AI-Based Posture Correction, Real-Time Exercise Tracking and Feedback using Pose Estimation Technique

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Abstract*— Physical activity is an essential component of physical and mental health-being. Although physical activity offers numerous advantages, maintaining proper posture could be difficult, especially when it comes to complex movements or poses. This task is even challenging for the ones who exercise at home, those who have disabilities, or social anxiety. In order to deal with this issue, this work proposes an AI gym tracker app powered by advanced pose estimation technology through OpenCV and Mediapipe which are two popular frameworks being used in computer vision to access and solve several real-life problems through pose-estimation. This paper describes an AI-powered gym tracker app built with MediaPipe and OpenCV. It uses real-time pose estimation and joint angle calculation to provide feedback on exercise form as well as expanded rep count. This application employs a unique method by using dynamic angle thresholds and joint distance computations to provide precise feedback about user posture. It demonstrates the application's effectiveness in assisting users in maintaining proper form and tracking their workout progress by demonstrating a counter. Future work is to broaden its functionality to embrace more exercises and to further add other forms of decision feedback system, thus exploring the possible incorporation of this application into various fitness apps which would in-turn enhance the overall experience of the users.

***Keywords*— Pose Estimation, Joint Angle Calculation, Gym Tracker, Real-Time Feedback, Expanded Rep Count**

I. Introduction

Regular physical activity is widely acknowledged as a cornerstone of good health and overall well-being. Its benefits extend beyond physical fitness, encompassing mental health, stress reduction, and improved quality of life. Having the correct posture while working out is key to decreasing injury risk and boosting the benefits of a workout. The application of AI and Computer Vision might completely change home exercises by delivering customization and instantaneous feedback.

Establishing and maintaining a routine of moderate exercise has been linked to a reduced risk of chronic conditions such as heart disease, obesity, and type-2 diabetes. The advent of the COVID-19 pandemic has introduced various challenges due to the limited access to gym and training facilities. Lockdowns, social distancing measures, and the closure of public spaces, including gyms, disrupted established exercise routines for many individuals. The resulting limitations prompted a shift toward at-home workout solutions, as people sought alternatives to maintain their fitness amidst the lockdowns imposed.

Even before the pandemic, various barriers hindered individuals from engaging in traditional gym workouts. Factors such as physical disabilities could limit access to gym facilities, while social anxiety or a privacy preference discouraged some from participating in communal fitness spaces. Furthermore, the financial burden of gym memberships, coupled with issues like overcrowding and inconvenient schedules, posed additional challenges to maintaining a consistent fitness regimen.

For individuals engaged in home workouts, the absence of personalized care poses a significant challenge. Maintaining proper form and technique during exercise is critical for increasing each muscle contraction while avoiding potential risk of back pain, herniated disc, or piriformis syndrome. Tracking and posture correction by the individual without assistance can be difficult.

This paper proposes a novel AI-powered gym tracker application that addresses these issues through pose estimation and joint angle calculation. The application analy zes a user's body position from a webcam feed using MediaPipe, a free and open-source framework for real-time pose estimation. The detected pose is used to extract joint coordinates, which are then used to calculate joint angles for specific exercises. This enables the application to evaluate exercise forms and provide real-time feedback to the user.

Joint angle measurements have been applied in our work to verify the correct performance of specific exercises, since specific movements call for exact angles to execute successfully. For example, in case of planks, the body should hold a firm straight 180-degree alignment from top to bottom.

Should the angle change, it may induce improper form and possible strain. The tracker is not limited to counting repetitions; it also offers personalized suggestions for each exercise. For example, the application prompts users to adjust their hand position for curls or to maintain a straighter hip posture during planks.

The application calculates angles for joints relevant to curls, squats, pushups, and plank exercises which are a base to most of the exercises that are present. These exercises as a base can thus be used to implement variations over a wide set of exercises into the application. The application detects when the user completes a full repetition of each exercise and increments the count accordingly. This holistic approach not only tracks progress but also assists users in refining their technique.

The initial implementation serves as a proof-of-concept for the efficacy of AI-powered gym trackers. To enhance the users' experience even further, further research will focus on expanding available variations of the enabled exercises, developing more personalized feedback loop and considering the possibility to incorporate within fitness applications.

