Human Movement Analysis for Sports Performance Evaluation

Group 11

Problem Statement

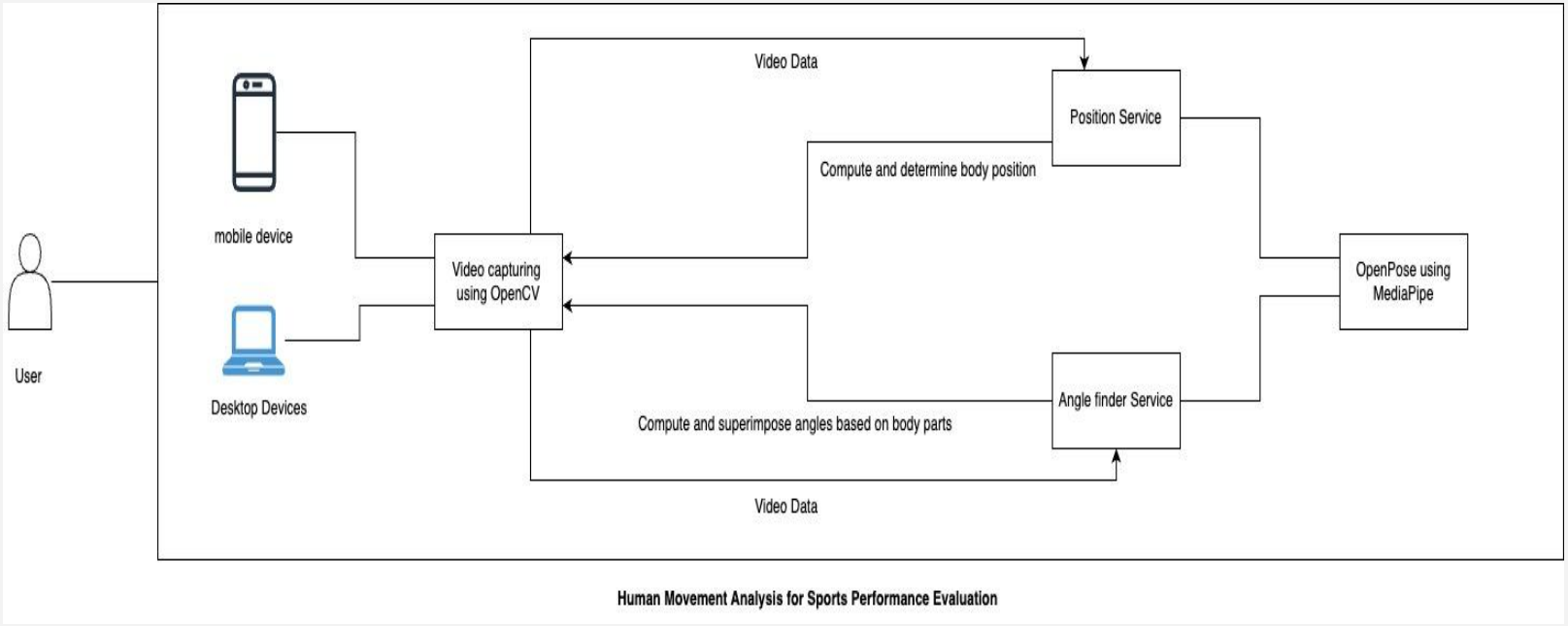
- The problem statement is to **identify human movement patterns during sports and physical exercise** to enhance athletic performance and lower the chance of injury.
- There is a rising demand for accessible, accurate, and efficient tools to **track and enhance exercise performance**, as well as the growing interest in personal fitness.
- **Proper exercise form is essential for preventing injuries,** maximizing workout effectiveness, and reaching long-term fitness objectives.
- Access to professional trainers or physiotherapists who can **provide individualized feedback** on exercise form and performance is frequently restricted or prohibitively expensive.
- There is a growing demand for **technological solutions that can help users monitor and improve their performance and form**.

Proposed Solution

- This project proposes a computer vision-based system to **track exercises, count repetitions, evaluate exercise form, and provide real-time feedback** to users.
- **OpenCV and MediaPipe** framework are used to perform pose estimation, analyze body landmarks, and calculate angles between joints.
- The proposed system has four key components: **pose detection, body landmark analysis, angle calculation, and exercise form evaluation**.
- The proposed system provides a comprehensive solution for **tracking performance and form**, enabling users to improve their exercise routines and achieve their fitness goals more effectively.

System Design

Architecture



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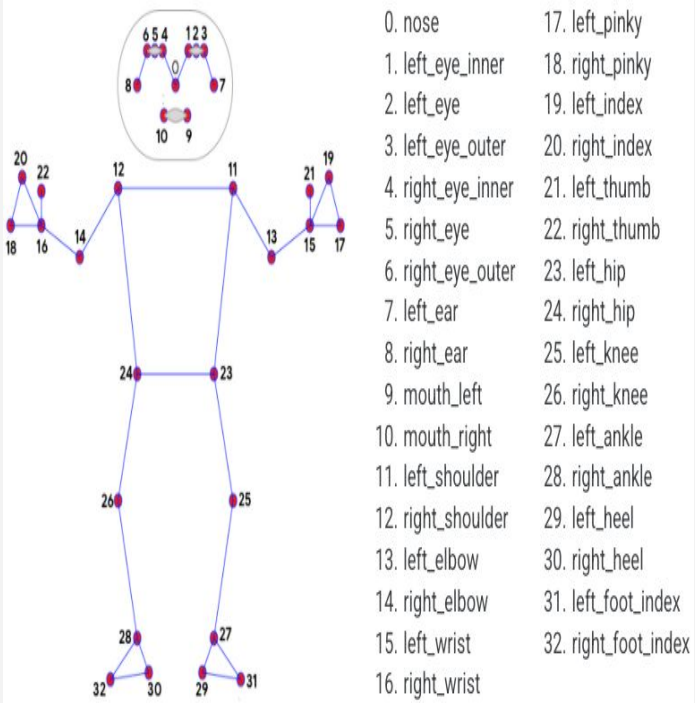
Method

