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Real-Time Posture Monitoring for Effective Exercise Using MediaPipe Python

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Abstract - Maintaining proper posture during exercise is crucial for preventing injuries and maximizing workout efficiency. This project aims to develop a real-time posture monitoring system using MediaPipe and OpenCV to provide instant feedback on the exercise form. The system captures video input through a webcam, processes it using OpenCV, and utilizes MediaPipe's pose-estimation model to detect key body landmarks. By analysing the joint angles and comparing them to predefined optimal postures, the system evaluates the user's form and provides corrective feedback in real time. This approach eliminates the need for expensive wearable sensors, making posture monitoring more accessible and user friendly. The literature review highlights the effectiveness of computer vision-based solutions in fitness applications and identifies key challenges, such as occlusions, varying lighting conditions, and real-time processing constraints. The proposed system addresses these issues by optimizing the pose-estimation accuracy and feedback mechanisms. Testing and user surveys confirmed the system's effectiveness, achieving 90% accuracy for squat posture detection and 86% accuracy for lunges under typical home-workout conditions. The expected outcome of this project is a functional real-time exercise posture monitoring system that enhances the user training experience by ensuring a proper form. Future improvements may involve integrating machine learning techniques to personalize feedback and expand the system to multi-user environments. This project contributes to the advancement of computer vision applications in fitness and rehabilitation domains.

Keywords— MediaPipe, OpenCV, Real-time Posture Monitoring, Joint Angle Calculation, Squats, Lunges

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1. INTRODUCTION

Home workouts have become increasingly popular nowadays, specifically after the world shift to remote and stay-at-home lifestyles, which have brought their own challenges and advantages. Performing exercise alone at home without professional supervision can lead to ineffective workout efficiency, incorrect posture, and high risk of injury. The lack of real-time feedback during unsupervised workouts may result in incorrect movements, which can hinder

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exercise progress or cause long-term harm. These issues are especially significant for rehabilitation patients or individuals recovering from injuries, such as knee surgery patients, who need to follow proper forms to avoid setbacks. The motivation for this project stemmed from a personal rehabilitation experience of Anterior Cruciate Ligament (ACL) injury, where the absence of real-time posture guidance during physiotherapy exercises made recovery more challenging and worrying. Recognizing this gap, this project aims to create an accessible, low-cost, and user-friendly solution that helps users correct their exercise posture in real time without requiring guidance from professional trainers or expensive equipment.

Existing posture correction systems require expensive equipment and are complex to set up, making them inaccessible to anyone who needs them. These concerns can be addressed with the development of this project, which is a real-time posture monitoring system that relies only on a standard webcam that will make it low-cost, accessible, and user-friendly. This project uses MediaPipe Pose to detect 33 key body landmarks and angles and OpenCV for live frame input and instant feedback. The system only focuses on two types of exercises, squats and lunges, which are commonly performed by rehabilitation patients recovering from knee surgery that require proper posture and form to be free from any injury and earn an effective workout session. By leveraging computer vision and Python's MediaPipe Pose estimation, the system provides live posture monitoring with color-coded feedback to guide the user to fix their posture in real time to ensure a proper form.

The objective of this project was to develop a reliable posture detection system that operates in real time by leveraging MediaPipe Pose Estimation and OpenCV, relying only on a standard webcam. It is designed to assess and categorize posture accuracy based on key body angles during squats and lunges, classify the posture as good, adjust, or bad, and offer immediate on-screen color-coded feedback to help users maintain a proper form. In addition, the system includes a simple graphical user interface (GUI) built with Tkinter to improve its usability. Through this approach, the project contributes to the growing use of computer vision in fitness and rehabilitation by offering an intelligent real-time solution that ensures safe and effective exercise practices. This project has great potential to be advantageous for a wide range of users, such as individuals who exercise independently at home, including beginners, workout enthusiasts, and rehabilitation patients.

2. LITERATURE REVIEW

The growth of computer vision and human pose estimation technologies has recently attracted attention. Manual poster correction relies on manual observations from professional trainers or physical therapist trainers that the correctness of the exercise form is not fully accurate at all times. The development of a posture monitoring system will help workout enthusiasts and deliver a cost-effective system that will improve the effectiveness of exercise [1]. There are several types of pose-estimation frameworks, such as MediaPipe, TensorFlow, and OpenPose. These frameworks utilize modern solution technologies, such as deep learning and machine learning [2]. This section on literature review discusses and analyses existing work related to posture monitoring. This research aims to discover the strengths, limitations, and future enhancements of other projects to improve and achieve high accuracy in form correction [3].

