AI-Powered Personal Fitness Trainer Using Computer Vision and IoT Sensors

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***Abstraction*-Physical fitness is essential for a healthy lifestyle, yet professional personal trainers are expensive and inaccessible to most people. Existing fitness applications only provide pre-recorded videos with no real-time feedback. This paper presents a AI-powered**
personal fitness trainer that uses a USB webcam with MediaPipe pose estimation to detect and correct exercise form in real time, an ESP32 microcontroller with MPU- 6050 IMU sensor for wireless repetition counting, and a MAX30102 sensor for continuous heart rate monitoring. Voice-based corrective feedback is provided instantly when wrong posture is detected. Personalized workout plans are generated using the Claude AI API based on the user's age, weight, and fitness goals. The entire system operates on a standard PC making intelligent fitness coaching accessible to everyone.

KEYWORDS: Pose Estimation, Media Pipe, Exercise Form Correction, ESP32 MPU-6050, MAX30102, Heart Rate Monitoring .

I. INTRODUCTION

Regular physical exercise is one of the most important factors in maintaining good health. However, exercising with incorrect form is extremely common among beginners and leads to serious injuries over time. A professional gym trainer watches your body position during every exercise and corrects your mistakes immediately — but hiring a personal trainer is unaffordable for most people. Current fitness apps like Google Fit and Nike Training Club only play pre-recorded videos They cannot see the user, cannot detect wrong posture, cannot count repetitions automatically, and cannot monitor the user's heart rate during exercise. Recent advances in computer vision, wearable sensing technologies, and artificial intelligence present an opportunity to bridge this gap. Pose estimation algorithms such KEYWORDS: Pose Estimation, MediaPipe, Exercise Form Correction, ESP32 MPU-6050, MAX30102, Heart Rate Monitoring . as Google's MediaPipe Blaze Pose can accurately detect and track human body key points from standard camera feeds without the need for specialized depth sensors or expensive equipment.

A camera alone may not provide every piece of information needed for workout monitoring. The user may move outside the camera view, landmarks can become difficult to detect, and some movements may be ambiguous from a single angle. Inertial measurement units can provide complementary movement data, while heart-rate sensors can help monitor exercise intensity.

The proposed trainer uses a USB webcam with OpenCV and Media Pipe to estimate posture and calculate joint angles. Media Pipe provides 33 body landmarks, and selected coordinates are used to calculate angles for exercises such as squats, bicep curls, and push-ups. An ESP32 gathers movement information from an MPU-6050 IMU and heart-rate readings from a MAX30102 sensor. The software combines these inputs to support repetition counting, exercise-state detection, and posture feedback.

When incorrect movement is detected, voice prompts guide the user toward better posture. The system can issue a warning when heart rate reaches a configured caution threshold, allowing the user to stop and rest when appropriate. Workout sessions and repetition counts can be stored for progress review. The Claude AI application programming interface (API) can generate a workout plan based on user-provided details, goals, and progress. These recommendations are general fitness guidance and do not replace professional medical advice. The main objective is to combine affordable hardware and accessible software into one interactive platform. The system integrates camera-based pose estimation, sensor-based movement measurement, heart-rate monitoring, voice interaction, and personalized workout planning. Its modular design allows components to be tested separately before integration. The project can be evaluated through posture detection, repetition counting, feedback timing, sensor readings, and testing in a real workout environment.

II. RELATED WORK

Research in intelligent fitness assistance covers camera-based pose estimation, wearable and IoT sensing, machine-learning methods for exercise analysis, and interactive coaching systems. Earlier studies show that these technologies can support exercise monitoring, but differ in sensors, feedback methods, and how many functions are combined in one system

A. Computer-Vision-Based Pose Estimation

[1] describes real-time pose detection using MediaPipe to estimate body landmarks and calculate joint angles. [2] discusses OpenCV and MediaPipe methods for extracting landmarks from video and tracking exercise movements. [8] examines skeletal landmarks for identifying movement phases, while [11] reports key point-based pose analysis for estimating joint angles from exercise videos. These approaches show that a standard camera can analyze posture without a dedicated motion-capture suit. However, visual accuracy can depend on lighting, camera placement, occlusion, and whether relevant joints remain visible.

