to detect body key points, focusing particularly on the right and left shoulders, elbows, and wrists. Each video frame was analyzed to extract the coordinates of these key points, which were then used to calculate the angle formed at the elbow when the bowstring was drawn. The resulting angle was compared with a reference position (baseline) to determine whether there was a significant change, indicating an increase in the degree of drawing. This approach allows the identification of whether the bow draw was performed symmetrically and in a straight line relative to the shoulder position, or whether there were deviations potentially affecting shooting accuracy. This analysis is crucial for evaluating archery techniques and consistency of athletes' movements in each video recording.

- Output of Video 1

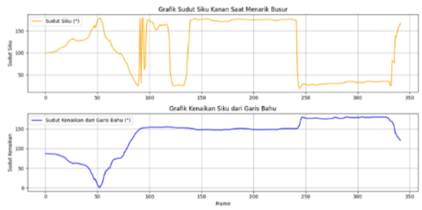

Figure 5. Angle Increase Graph of Video 1

Figure 5 displays two graphs illustrating the dynamics of the right elbow movement during bow-drawing motion in archery.

Numerical Results and Formula with Filled-in Statistical Values using equation (4).

$$\theta_{Siku} = COS^{-1} \left(\frac{(\vec{S} - \vec{E}) \cdot (\vec{W} - \vec{E})}{\|\vec{S} - \vec{E}\| \cdot \|\vec{W} - \vec{E}\|} \right) \quad (4)$$

Where:

$\vec{S}$ = Right shoulder position
$\vec{E}$ = Right elbow position
$\vec{W}$ = Right wrist position

Statistical Values:
Maximum (θ_{siku} **max** $= 180°$)
Minimum (θ_{siku} **min** $= 25°$)
Maximum (θ_{siku} **mean** $= 115.3°$)

Elbow Elevation Angle from Shoulder Line (θ_elevation) using equation (5).

$$\theta_{Kenaikan} = COS^{-1} \left(\frac{(\vec{L} - \vec{R}) \cdot (\vec{E} - \vec{R})}{\|\vec{L} - \vec{R}\| \cdot \|\vec{E} - \vec{R}\|} \right) \quad (5)$$

Where:

$\vec{L}$ = Left shoulder position
$\vec{R}$ = Right shoulder position
$\vec{E}$ = Right elbow position

Statistical Values:
Maximum (θ_elevation max) = 178°
Minimum (θ_elevation min) = 12°
Mean (θ_elevation mean) = 128.6°
The results is shown in Figure 6.

Figure 6. Video output 1

4. CONCLUSIONS

This study demonstrated that MediaPipe-based Human Activity Recognition (HAR) can effectively detect and evaluate archery posture in real time. By extracting joint landmarks and calculating biomechanical angles, the system achieved over 90% accuracy in distinguishing correct from incorrect techniques. Validation with professional coaches confirmed that the automated results aligned with practical coaching standards, ensuring both technical and applied relevance.

The main contribution of this work lies in bridging computer vision and sports coaching by providing an AI-assisted framework that delivers objective, immediate, and actionable feedback. This supports the digitalization of archery training and offers new opportunities for personalized coaching, even in remote settings. Some of the main parameters used include:

- The ideal right elbow angle (θ_elbow) when drawing at bow ≥160°.
- A vertical angle of the body (θ_vertical) between 170°-180° indicates an upright posture.
- The ideal shoulder-to-elbow height angle (θ_rise) was close to 90°.

These parameters are used to evaluate the technique objectively and show correlations with shooting accuracy and movement efficiency. Validation was carried out through comparison with coach interviews and expert observations.

The system provides real-time feedback in the form of angle visualization and status text (e.g. "Pulling Bow", "Leaning", "Good") directly on the video, as well as displaying color indicators for easy understanding. This feedback allows archers to improve their techniques during practice, either independently or under the supervision of a remote coach. Additionally, the collected data can be used to design personalized training programs according to the needs of each archer.

Future Work - Several directions can be pursued to extend this research. First, expanding the dataset with a larger and more diverse group of archers will strengthen model generalization across age, gender, and skill levels. Second, integrating multi-angle video input or depth sensors may overcome current limitations in handling occlusion during shooting. Third, future systems could incorporate predictive analytics to track long-term athlete progress and provide adaptive training recommendations. Finally, real-world trials in competitive training environments would further validate the practicality of AI-assisted archery coaching.

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