2.1 Categorization by Methods and Techniques Used

Based on this research paper, many of its studies leverage MediaPipe Pose as their main framework. [4] achieved 78% Jaccard Similarity with human evaluators on the standardized pulling posture of air cadets using MediaPipe and OpenCV by applying form checking. Similarly, [5] offers a real-time posture monitoring system with landmark detection and algorithm-based posture analysis. Moreover, exercises such as crunches, squats, and push-ups were analysed by the development of a Personal Exercise Trainer from [6], which uses pose estimation to track each exercise movement. The Exponential Moving Average (EMA) was applied in [7] to achieve stable landmark coordination and improve the accuracy of squat training assistance by incorporating dynamic thresholding techniques for motion state classification. A high accuracy in evaluating exercises by employing calculation of joint angle, pull-ups (92%), push-ups (83%), and squats (78%) shows the effectiveness of pose estimation for pose correction [8]. Machine learning has also been applied using Random Forest classifiers for pose classification. For example, a system was designed to analyse key point movements to aid Parkinson's disease patients while performing specific physiotherapy exercises, utilizing Random Forest, achieving an accuracy of 97.13% for fingertip exercises and 98.26% for claw stretch exercises [9]. Correspondingly, another study also leveraged Random Forest classification, but on sports posture analysis. Their results showed an accuracy of 85.03% in predicting crickets, football, and basketball [10].

2.2 Accuracy and Performance

In addition, a system was developed that primarily focused on detecting real-time posture tracking and a workout repetition counter by leveraging MediaPipe and OpenCV to analyse posture alignment and provide instant feedback [11, [12]. Some research introduced motion tracking systems for real-time movement analysis using joint angle calculations via trigonometry but lacked advanced classification techniques [13], [14]. Moreover, [15] incorporated deep learning model classification, and the Bi-GRU model that acquires a 94% accuracy rate with an attention layer to classify squats surpasses other models, Bi-LSTM and Bi-RNN alternative, owing to its superiority in handling temporal dependencies. [16] employed machine learning classifiers such as KNN, Random Forest to track improper lifting techniques in a workplace setting, with Random Forest management to record the highest accuracy of 99.71%. Some studies have incorporated machine-learning models to improve the performance of posture detection and classification on a real-time tracking base. By utilizing the COCO 2020 dataset and an exercise-specific algorithm for each posture, it achieved an accuracy rate of 87 % %for correct repetition [17-18]. A study that implemented the most advanced Artificial Intelligence (AI) was from [19], who developed AI-FIT COACH, which is an AI-based mobile application that integrates pose detection correction and smart guidance. The program leveraged TensorFlow and MediaPipe for real-time posture monitoring and applied voice assistance and video uploads for delayed analysis. Lastly, CNN-GRU models applied to yoga posture correction for temporal spatial analysis of 24 yoga poses managed to record an impressive 98.17% training accuracy and 93.28% test accuracy [20].

3. RESEARCH METHODOLOGY

The methodology for this posture monitoring project aims to achieve high accuracy along with a correct and proper posture for performing squats and lunges by leveraging MediaPipe Python. Live video frames on standard webcams, pose detection of body landmarks, key joint angle calculations, and instant correction feedback were the main purposes of this project. The process was built on three main structures: posture detection, key joint angle analysis, real-time feedback integration, and proper testing and validation.

First, video input is captured live using a webcam and will continue to be processed by the OpenCV implementation. 33 key body landmarks were extracted by MediaPipe for each captured frame. Important data are collected by enabling the detailed tracking of user movements and are vital for the calculation of joint angles. Critical joint angles, such as the hip, knee, and ankle, were evaluated based on threshold recommendations from the professional. With this, the system should be able to assess whether the exercise performed is correct or incorrect to maintain effectiveness and avoid unnecessary injury.

The next phase is related to interactions between the system and user. Color-coded feedback provides guidance to the user as a real-time feedback mechanism to adjust posture while performing an exercise. As the session continues, the user's form will be evaluated by providing the necessary feedback to retain an efficient exercise session. The final system section includes the involvement of multiple users to assess the accuracy of the pose detection. A survey was conducted to test the usability and adaptability of this system in real-world home workouts in various environments such as lighting conditions, clothing, and different types of users. The feedback responses collected help to improve the system and prove its effectiveness on real users. Figure 1 illustrates the workflow of the system, which starts by capturing real-time video feed from a webcam and then processing it using OpenCV.

Body landmarks of the posture that are detected with MediaPipe Pose are analysed by the system by calculating the key joint angles that are involved in each exercise. These calculations help determine whether the user is performing the correct posture while performing exercises on squats or lunges.

Once the angle was calculated, the system assessed whether the exercise session was ongoing. If it remains active, the system will continue to show the results of the exercise evaluation based on the threshold set. Green indicators are displayed on the screen as a correct posture performed, while red indicator, "Bad Posture" as to let the user know they need to adjust their body form. This real-time correction feedback helps the user make real-time adjustments to their posture. The loop continues if the session is still active, allowing the system to steadily monitor user posture and display immediate feedback correction.