B. Wearable Sensors and Fitness Monitoring

Ou et al. [7] explored mobile robot navigation using sensor fusion and deep reinforcement learning. The study listed as [10] focuses on integrating multiple two-dimensional LiDAR and visual–inertial sensors within a SLAM framework. The survey identified as [11] addresses current requirements and advancements in assistive systems for visually impaired people. Uscinski's et al. [13] examined sensor-fusion-based navigation for autonomous mobile robots, while Al-Tawil et al. [14] addressed mobile robot navigation using enhanced two-dimensional mapping and multisensor fusion. Together, these research directions emphasize the role of combining complementary sensor inputs to improve environmental perception and navigation. For the proposed system, LiDAR, ultrasonic sensing, a camera, and an IMU provide a hardware foundation for gathering different types of environmental and motion-related information.

C. Machine Learning and Exercise Analysis

[4] considers machine-learning approaches, including support vector machines, Random Forest, convolutional neural networks, and long short-term memory networks, for analyzing movement and sensor data. [6] describes combining pose information with additional user cues, while [16] reviews machine-learning applications for exercise correction and injury prevention. These approaches suggest that combining different inputs can improve interpretation of exercise activity. The proposed implementation focuses on MediaPipe pose estimation together with IMU readings and heart-rate data to keep the system practical and modular. D. Interactive Feedback and Personalized Training

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[9] presents an interactive workout assistant for detecting exercise form and providing corrections. [19] discusses an AI-based digital fitness trainer that analyses posture, tracks performance, counts repetitions, and provides personalized workout guidance. [20] proposes recommending stretches by comparing a user's posture with candidate stretch poses. These systems demonstrate the value of timely feedback and individualized recommendations. The proposed project provides voice-based posture correction.

E. Research Gap and Relevance to the Proposed System

The reviewed studies address pose estimation, wearable monitoring, movement analysis, and personalized recommendations, but differ in hardware, interaction style, and monitoring capability. A practical low-cost system combining visual posture checking, sensor-supported repetition counting, heart-rate monitoring, voice feedback, and personalized planning is therefore useful. The proposed project integrates these functions around a computer and an ESP32-based sensor unit. Its contribution is the combination of multiple information sources in one prototype, with modular components that can be tested and improved separately.

TABLE I. COMPARISON OF SELECTED RELATED WORKS

Ref	Key feature	Limitation
[1],[2]	MediaPipe and OpenCV for pose landmarks and joint-angle estimation.	Mainly addresses camera-based posture analysis; sensor fusion is not the central focus
[3], [5]	Wearable and fitness sensors for posture, activity, and motion monitoring.	Sensor readings alone may not fully verify visual exercise form.
[4], [6]	Machine learning and multimodal data for analysing movement and physical cues.	Methods may require additional models, data, or implementation effort.
[8], [11]	Pose landmarks and key point-based joint-angle analysis.	Camera view and landmark visibility can affect posture assessment.
[9], [18]	Interactive form correction and AI-based personalized fitness guidance.	System designs and available features differ; combined sensor monitoring is not guaranteed.
[19]	Posture-based stretch recommendations using similarity comparison.	Focuses on recommendation rather than a complete live workout-monitoring system.
[20]	Personalized fitness trainer system for monitoring physical activities and providing customized workout guidance.	Accurate fitness assessment requires reliable sensor data, proper exercise recognition, and real-world testing to validate performance.
Proposed	MediaPipe, a USB webcam, ESP32 microcontroller, MPU-6050 IMU sensor, MAX30102 heart-rate sensor	Further testing and optimization are required to improve posture detection accuracy, ensure reliable repetition counting and heart-rate monitoring

III. PROBLEM IDENTIFICATION AND OBJECTIVES

A. Problem Identification

No Real-Time Posture Correction:-Most fitness apps display pre-recorded videos. None offer live AI feedback correcting your form as you exercise. High Cost of Personal Trainers-Human trainers. No affordable AI alternative exists that combines planning + correction. Lack of Sensor Fusion-Existing systems use either camera OR wearable sensors not both. Combined data gives far more accurate results. No Voice-Based Correction-Users cannot watch a screen while exercising. Voice feedback is essential but missing in most low-cost systems. Generic Workout Plans-Apps offer one-size-fits-all plans. No system adapts the plan in real time based on today's performance and health data.

B. Objectives

To implement real-time pose correction by detecting 33 body key points using media pipe, joint angles and provide instant voice correction when form deviates from ideal.

OBJECTIVES : To detect motion peaks and count exercise repetitions with accurately using MPU- 6050 IMU sensor on wrist/ankle. To monitor heart rate and BPM using MAX30102throughoutworkout and warn user when heart rate exceeds safe training zone. To implement ai personalized workout plans using claude LLM API to generate customized weekly workout plans based on user age, goals, fitness level and progress.

