The Smart Fitness Coach*

*ECE 445 Senior Design Project

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***Abstract*—This document is a proposal for our senior design project: The Smart Fitness Coach. The Smart Fitness Coach is a mobile app designed for processing camera-captured patterns in real-time, which estimates the user's body pose, with action recognition and evaluation, and presents visual feedback to finally reduce injuries and enhance fitness.**

***Index Terms*—Software, Fitness, Deep Learning**

I. Introduction

A. Objective and Background

Goals: With the rise of the national fitness campaign, more people are exercising at home for convenience. However, a lack of professional guidance often leads to incorrect exercise forms, increasing the risk of injuries and reducing workout efficiency. The Smart Fitness Coach aims to solve this problem by providing real-time exercise feedback, improving posture correction, and offering personalized fitness guidance.

Functions:

1) Recognize user exercise movements through video input.
2) Analyze posture using pose estimation techniques.
3) Provide real-time feedback, highlighting misaligned body positions.
4) Suggest improvements and recommend personalized workout schedules.

Benefits: This app enhances workout safety and efficiency by ensuring users maintain proper posture during exercises. By reducing incorrect form-related injuries, it makes fitness more accessible and effective for home users. Additionally, the real-time feedback feature excels conventional fitness apps which rely on pre-recorded guidance.

Features:

1) Real-time Posture Correction: Uses AI-based pose estimation to detect incorrect forms and provide immediate feedback.
2) Personalized Workout Plans: Adapts recommendations based on user progress and performance.
3) User-friendly Mobile Interface: Provides visual cues and alerts for better engagement.
4) Cloud-based Data Storage (Optional): Allows users to track exercise history and performance improvements.

B. High-Level Requirements List

1) The system must accurately identify and classify user movements with at least 90% accuracy using pose estimation and action recognition models.
2) The real-time feedback system should provide exercise corrections within 1 second of detecting improper form.
3) The mobile application should support at least five common exercises (e.g., squats, push-ups, lunges, planks, jumping jacks).
4) Users should be able to track their exercise history (optional) and receive personalized recommendations based on past performance.

II. Design & Requirements

A. Frontend

The frontend is crucial for user engagement and interaction. It makes the system accessible and understandable for the user, allowing them to interact with the system through the user interface. The user is able to receive immediate feedback and guidance from the user interface, which presents visual feedback on exercise form and clearly shows what is correct and incorrect in their posture.

Requirements:

- **Requirement 1:** The real-time feedback mechanism should be responsive, with minimal lag between the actual exercise and the display of feedback.
- **Requirement 2:** The exercise suggestion algorithm should be able to analyze user performance data accurately to provide relevant and useful workout recommendations.

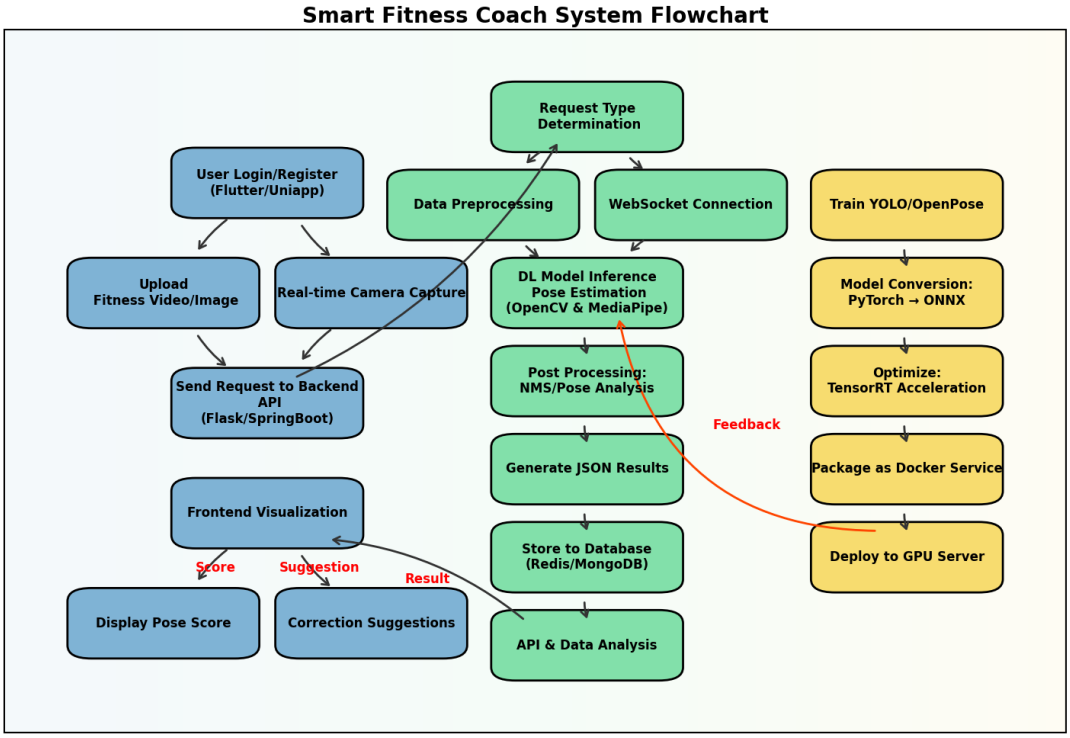

Fig. 1. The Smart Fitness Coach Flowchart.