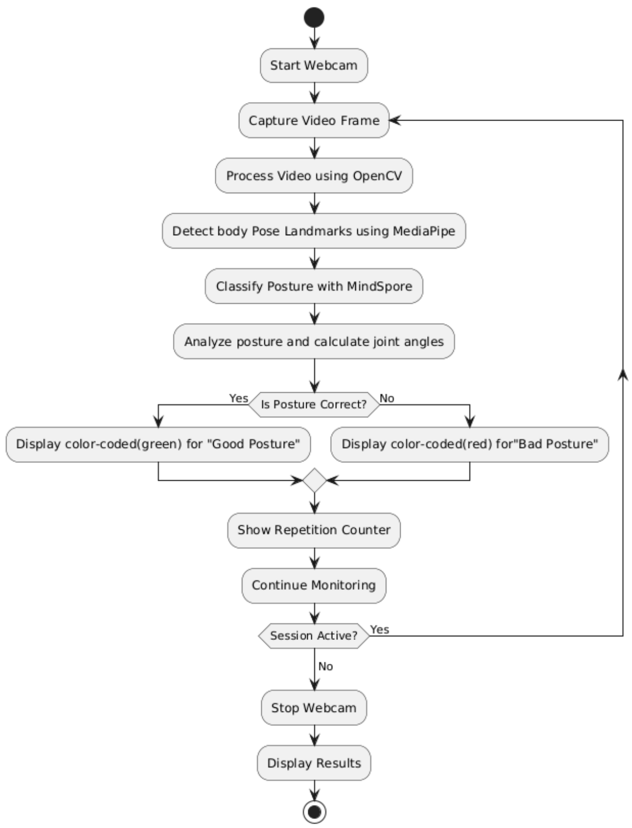


Figure 1. Activity Diagram

As shown in Figure 2, the MediaPipe Pose model detects 33 key body landmarks that are used for full-body posture tracking.

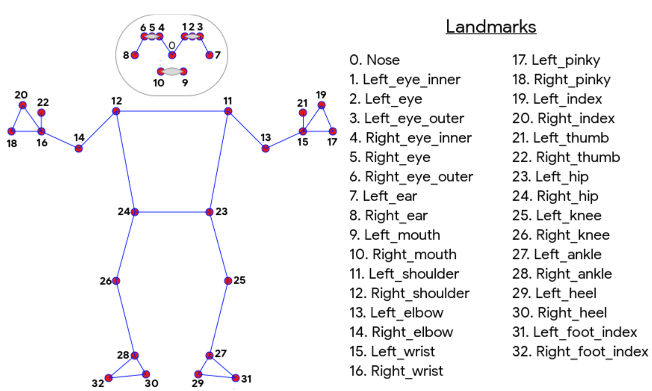


Figure 2. MediaPipe Pose Landmarks

These landmarks represent critical joints and points such as the nose, eyes, shoulders, elbows, wrists, hips, knees, ankles, and toes. By accurately identifying these points in real-time from a video frame, MediaPipe enables the system to track the user's posture and movement. In this project, these landmarks are essential for calculating joint angles, especially at the hips, knees, and ankles (landmarks 23–28), to determine whether exercising on squats or lunges is performed correctly. The landmark-based structure ensures precision, making it a powerful tool for posture analysis and feedback generation during physical exercises. Figure 3 shows the angle calculation formula.

```
Function calculate_angle(pointA, pointB, pointC):

    Convert pointA, pointB, pointC into arrays:
        a ← pointA
        b ← pointB
        c ← pointC

    Compute the angle in radians between vectors:
        angle1 ← arctangent of (c.y - b.y) / (c.x - b.x)
        angle2 ← arctangent of (a.y - b.y) / (a.x - b.x)
        radians ← angle1 - angle2

    Convert radians to degrees:
        angle ← absolute value of (radians × 180 ÷ π)

    If angle > 180:
        angle ← 360 - angle

    Return angle
```

Figure 3. Angle Calculation Formula

The *calculate_angle* function is the core part of the real-time posture monitoring system and is responsible for determining the exact angle formed by the MediaPie Pose on three key body points, namely the hip, knee, and ankle. When the system captures video frames through the webcam, it identifies these landmarks as coordinate pairs of the detection joint angle and passes them to this function. Inside the function, each point was converted into a NumPy array to make it easier to achieve efficient mathematical operations. Using basic trigonometry, the function calculates the angle between the vectors extending from the middle point (knee) to the other two points (hip and ankle). This is performed with the arctan2 function, which computes the difference in orientation between the two vectors and converts the result from radians to degrees. The function ensures that the returned angle stays within a valid range by adjusting any value above 180 °to its equivalent interior angle because joint bend measurements are meaningful only within 0 °to 180 °. By returning this precise angle, the system can instantly evaluate whether a squat or lunge is performed within the safe and effective thresholds. This allows the application to provide clear, real-time feedback, classifying each repetition as good, requiring adjustment, or incorrect, thereby guiding the user toward proper form and helping to prevent injury.