To implement adaptive training system by automatically adjusting next current session repetition completion, heart rate and form score.

IV. PROPOSED SYSTEM ARCHITECTURELOGY

Fig. 1 shows the block diagram of the proposed system, illustrating the interconnection between the camera module, AI pose detection, ESP32 microcontroller, heartbeat sensor, repetition counter sensor, buzzer/speaker, display unit, and power supply.

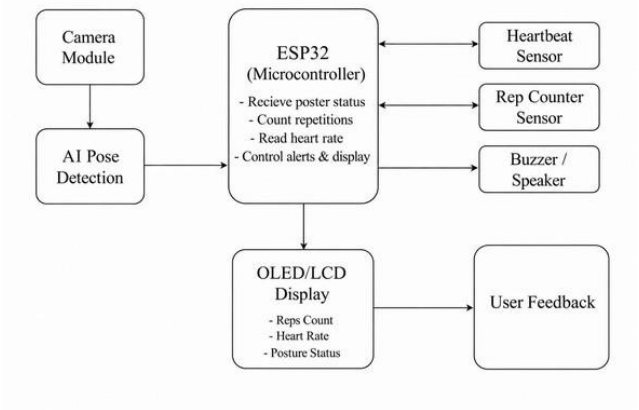

Fig. 1.Block diagram of the proposed AI-Powered Personal Fitness Trainer

The proposed AI-Based Smart Exercise Monitoring and Posture Correction System consists of the following major units: the sensing unit, processing unit, user feedback unit, and display unit. These units are interconnected to provide real-time exercise monitoring, repetition counting, heart rate measurement, and posture correction.

A. Sensor Unit

The sensor unit consists of a camera module, heartbeat sensor, and repetition counter sensor. The camera module captures the user's movements during exercise. The heartbeat sensor measures the user's heart rate, while the repetition counter sensor helps monitor exercise repetitions. These inputs support real-time exercise monitoring and performance tracking.

B. AI Pose Detection Unit

The AI pose detection unit processes the images captured by the camera module to identify the user's body posture and movements. It analyzes the user's exercise position and determines whether the posture is correct or incorrect. The detected posture information is sent to the ESP32 microcontroller for further processing.

C. Processing and Control Unit

The ESP32 microcontroller acts as the central processing unit of the proposed system. It receives posture information from the AI pose detection unit and data from the heartbeat and repetition counter sensors. It processes the inputs to count exercise repetitions, monitor heart rate, identify posture status, and control the alerts and display unit.

D. User Feedback Unit

The user feedback unit consists of a buzzer or speaker and an OLED/LCD display. The buzzer or speaker provides audio alerts when incorrect posture is detected or when user attention is required. The display provides real-time information about exercise repetitions, heart rate, and posture status. This feedback helps users perform exercises more effectively and safely.

E. Display Unit

The display unit consists of an OLED/LCD display connected to the ESP32 microcontroller. It displays the number of completed repetitions, the user's heart rate, and the detected posture status. This enables users to monitor their exercise performance and receive immediate feedback during workouts.

V. METHODOLOGY

The methodology of the proposed system is represented using a flowchart. The process begins with the initialization of the ESP32 microcontroller and connected sensors. The camera module captures the user's exercise movements, and the AI pose detection system analyzes the body posture.

Next, the detected posture information is sent to the ESP32 microcontroller. The system reads the user's heart rate and repetition counter data and processes these inputs to monitor exercise performance.

The system then checks whether the user's posture is correct. If incorrect posture is detected, an audio alert is generated through the buzzer or speaker to notify the user. If the posture is correct, the system continues monitoring the exercise and counts the repetitions.

The OLED/LCD display is updated with the repetition count, heart rate, and posture status. This process continues in real time until the user completes the exercise session or stops the system.

This flowchart describes the intended navigation sequence of the proposed system.

