FitFusion: Real-Time Exercise Form Correction Using OpenCV

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***Abstract*—Maintaining the correct form during exercise is crucial to preventing injuries and improving performance. While personal trainers can help, factors like cost, availability, and personal preference often make them inaccessible. To bridge this gap, we developed an AI-powered Exercise Form Correction System that uses OpenCV-based pose estimation to analyze workout posture in real-time and provide instant feedback. Our web-based application, built with HTML, CSS, JavaScript, React and OpenCV, tracks key body points to evaluate posture accuracy. If an incorrect form is detected, users receive immediate corrections through pop-up notifications. Additionally, the system includes a BMI calculator and generates customized meal plans based on BMI categories, offering a more holistic fitness solution. Testing and evaluation show that our approach effectively identifies improper exercise forms, making it a cost-effective and accessible alternative to traditional personal training. Future advancements could include deep learning integration, larger datasets, and wearable sensor fusion to enhance accuracy and adaptability, making AI-driven fitness assistants even more effective.**

***Index Terms*—Exercise Form Corrector, Convolutional Neural Network (CNN), Machine Learning, OpenCV, Exercise Applications**

I. INTRODUCTION

Exercise-related injuries are a growing concern, often stemming from improper form or misuse of equipment. In 2020, the U.S. Consumer Product Safety Commission (CPSC) reported over 400,000 injuries linked to exercise equipment, many of which were caused by poor posture or incorrect movement patterns. Studies indicate that 30-50% of weightlifting injuries result from improper technique, while yoga-related injuries have also risen, with approximately 5,500 emergency visits recorded in the U.S. in 2017 alone. These statistics highlight the importance of maintaining correct exercise form to prevent injuries and maximize workout efficiency.

Common Injuries Due to Poor Form

- Sprains and Strains: Overstretching or incorrect movement can cause ligament sprains and muscle strains.
- Joint Injuries: Misalignment during workouts may lead to excessive stress on joints, increasing the risk of tendonitis, bursitis, or even dislocations.

To address these challenges, AI-driven fitness solutions are gaining traction. Figure 1 illustrates the architecture of our Exercise Form Corrector System, which integrates key features like real-time workout tracking, BMI analysis, and meal planning to enhance user performance and safety.

Recent advancements in deep learning and pose estimation algorithms have significantly improved exercise form correction methods. This paper reviews existing research on these technologies, identifying key trends, challenges, and potential enhancements. Our project, an AI-based Exercise Form Corrector Application, leverages Convolutional Neural Networks (CNNs) and OpenCV to analyze real-time video input of exercises such as squats, push-ups, and lunges. By providing instant posture correction feedback, the system aims to reduce injury risks and improve workout efficiency, making structured fitness guidance more accessible to users.

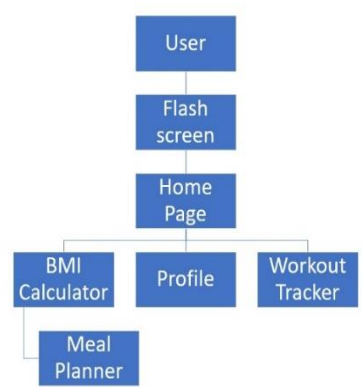

FIGURE. 1. System Architecture of Website.

II. LITERATURE SURVEY

Human pose estimation has gained significant attention, especially in fitness applications where correct posture is crucial to prevent injuries and enhance performance. Various studies have explored how artificial intelligence can assist in tracking and correcting exercise forms.

Kreiss et al. (2019) introduced PifPaf, a technique designed to detect multiple human poses in crowded environments [1]. Their approach improved accuracy in identifying body key points, making it suitable for applications like self-driving cars and robotics. Similarly, Aonty et al. (2023) developed a group-based CNN model trained on the MPII dataset, achieving impressive accuracy in recognizing human poses. [7].

In the fitness domain, Mahendran (2021) proposed a fitness tutor app that uses PoseNet to analyze body posture during workouts [5]. This system extracts reference images from YouTube to compare users' poses and offer guidance. Turner et al. (2024) took this further by applying YOLO for person tracking and Graph Convolution Networks (GCN) for analyzing workout posture [10]. Their system provided real-time feedback on common exercises like squats and lateral raises, helping users correct improper form.

Another interesting approach was explored by Chen et al. (2023), who developed a CNN-LSTM model to recognize movements in traditional Chinese exercises [8]. By combining feature extraction from images (CNN) with time-sequence analysis (LSTM), they achieved highly accurate motion tracking. Meanwhile, Raza et al. (2023) applied machine learning algorithms like Random Forest and Logistic Regression to classify exercise movements in physiotherapy, achieving over 99% accuracy in detecting incorrect postures [6].

A broader perspective on pose estimation techniques is offered by Munea et al. (2020), who reviewed various deep learning models such as DeepPose, Mask R-CNN, and Faster R-CNN [4]. Their analysis highlighted key challenges, including occlusion, rare pose detection, and real-time implementation.

From these studies, it is evident that deep learning-based pose estimation, combined with real-time feedback, plays a crucial role in exercise correction. Building on these advancements, our work integrates OpenCV-based pose estimation with instant feedback, ensuring users perform exercises with the correct form.

III. METHODOLOGY

A. System Flow:

The website will consist of a user-friendly UI developed in HTML, CSS, JavaScript and React. The next step is to train the model using OpenCV and python to detect incorrect form followed by the integration of model with the website and finally the testing of application for any bug.