The proposed system uses MediaPipe's pose estimation landmarks to assess posture accuracy in real time, focusing specifically on key lower-body joints, the hips (landmarks 23 and 24), knees (landmarks 25 and 26), and ankles (landmarks 27 and 28). For squats, as illustrated in Figure 4, both legs were monitored symmetrically, and a good squat was defined as a knee angle (hip-knee-ankle) within the range of 80° to 100°. This ensures that the user is squatting deep enough to activate major muscle groups such as the quadriceps, glutes, and hamstrings, without going deep enough to cause joint strain. Angles below 80° may indicate over-flexion and risk of injury, whereas angles above 100° suggest an incomplete squat with reduced training effectiveness.

```
# Squat joint angle
If angle is between 80 and 100 (inclusive):
    Set color to green (0, 255, 0)
    Set feedback to "Good Squat"

Else if angle is between 60 and 79
     OR angle is between 101 and 120:
    Set color to yellowish-orange (0, 205, 255)
    Set feedback to "Adjust Squat"

Else:
    Set color to red (0, 0, 255)
    Set feedback to "Bad Squat"
```

Figure 4. Squat Angle

In the case of lunges, as shown in Figure 5, the system analyses each leg independently owing to the staggered stance. A good lunge posture requires that the front and back legs maintain joint angles between 90° and 130°, measured again using the same hip-knee-ankle landmarks (23–28). For the front leg, this angle helped confirm that the thigh was parallel to the ground and the knee remained aligned over the ankle, whereas for the back leg, it ensured appropriate stretch and stability without overloading the knee joint. Angles outside this range may suggest improper foot placement, shallow depth, or a potential imbalance. By constantly comparing the measured angles to the defined optimal ranges, the system offers immediate visual feedback to guide the user's adjustments and support correct posture and movement over time, making it an effective aid for both general fitness routines and physiotherapy rehabilitation exercises.

```
# Lunges joint angle
If front_leg_angle is between 90 and 130 (inclusive) AND back_leg_angle is between 90 and 190 (inclusive):
       Set color to green (0, 255, 0)
       Set feedback to "Good Lunges"

Else if front_leg_angle is between 70 and 89 OR back_leg_angle is between 70 and 89:
       Set color to yellowish-orange (0, 205, 255)
       Set feedback to "Adjust Lunges"

Else:
       Set color to red (0, 0, 255)
       Set feedback to "Bad Lunges"
```

Figure 5. Lunges Angle

4. SYSTEM REQUIREMENTS AND TESTING

The testing phase of Real-Time Posture Monitoring for Effective Exercise using the MediaPipe Python system is described here. It presents evidence of how the system was verified in terms of usability, detection accuracy, real-time performance, and practical effectiveness under different conditions.

4.1 System Limitations

- **2D Pose Detection**
  The system relies on 2D pose estimation via standard webcams, which lack the depth perception of 3D systems. This limits the accuracy of the tracking of complex or nuanced movements.

- **Environmental Factors**
  is affected by poor lighting, cluttered backgrounds, and unstable camera angles, which can reduce the precision of postural detection in uncontrolled settings.

- **User Variability**
  Differences in body types, clothing, or exercise styles may hinder the consistent detection of key landmarks, particularly when joints are obscured by loose or dark clothing.

- **Exercise Scope**
  The system currently supports only a limited range of bodyweight exercises, involving only squats and lunges. It does not accommodate exercises involving equipment or highly dynamic movements, which would require a more complex calibration.

- **Basic Feedback Mechanism**
  is focused solely on posture correction. The system does not provide advanced features, such as workout tracking, training progression, or personalized recommendations.

- **Single-User Design**
  The system supports only one user at a time and cannot distinguish between multiple users in the same camera frame, making it unsuitable for group workouts.

- **Webcam Dependency**
  Accuracy is heavily reliant on the webcam quality. Low-resolution or low-framerate webcams may significantly degrade the detection performance.

4.2 System User Interface (GUI)

Below is the main GUI page of the system (Figure 6), which was developed using Tkinter. The GUI provides a simple Start and Quit button, displays the selected mode (Squat or Lunge), and shows real-time feedback during the exercise.

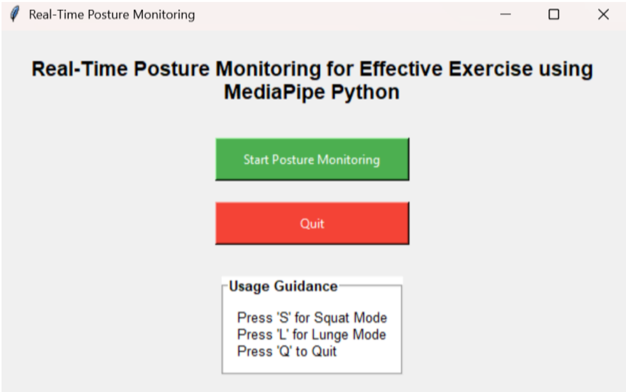


Figure 6. Main GUI

Description:

- The GUI is designed to be lightweight and easy to navigate.
- Green button for Start and Red button for quit.
- Users are given guidance and switch modes by pressing S (Squat) or L (Lunge), and for stopping the program, Q (Quit program).

4.3 System Requirements and User Positioning

Before starting any exercise session with the Real-Time Posture Monitoring System, it is important to follow the basic setup requirements to ensure that the system correctly detects all body landmarks and provides accurate feedback.

a. **Full-Body Visibility**

   The user must position themselves such that their entire body, from head to toe, is fully visible in the camera frame, as shown in Figure 7. This ensures that the MediaPipe Pose can track all 33 key landmarks, including the hips, knees, and ankles, which are essential for calculating joint angles.

b. **Distance from Camera:**

   Users were required to stand approximately **2 meters (±0.5 meters)** away from the camera. This distance is optimal for capturing the full body, while maintaining sufficient detail for precise pose detection.

c. **Environment Setup:**

   The testing area should have sufficient lighting and a clear, uncluttered background to reduce the detection errors caused by shadows, obstacles, or background noise.