The contribution of this work are as follows:

- The proposed method notifies the user of mistakes whilst also offering specific suggestions for improvement in form and posture.
- It evaluates the overall posture by analyzing the distance between different joints.
- It provides users with real-time, personalized feedback, offering corrective measures to enhance their exercise technique effectively.

The remaining sections of the paper are organized as follows: Section II provides a concise review of the literature on AI-powered gym trackers, highlighting existing approaches, limitations, and potential advancements. Section III delves into the application's technical details, describing the chosen architecture and implementation with MediaPipe and OpenCV.

Section IV elaborates the methodology that was used to create the gym application, including algorithms, calculations, and evaluation metrics. Section V presents the experimental results, demonstrating the application's ability to track the exercise repetitions accurately and provide valuable real-time feedback. Finally, Section VI summarizes the main findings, discusses potential limitations, and outlines future research directions for further development and exploration of AI-powered gym tracker applications.

II. Literature Survey

Innovative applications in fitness and training are due to the rapid advancements in computer-vision and artificial-intelligence. Several studies have been conducted on to assess the use of pose estimation in fitness applications, which include multiple methods such as Recurrent Neural Networks (RNNs), Simultaneous Localization and Mapping (SLAM) and Convolutional Neural Networks (CNN).

With these advancements evaluated, the study becomes relevant to existing literature, while it attempts to bridge the gap between generic pose estimation and targeted exercise feedback. Most important of all, the literature survey details the relevant methodologies that have been used to build virtual trainers.

Junchao Zhu et al. [1], Xiaochuan Fan et al. [2], and Christos Papaioannidisat et al. [3] explored numerous possible incorporations of pose estimation in dynamic exercising settings and activities with the help of neural networks, CNNs, and SLAM.

Subsequently, [3-7] detail the existing and emerging issues in human pose estimation such as sign language recognition, CNNs, while considering the role of having the right posture during weight training. [5], [6], [8] discuss on efficiency of human pose estimation techniques by making use of having lightweight models, collateral modules, and innovative architectures for estimating human poses while also improving and optimizing the algorithm's complexity.

Ahmed Sharshar et al. [9] and Isha Chaudhary et al. [10] advanced in field by introducing multi-modal datasets for workout activities, highlighting the diversity of data sources and potential applications in motion modelling, human-pose estimation and virtual gym coaching. In the context of fitness applications [10-13] pinpoint the need of feedback loop by utilising both computer vision for detection and artificial intelligence to analyse the preciseness of user's exercising pose.

Several research [9-15] focused on the fitness and wellness mobile applications. They comprehend datasets and models of smart gym trainer software; yoga tracker and workout analyser which focus on aspects of how personal training can impact the fitness industry. P. Sudharshan Duth et al. [16] investigated Pose Net for its use in finding and tracking human movements in video sequences by separating the object with respect to the background.

S. S. Teja Gontumukkala et al. [17] showcased MediaPipe for real-time recognition of hand gestures in gameplay, integrated with a Configured Convolutional Neural Network. The technology provides high accuracy in gestural tracking and classification, which is key for intuitive interaction in a hand-cricket game.

S. Maganti et at. [18] demonstrated a method that makes predictions of a person's height and weight using only their facial characteristics, this approach differentiates itself from traditional measurement techniques by depending exclusively on facial traits.

Lastly, it is essential to design proper AI-based gym trackers that can aid in identifying and correcting the mistakes which enhances the efficiency of each workout. There exists a requirement of progress tracking and a feed-back loop which could work in real-time over each exercise performed. These gaps are addressed in the proposed application by employing MediaPipe and OpenCV for the identification of the human pose, every repetition performed and calculation of the joint angle which consequently would help users reach their fitness goal effectively.

III. Proposed Methodology

The model leverages OpenCV for real-time video capture during workouts, fulfilling the requirement for live input and feedback for workouts. The foundation of the proposed work's pose detection system is built upon the Mediapipe framework, a versatile tool for various computer vision applications. Within Mediapipe, 33 landmarks are identified across the human body, serving as key reference points for pose detection. These landmarks are nothing but joints across the human body, enabling the application to discern body parts and their positions.