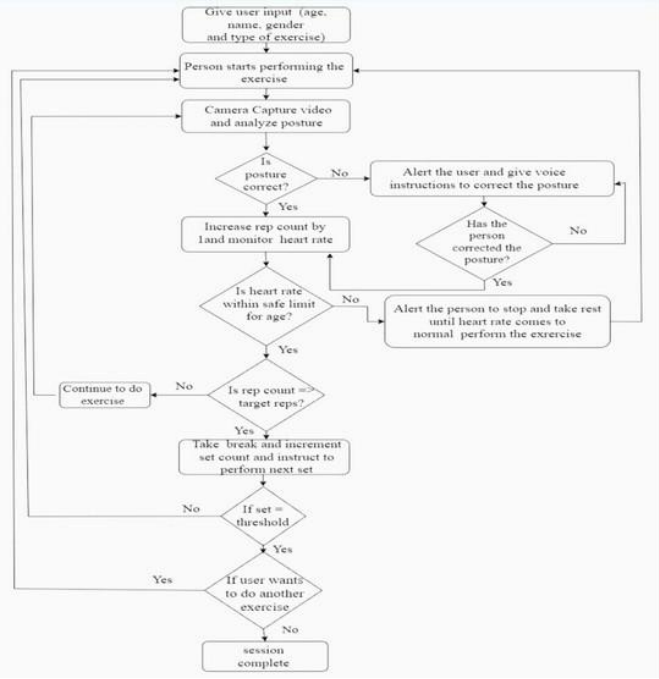

Fig. 2. Flowchart of the proposed system methodology.

VI. EXPECTED BENEFITS AND LIMITATIONS

A. Expected Benefits

The proposed system is designed to provide an intelligent and interactive fitness training platform that helps users perform exercises correctly and monitor their fitness activities. The integration of computer vision, IoT sensors, and artificial intelligence enables the system to analyze body posture, count exercise repetitions, and monitor heart rate. The webcam and MediaPipe are used to detect body landmarks and calculate joint angles.

The ESP32 microcontroller, MPU6050 sensor, and MAX30102 sensor provide the hardware foundation for movement tracking and heart-rate monitoring. The MPU6050 detects body movements and supports repetition counting, while the MAX30102 measures the user's heart rate during exercise. The integration of these components improves workout monitoring and helps users maintain proper exercise techniques

B. Limitations

The proposed system integrates multiple hardware and software components, making efficient coordination between the webcam, sensors, processing unit, and microcontroller an important consideration. The accuracy of posture detection depends on camera positioning, lighting conditions, and the visibility of the user's body. Similarly, sensor readings may be affected by improper placement, movement, and environmental factors. Bluetooth communication between the ESP32 and the computer may also experience delays or interruptions during operation.

Another limitation is that the performance of the system depends on the processing capability of the computer or device being used. Processing video frames, analyzing body movements, and collecting IoT sensor data simultaneously may cause delays on devices with limited resources. Sensor readings may also be affected by improper placement, hardware faults, or measurement errors. In addition, the system may support only a limited number of exercises and may require further training and testing to improve its accuracy for different workout activities. Some advanced AI-based feedback features may depend on internet connectivity, making them less accessible in areas with poor network coverage.