Description:

- Before starting, position yourself, so your whole body (head-to-toe) is visible on the screen.
- This helps the system detect all body landmarks correctly.
- Full visibility ensures accurate joint angle calculation and posture classification.
- Proper framing allows the system to give reliable feedback for squats and lunges.

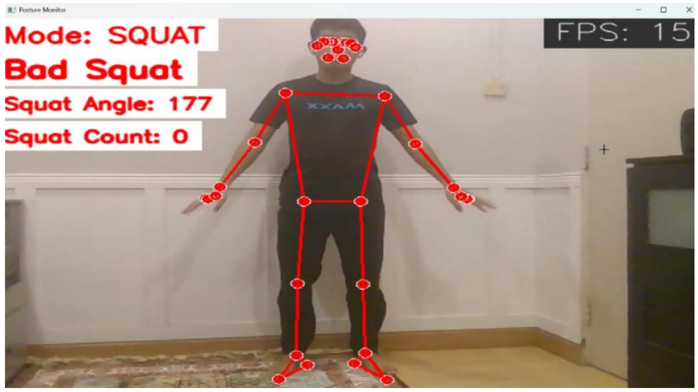


Figure 7. Example Proper Full-Body Visibility

5. RESULTS AND DISCUSSIONS

5.1 Functional Testing

Table 1 shows the functional testing of the test case with its expected output.

Table 1. Functional Testing

Test Case	Description	Expected Output	Result
Webcam Activation	Start webcam on clicking the “Start” button in GUI	Webcam feed starts and appears on screen	Pass
Pose Detection	Detect 33 body landmarks using MediaPipe	Landmarks correctly shown on user’s body in real time	Pass
Joint Angle Calculation	Calculate knee, hip, and ankle angles using landmark coordinates	Accurate angle values computed in degrees	Pass
Exercise Classification	Categorize squat/lunge as Good, Adjust, or Bad based on angle thresholds	Correct feedback label appears: Good / Adjust / Bad	Pass
Mode Switching	Switch between squat and lunge modes using keys ('S' for squat, 'L' for lunge)	Mode changes and detects correct exercise type	Pass
Live Feedback Display	Provide visual feedback on posture in real time	Coloured label displayed (green/yellow/red) with angle info	Pass
Repetition Counter	Count number of valid repetitions (squats or lunges)	Repetition count increases only when posture is correct	Pass
Data Logging	Log results to a text file after session	File with session summary saved (FPS, total squats, lunges)	Pass
GUI Start/Quit Button	Ensure Start activates camera, and Quit exits the program	Application responds correctly to both buttons	Pass
User Instructions Display	Show mode-switch and quit instructions on GUI	Instructions visible and readable to users	Pass

5.2 User Testing and Survey Results

A survey on user testing and feedback was conducted with **30 respondents** (Figure 8). This survey aims to collect practical data by assessing system performance on the accuracy of each squat and lunge performed under different conditions and environments, and to explore user feedback on how the system operates.

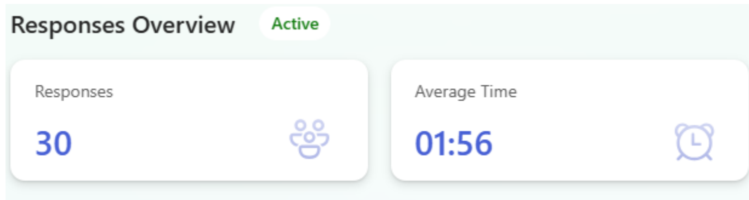


Figure 8. Survey Respondents count

Figure 9 illustrates the variation in participants' height and weight, with the tallest measuring 190 cm and the shortest 163 cm. The heaviest respondent weighed 100 kg, whereas the lightest weighed 46 kg. Fitness levels were distributed in 46.7% of beginners, 33.3% of intermediate athletes, and 20% of athletes.