For real time input data capturing and processing, OpendCV and Mediapipe are used which help in accurate pose estimation and joint tracking. The video feed is initiated using OpenCV to provide real time frames as input to the pipeline. Then, these frames are processed by Mediapipe using its pre-trained pose estimation models to detect and map these key skeletal landmarks. Each exercise is broken down into these landmarks (representing specific joints) which are extracted and used to calculate angles and distances relevant to each exercise.

Before the neural network model can evaluate the posture, based on predefined parameters, it needs to be fed with landmark data – the historic point to which the model will compare itself. During real time form validation and error correction, the model compares the observed joint angles and positions to the ideal values stored during training. What this allows for is an immediate feedback, such as 'Put Hands', 'Go Down', or 'Spread Legs', so that the user can keep the right form during their workout.

The landmarks are crucial for judging workout postures, serving as three extreme points to calculate angles using specific joints involved in each exercise. For instance, in a push-up, angles between the shoulder, elbow, and wrist joints are computed. The Fig. 1 shows different landmarks with their names via the Mediapipe framework facilitate pose estimation. These frameworks can help in incorporating a complete spectrum of exercises.

The proposed methodology defines a layered structure for the instantaneous analysis and feedback of poses. OpenCV has been used for video recording combined with MediaPipe to perform pose estimation in the proposed model.

The steps involved in the methodology are:

- Data Acquisition and Preprocessing
- Joint Angle Calculation
- Form Validation and Error Correction
- Feedback Mechanism

This methodology helps the application to stand out compared to current models, which usually only refer to repetitions measured by fixed angles, without considering the overall context of the exercise.