- The proposed system is based on **MediaPipe and OpenCV-built pose detection module** for tracking and providing feedback on weightlifting performance.
- It uses 33 Keypoints COCO + Blaze Palm + Blaze Face
- The system consists of several components and steps that work together to process images or **video frames, identify human poses, calculate angles between** body landmarks, and verify proper exercise form.
- The primary components of the system include poseDetector class, **findPose** method, **findPosition** method**,** and **findAngle** method.
- The poseDetector class launches the MediaPipe Pose solution with user-defined or default parameters and configures the necessary MediaPipe components for drawing pose landmarks and connections on the input image.



Implementation

- The **findPose** method processes the input image or video frame, converts the image color space, and detects the human pose using the MediaPipe Pose component.
- The **findPosition** method retrieves the x and y coordinates of each landmark, adds them to a list (lmList), and draws circles around the landmarks on the input image if the draw parameter is set to True.
- The **findAngle** method computes the angle between three body landmarks based on their positions in the lmList, retrieves the landmarks' pixel coordinates, and uses the arctangent function to calculate the angle value.
- The **system uses calculations of angles between specific body** landmarks to determine if an exercise is being performed correctly and provide real-time feedback to the user.
- The system also monitors the user's progress throughout the exercise session by **counting exercise repetitions based on angle values**.

Evaluation

The evaluation of the proposed system includes the following metrics (Tested Live and through 10 videos per exercise and 100 images using American College of Sports Medicine standards):

- **Pose Detection Accuracy**: It measures the accuracy of the system in detecting human poses in images or video frames.
- **Angle Calculation Error**: This metric evaluates the difference between calculated angles and actual angles for datasets with annotations.
- **Form Evaluation Accuracy**: It measures the system's accuracy in evaluating the exercise form based on the ground truth annotations.
- **Repetition Count Error**: This metric measures the difference between the system's counted repetitions and the actual number of repetitions performed in the annotated datasets.

Metric	Industry Accepted	Achieved by our system
Pose Detection Accuracy	> 90	Normal Exercise - 90-95% Complex Exercises: 70-85%
Angle Calculation Error	< 5°	2 - 15% (due to dependence on video quality)
Form Evaluation Accuracy	> 85	78 % - 92 %
Repetition Count Error	< 10%	5 % - 17 %

Demo

Our System - Advantages and Limitations

Advantages

1. **Accurate tracking**: The computer vision-based approach using OpenCV and MediaPipe provides accurate tracking of exercise performance and form, which can help users identify areas for improvement and make adjustments to their routines.
2. **Real-time feedback**: The system provides real-time feedback on exercise form, which can help users adjust their movements during the exercise to maximize their workout effectiveness and reduce the risk of injury.
3. **Cost-effective**: The system offers a cost-effective solution for tracking and improving exercise performance, eliminating the need for costly professional trainers or physiotherapists.
4. **Personalized feedback**: The system can provide personalized feedback on exercise form and performance, which can help users tailor their routines to their individual fitness goals and needs.
5. **Comprehensive tracking**: The proposed system offers a comprehensive solution for tracking weightlifting performance and form, providing users with a wealth of features for monitoring and assessing their exercise routines.
6. **Low Computer Power:** The proposed system can be run on any basic device which helps in improving accessibility.

Limitations

1. **Dependence on camera quality**: The accuracy of the system depends heavily on the quality of the camera used. If the camera is of poor quality or the lighting conditions are not optimal, the system's accuracy will be affected.
2. **Limited exercise types**: The system may not be able to accurately detect and track all types of exercises. The accuracy of the system may vary depending on the complexity of the exercise and the specific body landmarks involved.
3. **Calibration and setup time**: The system may require some calibration and setup time to ensure accurate tracking and detection. This can be time-consuming, especially for users who are not familiar with the system.

Future Work

Enhancements

- **Multi-person Pose Detection**: The current system is designed for single-person exercise tracking. In the future, the system can be extended to support multiple people in the same frame, allowing group exercise tracking and analysis.
- **Integration with Wearable Sensors**: The system can be further improved by integrating it with wearable sensors such as accelerometers and gyroscopes. This will provide additional data on the user's motion and enable more accurate tracking of exercise form.
- **ML based Exercise Recognition**: While the current system uses a rule-based approach to recognize specific exercises, a machine learning-based approach can be explored to identify a broader range of exercises and improve recognition accuracy.
- **Real-time Feedback and Coaching**: In addition to providing visual feedback on exercise form, the system can be extended to provide real-time audio feedback and coaching to guide the user through the exercise and help them maintain proper form.
- **Integration with Fitness Apps**: The proposed system can be integrated with existing fitness apps to provide a comprehensive solution for tracking and monitoring exercise performance. This will allow users to track their progress over time and set personalized fitness goals.

Thank You