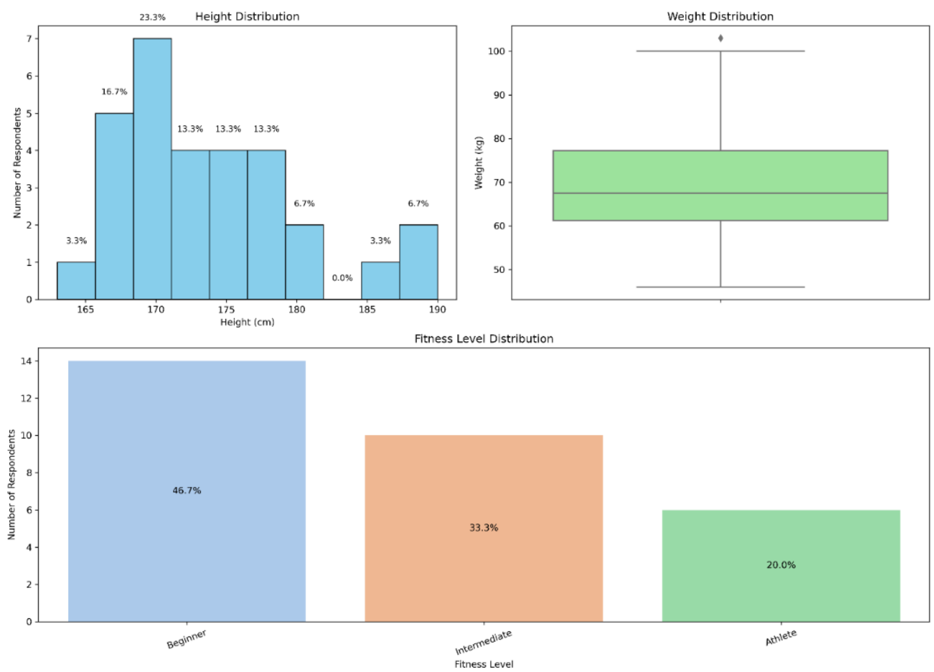


Figure 9. Survey (Height, Weight & Fitness Level) Distribution

The age of respondents is illustrated in Figure 10, ranging from 18 to 26 years, with the youngest participant being 18 and the oldest being 26.

The results in Figures 11 (Squat accuracy) and 12 (Lunges accuracy) show that the developed system effectively identifies correct and incorrect postures with a high level of accuracy.