RESULT

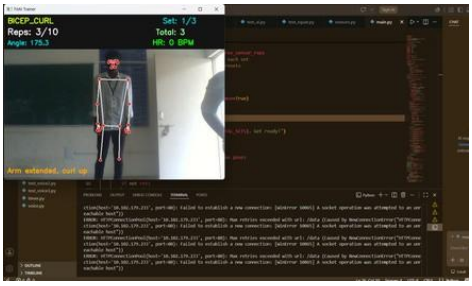

Fig. 3.1 33 Anatomical point detection

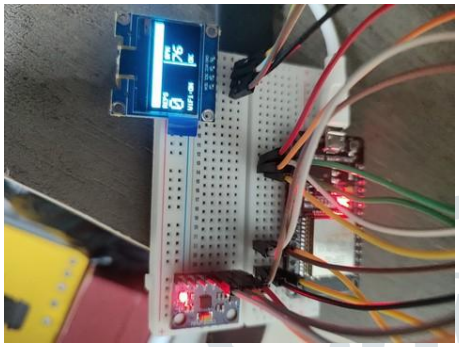

Fig. 3.2 Wearable Watch Display

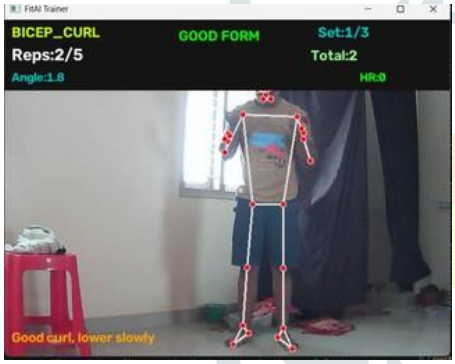

Fig. 3.3 Good Form Of Biceps Curl

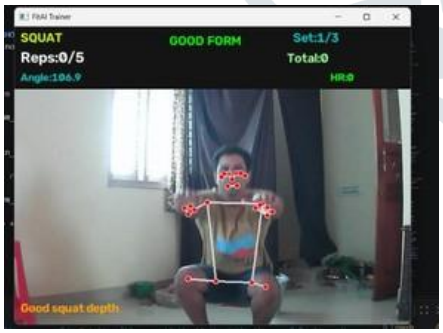

Fig. 3.4 Good Form Of Squads Curl

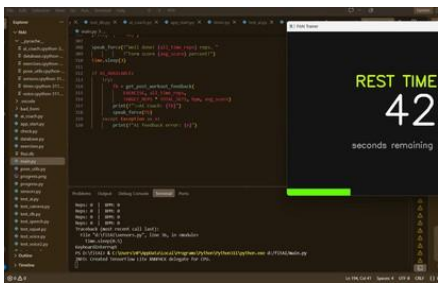

Fig. 3.5 Rest Timer

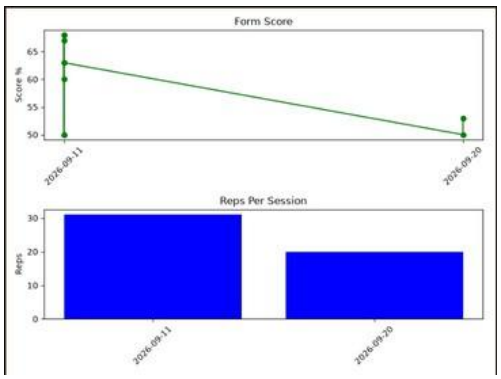

Fig. 3.6 Form Score and Repetition Graph

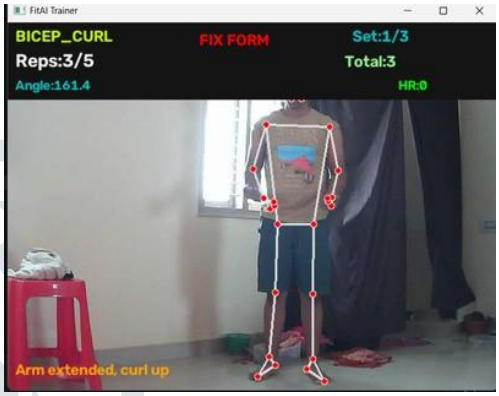

Fig. 3.7 Bad Form Of Biceps Curl

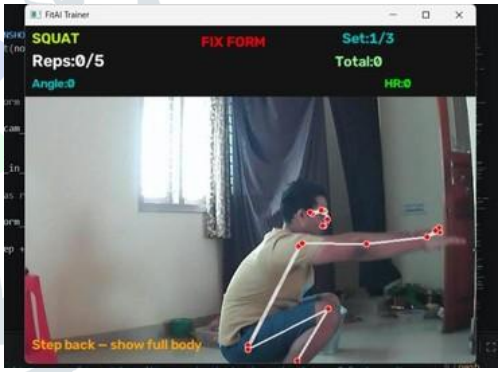

Fig. 3.8 Bad Form Of Squads Curl

The proposed AI-powered personalized fitness trainer using computer vision and IoT sensors provides an effective approach to monitoring and improving exercise performance. The system uses a camera and MediaPipe pose estimation to detect body movements, analyze joint angles, and evaluate exercise postures. It helps count repetitions, identify incorrect movements, and provide real-time feedback to users. The integration of IoT sensors enables the collection of relevant sensor data, such as heart rate, to support workout monitoring. The system also supports exercise session tracking and provides voice instructions to guide users during workouts. Overall, the project demonstrates the potential of artificial intelligence and IoT technology to make fitness training more accessible, interactive, and personalized.

FUTURE SCOPE

In the future, the AI-powered personalized fitness trainer can be improved by adding more exercises and using advanced AI algorithms to increase posture detection accuracy. A mobile application can be developed to provide personalized workout plans and track users' fitness progress. Integration with smartwatches and advanced IoT sensors can help monitor health parameters during exercise. The system can also be enhanced with real-time posture correction, voice assistance, and offline functionality to provide a more convenient and effective fitness training experience.

VII. CONCLUSION

The proposed AI-Based Smart Fitness Training System aims to help users perform exercises correctly by combining artificial intelligence, computer vision, and IoT-based sensors. The integration of a webcam, MediaPipe, ESP32 microcontroller, MPU6050 sensor, and MAX30102 sensor provides a foundation for body posture detection, exercise repetition counting, movement tracking, and heart-rate monitoring. The system helps users understand their exercise performance and receive real-time feedback during workouts.

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