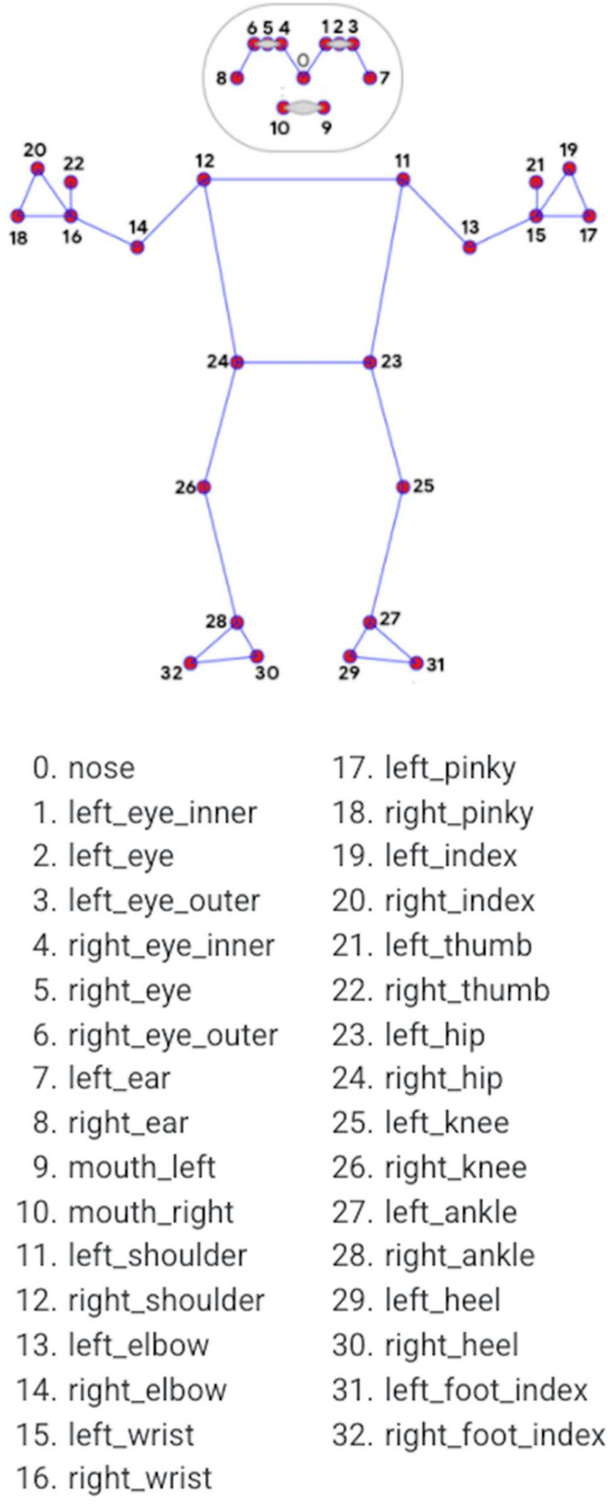

Fig. 1 MediaPipe Landmarks with Names

To facilitate angle calculations, NumPy, a powerful Python library for array manipulation and mathematical operations involving angles has been used. NumPy's efficiency in handling arrays and mathematical functions enhances the accuracy of our calculations. Its proficiency in working with radians and angles is particularly advantageous in our context. Radians and angles are crucial to achieve proper form as it simplifies complex mathematical operations, streamlining the angle calculations required for precise pose detection.

The calculated angles are now used to determine whether an exercise performed by the user is a valid set of exercises or not based on set thresholds specified for each workout. The angles are not just important for repetition counting but also for correction. Taking the example of pushups, while the angle formed by shoulder, elbow, and wrist landmarks facilitates counting the number of correct pushups, the angle formed by shoulder, hip, and knee joints as well as the angle formed by knee and ankle joints plays a vital role in correcting a wrong posture a user might be having near hip and knee joints.

Apart from angles, this work also focuses on the distance between different joints to correct the form further. The angles between different landmarks such as ankles, elbows, and knees are equally important to maintain a proper posture in many exercises such as squats. After the calculation of all these parameters, the feedback is projected on the screen on a real-time basis for the user to see and correct his form and continue with their workout.

The system architecture for the proposed methodology is given in Fig. 2 and it involves:

- Start Video Capture (OpenCV): Opens video stream of OpenCV to conduct real-time input.
- **Real-time Video Feed (OpenCV Capture):** Capture the live video feed as displayed to the user during an exercise session.
- Pose Detection (Mediapipe): Employs Mediapipe framework to detect 33 landmarks spanning the human body, which are used as anchor points in pose detection.
- Calculate Landmark Angles (NumPy): Equally, it uses the NumPy package for ease of manipulation of array objects and mathematical computations to determine angles among given joints considering specific landmarks.
- Validate Exercise Form (Angle Thresholds): Verify whether the user performs an exercise correctly or not via all calc angles being between preset boundaries of each workout.
- Check Joint Distances for Form Correction (Distance Thresholds): Analyzes distance separating various joints to make final refinement of the user's technique and correct posture applied in exercises.
- Display Real-time Feedback on Screen: The projects real-related feedback which includes angle calculations and form correction on the screen, where user can see them and take actions.
- End: This terminates the model.

The above summarizes our system architecture of the model which shows how OpenCV and Mediapipe are used in the system to incorporate landmarks of the human body and thus estimating the correct angles for exercising which would enhance the user's form.