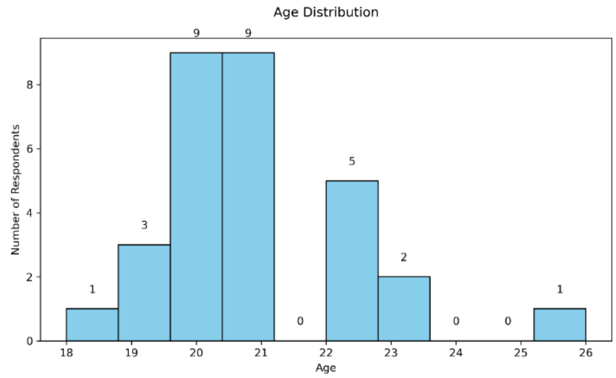


Figure 10. Survey Age Distribution

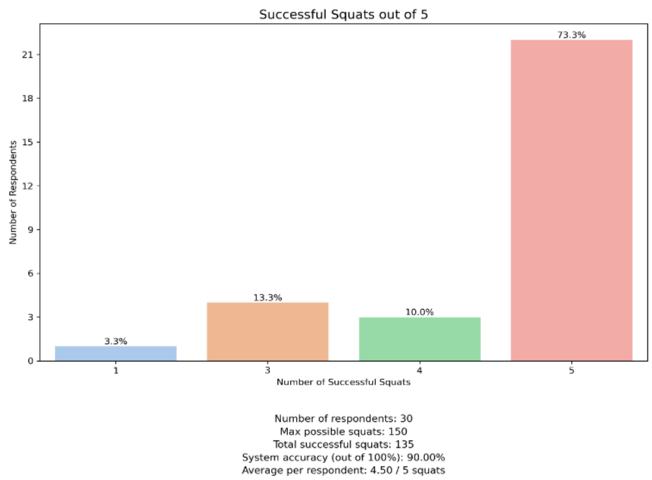


Figure 11. Squat Accuracy

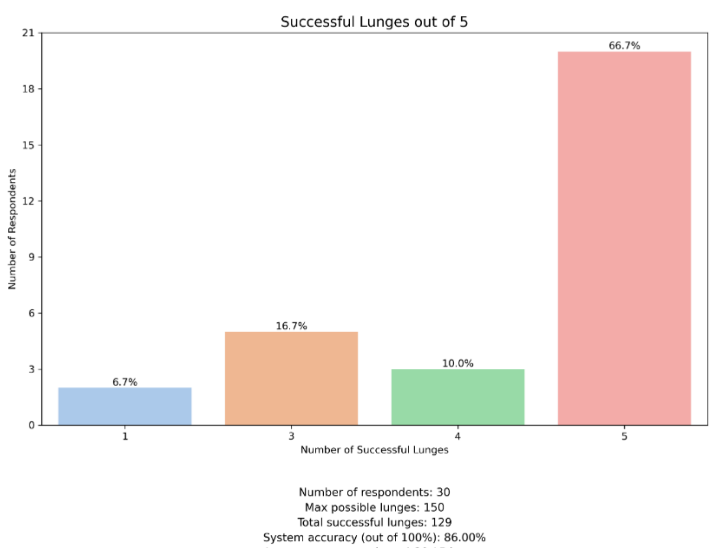


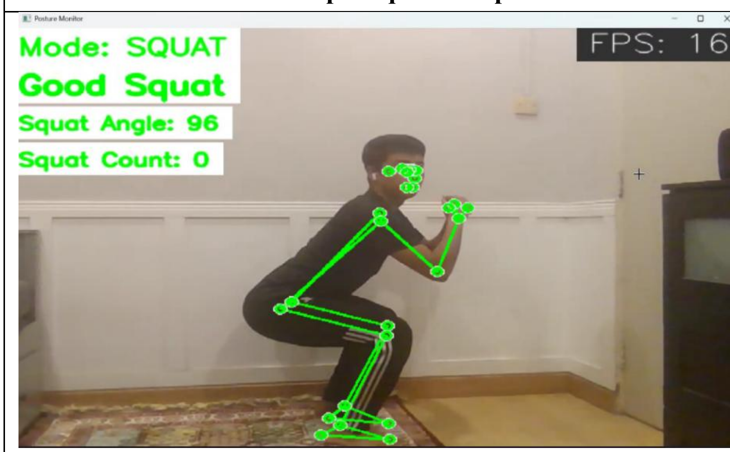
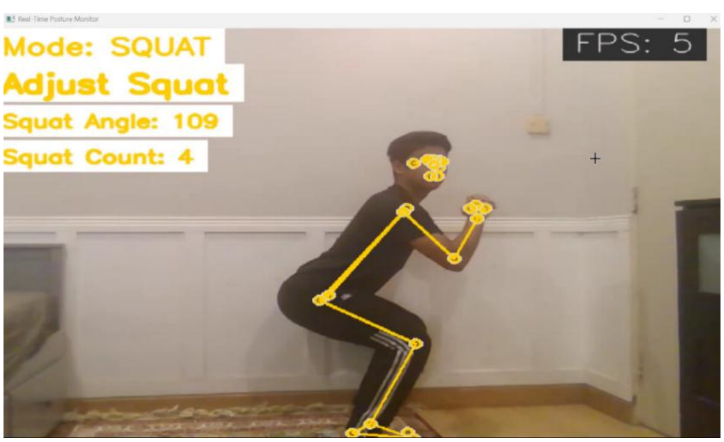
Figure 12. Lunges Accuracy

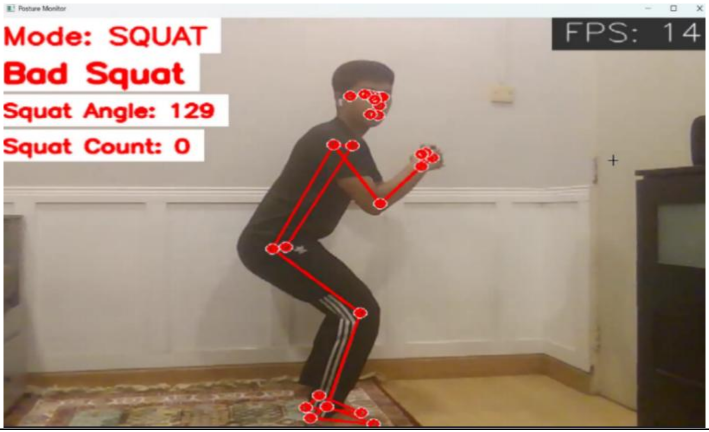
On average, out of five repetitions for each user, the system achieved 90% accuracy in detecting the correct squat posture and 86% accuracy in detecting the proper lunge posture. Lighting conditions also play a major role in how well the system performs, and bright lighting shows a high accuracy in detecting the correct posture. Users' clothing also affects system detection, and it is recommended to wear a standard fit or sportwear while performing the exercise while using the system. These performance levels make the system suitable for everyday use, even for standard consumer laptops.

5.3 Sample Output Images

In the squat output (Table 2), the system displays a clear visualization of the user's posture with body landmarks highlighted on the screen, showing the alignment of the hips, knees, and ankles. The system uses a color-coded feedback system, with green indicating the correct squatting position. The angle between the thigh and calf (measured at the knee) is likely to be shown as a numerical value, with the system confirming that the user has achieved an optimal angle between 80° and 100°. The screen also likely provides real-time feedback such as "Good Squat" in green text to reassure the user that their posture is correct, encouraging continued proper form. If the angle is outside the correct range, the system might highlight the posture in yellow or red, offering corrective suggestions like "Adjust Squat".

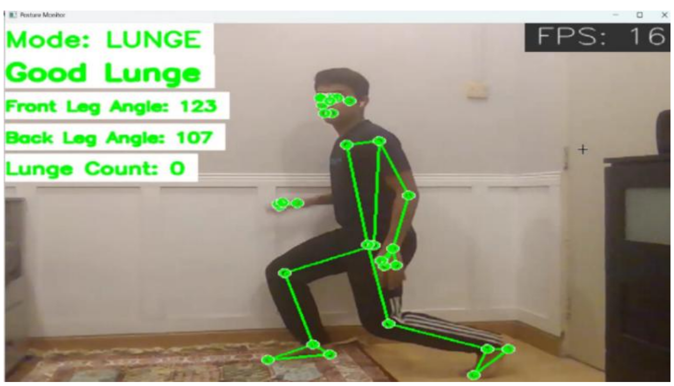
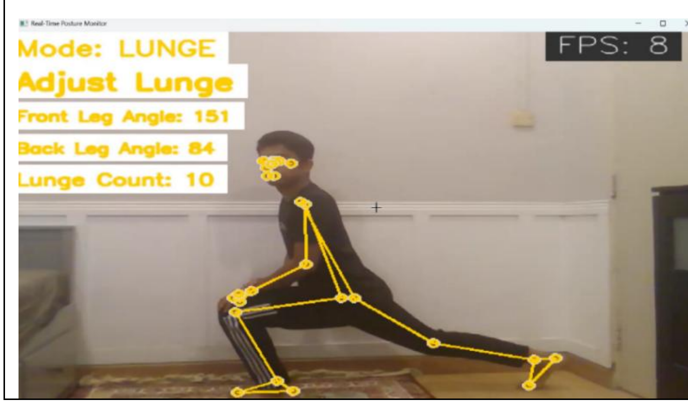
Table 2. Squat Output

