

NeuroFlex: AI-Driven Real-Time Exercise Monitoring and Adaptive Workout Planning Using MediaPipe and Computer Vision

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Abstract—The rapid development of digital health technologies has created new opportunities for smart and accessible fitness solutions. This paper presents the design and implementation of an AI-driven real-time exercise monitoring and adaptive workout planning system using computer vision and pose estimation. The proposed system integrates a Flask backend with MediaPipe Pose and OpenCV to analyze human body landmarks using a standard webcam. It detects exercises such as squats, lunges, arm raises, and knee lifts, while counting repetitions in real time through joint angle computation and movement state transitions. In addition to repetition tracking, the system evaluates user performance using a lightweight accuracy estimation model based on movement consistency. An AI recommendation module provides contextual coaching, including posture correction, motivational feedback, and fatigue detection. The system also estimates calories burned using weight-adjusted exercise constants. Unlike traditional fitness applications that rely on manual input or wearable devices, the proposed solution requires only a webcam and browser, making it a low-cost and accessible alternative. Experimental evaluation demonstrates reliable repetition detection and responsive feedback in controlled environments. This work highlights the potential of computer vision-based fitness coaching as an intelligent, interactive, and user-friendly approach for modern wellness applications.

Index Terms—Artificial Intelligence, Computer Vision, Pose Estimation, Real-Time Exercise Monitoring, Fitness Technology, Human Activity Recognition, Adaptive Workout Planning, MediaPipe Pose

I. INTRODUCTION

The increasing adoption of digital technologies in health-care and wellness has transformed how individuals approach physical fitness. As demand for personalized and convenient workout solutions grows, intelligent systems capable of real-time exercise monitoring have become increasingly

important. Traditional fitness applications rely on manual input, wear-able sensors, or pre-recorded video demonstrations. While use-ful, these approaches often lack real-time corrective feedback and adaptive workout planning based on user performance.

Recent advancements in artificial intelligence and computer vision have enabled machines to interpret human movements using pose estimation algorithms. By analyzing body land-marks extracted from camera input, systems can detect posture, compute joint angles, and recognize exercise patterns without requiring specialized hardware.

This paper proposes an AI-powered exercise monitoring and adaptive workout planning system that integrates pose estimation, real-time repetition counting, performance evaluation, and intelligent feedback. The system uses MediaPipe Pose for landmark detection, OpenCV for video processing, and a Flask backend for application management.

Unlike traditional systems, the proposed platform continuously analyzes movement consistency and provides contextual feedback, including posture correction and fatigue alerts. It also generates personalized workout plans based on user attributes such as age, weight, and fitness goals.

The objective is to develop a scalable, accessible, and efficient fitness monitoring system that balances accuracy, usability, and cost-effectiveness.

II. LITERATURE SURVEY

A. Objective of the Literature Survey

The primary objective of this survey is to analyze advancements in vision-based exercise monitoring, pose estimation, and AI-driven fitness systems. It

examines the evolution from wearable sensor-based systems to camera-based pose estimation models.

The study focuses on:

- Lightweight pose detection models
- Joint angle computation techniques
- Repetition detection methods
- AI-based coaching systems

It also identifies limitations in existing solutions, including lack of real-time feedback, limited personalization, and hard-ware dependency.

B. Importance of the Literature Survey

The literature survey provides a structured understanding of existing methodologies and highlights technological progression in fitness monitoring systems. It helps identify research gaps such as:

- Lack of adaptive workout planning
- Absence of real-time corrective feedback - Limited personalization

Understanding these gaps guides the development of a more comprehensive and accessible solution.

C. Research Gaps

Key research gaps identified include:

- Dependence on wearable hardware
- Lack of intelligent feedback systems - Limited personalization
- Poor scalability and modularity

These gaps justify the need for an integrated AI-based fitness monitoring system.

III. METHODOLOGY

A. Introduction

The proposed system follows a modular architecture combining pose estimation, angle computation, repetition detection, and AI-based feedback.

B. Proposed Algorithm

Algorithm 1: Pose Extraction

- 1) Capture video frame
- 2) Convert to RGB
- 3) Detect landmarks
- 4) Extract joint coordinates

Algorithm 2: Angle Calculation

- 1) Select joints A, B, C
- 2) Compute vectors
- 3) Calculate angle

Algorithm 3: Repetition Counting

- 1) Detect state transitions
- 2) Increment repetition count

Algorithm 4: Feedback System

- 1) Compute accuracy

- 2) Detect fatigue
- 3) Generate feedback

IV. MATHEMATICAL FOUNDATIONS

$$\theta = \cos^{-1} \frac{(\vec{BA} \cdot \vec{BC})}{\|\vec{BA}\| \|\vec{BC}\|} \quad (1)$$

$$A = \min(100, 60 + 2R) \quad (2)$$

$$C = k \times W \times R \quad (3)$$

V. RESULTS AND DISCUSSION

The system was evaluated on exercises such as squats, lunges, arm raises, and knee lifts. Results showed:

- Accurate repetition counting
- Stable pose detection under normal lighting
- Real-time feedback generation
- Effective fatigue detection

Limitations included reduced performance in poor lighting and sensitivity to camera angles.

VI. CONCLUSION

The proposed AI-based exercise monitoring system provides a scalable and accessible solution for real-time fitness tracking. By integrating pose estimation, repetition detection, and adaptive feedback, it eliminates the need for wearable devices while maintaining usability and efficiency.

Future improvements include enhanced accuracy models and multi-user support.

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