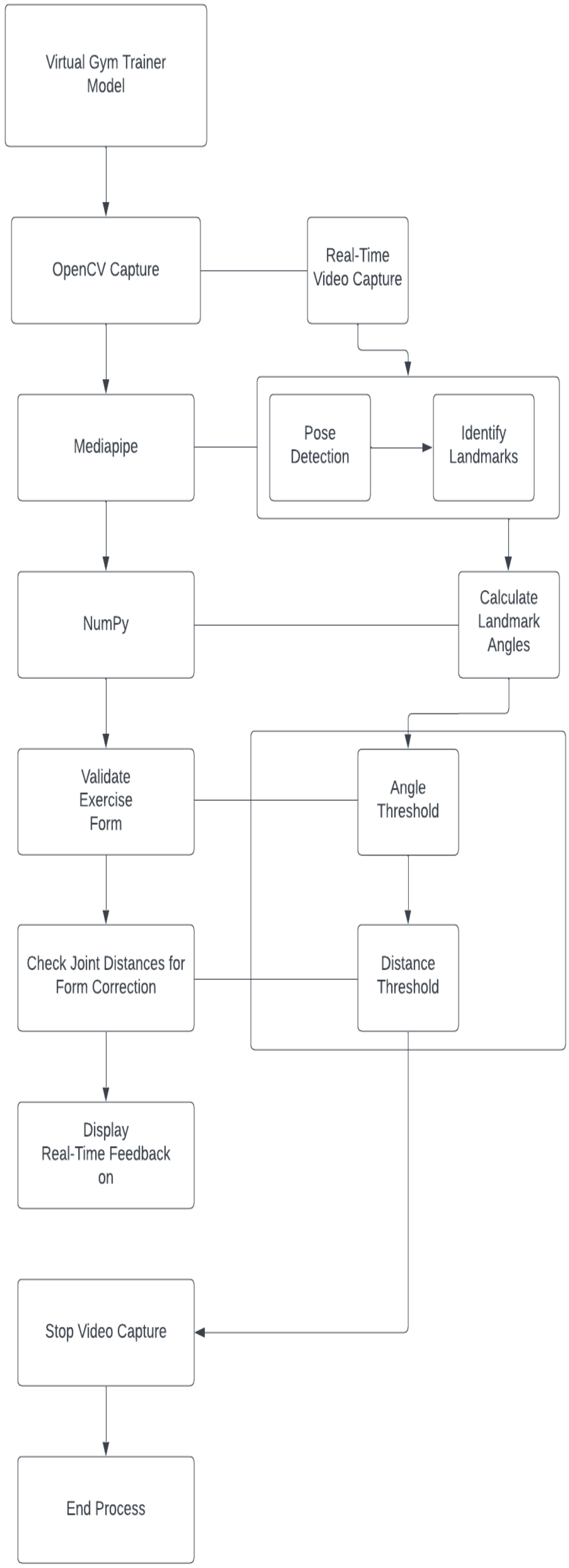

Fig. 2 System Architecture

IV. RESULT AND ANALYSIS

The virtual gym's visual parameters exhibit exceptional performance, showcasing precise detection of joints and accurate angle measurement. In the context of curl exercise, the system relies on the hand angle as a crucial determinant for evaluating exercise form. The video feed accurately captures and analyzes hand angles in real-time, providing a depiction of the exercise execution.

Fig. 3 Scenarios Captured while doing Hand Curls

Fig. 3 showcases the different scenarios captured on the live video feed. Transitioning to squats, the virtual gym introduces an additional parameter for accurate posture assessment. The system scrutinizes the position of the legs, requiring them to be appropriately spread apart for the exercise to be deemed effective. In instances where the legs deviate from the correct posture, the gym trainer promptly instructs corrective actions. This integration of additional parameters underscores the comprehensive approach of the AI gym trainer, ensuring not only the accuracy of individual joint angles but also the overall body posture during specific exercises. Fig. 4. showcases the different scenarios captured on the live video feed.

Fig. 4 Scenarios Captured while doing Squats

V. CONCLUSION AND FUTURE SCOPE

The proposed AI gym trainer excels in correcting the entire body posture of individuals performing various exercises. The system's ability to accurately detect joint angles and introduce specific parameters for exercise form evaluation is evident in the provided visual representations. The combined results affirm the effectiveness and precision of the AI gym trainer in guiding and correcting users to optimize their workout experience.

There are still areas for improvement and our future research will focus on enhancing the application by implementing a wider range of strength-training exercises and core exercises. More advanced machine learning models will be the target of future studies, which will also focus on their implementation to raise the precision of pose detection, especially in cases of complex, multi-joint activities including deadlifts and burpees.

Collaborating and integrating with numerous fitness applications can improve user experience and present a greater focus on fitness tracking and evaluation. Also, our goal is to use biometric data from wearable devices to supply a complete solution for fitness tracking. This integration may allow the system to deliver even more personalized suggestions, for instance, tailoring exercise toughness in response to user fatigue, as detected through heart rate variability.

In conclusion the AI gym tracker shows impressive results in delivering instant real-time feedback via joint angle calculations and pose estimation. The system moves forward by leveraging OpenCV and MediaPipe to assess user posture as it proposes solutions for exercises like squats and push-ups throughout workouts. Users gain advantages when using this method as it improves form and decreases injuries risk. In the future the focus will be on adding difficult exercises and incorporating AI models to improve the detection of body positions. By linking with wearable devices and various fitness platforms the application maximizes its fitness tracking capabilities while meeting users' specific needs.

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