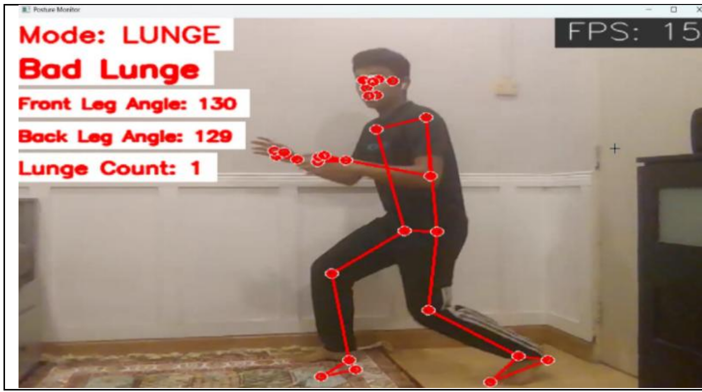
Sample Squats Output	Description
	**Good Squat** - Green body landmarks. - Knee angle is within the ideal range (80°–100°).
	**Adjust Squat** - Yellow body landmarks. - Knee angle is slightly outside the ideal range (60°–79° or 101°–120°)

	**Bad Squat** - Red body landmarks. - Knee angle is not in the target range (<60° or >120°).

For lunges, as shown in Table 3, the output displays similar landmark tracking, with a focus on both the front and back legs. The front leg angle (between the hip, knee, and ankle) and the back leg angle were calculated and displayed on the screen. When both angles fall within the predefined optimal range (e.g., the front leg between 90° and 130° and the back leg between 90° and 190°), the system displays a green message, such as “Good Lunge.” Color-coded feedback visually helps the user identify when they are performing the lunge correctly. If the angles deviate from the ideal range, the system provides corrective feedback indicating areas for adjustment to achieve a better form. Real-time feedback enables users to make immediate adjustments, thereby improving their performance over time.

Table 3. Lunges Output

Sample Lunges Output	Description
	**Good Lunges** - Green body landmarks. - The user’s front leg is bent at 90°–130°, and the back leg is extended at 90°–190°.
	**Adjust Lunges** - Yellow body landmarks. - One or both leg angles are slightly outside the target range.

	**Bad Lunges** - Red body landmarks. - Posture is significantly misaligned not in the target range.

The solution offered by this system has significant advantages over manual or traditional postural correction. A high-end system may offer slightly more accurate measurements, but it also relies on expensive hardware and a complex setup. However, this standard webcam still provides acceptable effectiveness, affordability, and functionality. The use of MediaPipe ensures efficient processing, which requires a standard computational method that allows this system to be widely used by anyone.

6. CONCLUSION

This project successfully developed and tested an AI-powered real-time posture monitoring system using MediaPipe and OpenCV, to enhance the safety and effectiveness of home workouts. By focusing on two fundamental exercises, squats, and lunges, the system demonstrates how computer vision can be used to assess posture accuracy, provide immediate feedback, and assist users in performing exercises in the proper form. The use of a standard webcam makes the system highly accessible and cost-effective, lowering barriers to entry for fitness enthusiasts and rehabilitation patients. Throughout the development, the system architecture was structured around four main phases: data collection, posture detection and analysis, feedback generation, and system validation. The integration of MediaPipe for landmark detection and custom logic for joint angle calculations allows the system to evaluate movement with high precision. Visual feedback mechanisms and color-coded indicators give users real-time cues to correct their form during active workouts. Compared with traditional motion-capture systems, this solution offers a balance of affordability, portability, and performance. Its simplicity in setup, requiring only a webcam and standard hardware, makes it a practical tool for home use. The adoption of open-source libraries ensures flexibility and scalability for future improvements or customizations tailored to individual user needs and specific training goals. In future work, the system can be expanded to support a wider variety of exercises, such as push-ups, planks, or yoga poses, increasing its versatility for both fitness and rehabilitation. Machine-learning techniques can also be introduced to improve the adaptability of posture classification and recommendations over time. These advancements would extend the value of the system as a long-term fitness companion and contribute significantly to the evolving field of AI-driven health technologies.

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AUTHOR CONTRIBUTIONS

Wan Izzul Wafiq bin Wan Noor Asmawi: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;
S. Prabha Kumaresan: Conceptualization, Project Administration, Investigation, Supervision, Validation, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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