- **Requirement 3:** The real-time feedback mechanism should be responsive, with minimal lag between the actual exercise and the display of feedback.

B. Backend

The backend is the core of the system, handling the complex processing required for accurate form recognition and feedback. The camera captures user movements and utilizes machine learning models to identify specific exercises by analyzing the movement patterns in the video feed. Then the system estimates the user's body pose to determine if it is correct. The data processing unit processes the video feed from the user's device in real-time. This ensures that the feedback sent to the mobile app during workouts has minimal delay.

Requirements:

- **Requirement 1:** The data processing should be fast enough to handle real-time video feeds without significant delay.
- **Requirement 2:** The pose estimation techniques should be accurate in different lighting conditions and for various body types.
- **Requirement 3:** The action recognition models should be trained well to accurately identify a wide range of exercises.

C. Cloud Database

The cloud database provides a centralized storage for all user-related data and models. It allows the system to access and analyze historical data for personalized feedback and enables the continuous improvement of the system through model updates.

Requirement:

- **Requirement 1:** The database should be secure to protect user data.
- **Requirement 2:** The data storage and retrieval speed should be fast to ensure efficient system performance.

D. Models to Use

1) OpenCV:

- **Versatile Image and Video Processing:** It provides a vast array of functions for image and video manipulation. In the Smart Fitness Coach, it can be used for tasks like preprocessing video frames, such as resizing, color conversion, and noise reduction, ensuring better input quality for subsequent analysis.
- **Computer Vision Algorithms:** It offers a wide range of computer vision algorithms like edge detection, feature extraction, and object tracking. These can assist in initial

stages of analyzing exercise movements, for example, detecting the edges of the body to get a rough outline for further pose estimation.

- **Performance Optimization:** OpenCV is highly optimized for performance, allowing for efficient processing of video feeds in real-time. This is crucial in the Smart Fitness Coach to ensure that there is minimal delay between the user's movement and the system's feedback.

2) MediaPipe:

- **Pose Estimation Capabilities:** MediaPipe has advanced pose estimation models that can accurately track the position and orientation of the body's joints. In the fitness context, it can precisely determine if a user's body is in the correct position during exercises like squats or push-ups, enabling detailed feedback on posture.
- **Multi-Modal Processing:** It can handle multiple modalities such as video, audio, and even hand gestures. This flexibility can be useful in a Smart Fitness Coach application to potentially incorporate additional features like voice commands or gesture-based interactions.
- **Pre-Trained Models and Ease of Use:** MediaPipe comes with pre-trained models that can be easily integrated into applications. This saves development time and effort, allowing developers to quickly implement complex pose estimation and action recognition features in the Smart Fitness Coach.

III. Ethics & Safety

A. Ethics Code Followed

1) User Privacy & Data Security: **GDPR/CCPA Compliance:** User data (e.g., video feeds, fitness metrics) is anonymized via SHA-256 hashing and encrypted using AES-256 during transmission and storage, directly addressing **Cloud Database Requirement 1** for secure data handling.

Informed Consent: Granular consent options (e.g., opt-in/out for video analysis) are integrated into the frontend UI, ensuring transparency and user control.

2) Algorithmic Fairness: **Bias Mitigation:** Action recognition models are trained on datasets spanning diverse demographics (age, BMI, ethnicity) and environmental conditions (low-light, cluttered backgrounds), fulfilling **Backend Requirement 2** for cross-scenario accuracy.

Transparency: Real-time feedback includes MediaPipe-generated skeletal overlays and textual metrics (e.g., "Hip alignment deviation: 5°"), aligning with **Frontend Requirement 1** for actionable guidance.

3) Accountability: **Ethics Audits:** Independent quarterly reviews ensure compliance with IEEE Standard 7000-2021 for AI transparency, with audit logs stored in the Cloud Database for traceability.

B. Safety Concerns & Mitigations

1) Physical Safety: **Risk:** Incorrect posture feedback due to model drift in dynamic environments.

Mitigation:

- **Dual Validation:** Combines MediaPipe's pose estimation (**Backend Requirement 3**) with an LSTM-based motion validator to flag anomalies.
- **Confidence Thresholds:** Feedback is delayed if system confidence $< 85\%$, requiring manual user confirmation via the frontend.

2) Cybersecurity: **Risk:** Data interception during cloud transmission.

Mitigation:

- **TLS 1.3 Encryption:** Secures all data streams to the Cloud Database, exceeding **Requirement 1** for security.
- **Zero-Trust Architecture:** Implements RBAC and MFA for database access, minimizing insider threats.

3) Psychological Safety: **Risk:** User demotivation from excessive feedback.

Mitigation:

- **Adaptive Feedback:** AI analyzes user stress (via facial expressions) to adjust feedback frequency, supporting **Frontend Requirement 3** for engagement.
- **Progress Gamification:** Achievements and badges incentivize consistent usage, enhancing user satisfaction.

References

[1] IEEE Standards Association, "IEEE Standard 7000-2021: Model Process for Addressing Ethical Concerns during System Design," 2021.

[2] European Union, "General Data Protection Regulation (GDPR): Technical Implementation Guidelines," 2018.