B. Data Collection:

In this project, the data collection process is centered around identifying and analyzing various exercise postures using a pre-trained pose estimation model. The MoveNet model, developed by TensorFlow, is employed for this purpose due to its high accuracy and efficiency in real-time human pose detection.

C. Types of Exercise:

The exercise postures considered in this project include a variety of commonly practiced fitness movements. These may include: Squats, Push-ups, Lunges, Planks, Jumping jacks. These postures were chosen because they are foundational exercises that involve distinct body positions and joint movements, making them suitable for pose-based classification.

D. Pose Estimation Algorithm:

The pose estimation technique utilized in this project is based on the MoveNet model, a state-of-the-art pose estimation framework developed by TensorFlow. MoveNet is capable of detecting 17 key human body landmarks (e.g., elbows, shoulders, hips, knees, ankles) in real time from input images or video streams.

MoveNet is a deep learning-based model that leverages convolutional neural networks (CNNs) to estimate human poses with high accuracy and low latency. It comes in two main variants:

- MoveNet Lightning – optimized for speed and suitable for mobile or edge devices.
- MoveNet Thunder – optimized for accuracy and suitable for applications where precision is critical.

E. Error Detection and Feedback Mechanism:

In this project, incorrect exercise postures are identified through analysis of the body keypoints extracted by the MoveNet pose estimation model.

Once the pose landmarks are detected, they are compared against predefined "correct form" criteria for each exercise.

The system uses the coordinates of 17 key body points (e.g., shoulders, hips, knees, ankles) to calculate joint angles and relative distances between body parts. These computed values are then evaluated against set thresholds that define correct posture for each specific exercise.

For example: In a squat, the angle at the knee joint should ideally be below a certain degree when fully lowered, and the back should remain relatively straight (monitored via shoulder-hip alignment). In a push-up, the elbows should bend to a certain angle, and the hips should remain in line with the shoulders (no sagging or arching).

By checking if these angles or positions fall outside the acceptable range, the system flags the posture as incorrect.

1. Logic Behind Pop-up Notifications for Wrong Form: When an incorrect posture is detected, a real-time feedback mechanism is triggered. This feedback is designed to help users quickly correct their form and avoid injury. The logic behind the pop-up notifications involves the following steps:
2. Continuous Monitoring: During the exercise, every frame is analyzed for posture correctness.
3. Rule-based Alerts: If one or more joint angles or positions deviate beyond the allowed thresholds for a certain number of consecutive frames (to reduce false positives), the system classifies it as a posture error.
4. Trigger Notification: A pop-up message or visual cue appears on the screen, indicating the specific issue (e.g., "Straighten your back", "Bend your knees more", or "Keep your hips aligned").
5. Optional Audio Feedback: Depending on the setup, the system may also provide spoken feedback for a more interactive experience.

This mechanism ensures that users receive timely and specific guidance, enhancing the safety and effectiveness of their workouts.

F. Additional Feature:

To enhance the overall fitness experience, the project includes two additional health-focused features: a BMI (Body Mass Index) Calculator and a Meal Plan Recommendation system. These features provide users with personalized insights and guidance beyond exercise form correction.

BMI Calculator: Formula and Logic

The BMI Calculator helps users assess whether their weight is within a healthy range based on their height and weight.

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$$

FIGURE. 2. BMI Calculation Formula

The user inputs their weight in kilograms and height in meters. The BMI is calculated using the above formula. Based on the BMI value, the user's weight status is classified into one of the following categories:

BMI Range	Category
Below 18.5	Underweight
18.5 – 24.9	Normal weight
25 – 29.9	Overweight

IV. IMPLEMENTATION

The implementation of the project combines web technologies for the frontend with Python-based machine learning for model training and backend logic. Real-time posture tracking is achieved through the integration of the MoveNet pose estimation model with OpenCV and a custom-trained classifier.

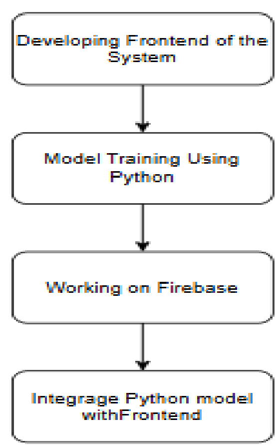

FIGURE. 3. Work Flow of the system

A. Frontend Development Tools Used

The user interface was developed using a combination of modern web technologies:

1. HTML & CSS: Used for structuring and styling the web pages.
2. JavaScript: For dynamic interactions and handling client-side logic.
3. React.js: Utilized to build a responsive and

component-based UI. React efficiently manages state and provides smooth integration with external libraries, such as webcam access and real-time feedback visuals.

B. Integration of OpenCV for Real-Time Posture Tracking

OpenCV (Open-Source Computer Vision Library) is integrated on the backend using Python. It is responsible for:

1. Accessing the webcam feed.
2. Capturing frames in real time.
3. Feeding each frame into the MoveNet model to extract pose landmarks.
4. Passing the extracted keypoints to a trained classifier to detect the exercise being performed and evaluate posture correctness.
5. Displaying visual feedback such as skeleton overlays or error messages on the video stream.
6. OpenCV acts as the bridge between video input and model predictions, enabling real-time analysis and feedback.

Steps Involved in Coding and Testing the System

A. Model Training in Python:

1. Used MoveNet to extract pose keypoints from labelled exercise video data.
2. Trained a custom classification model to recognize different exercise postures.
3. Saved the trained model for integration with the live system.

B. Frontend Development:

1. Built the UI using React components, styled with CSS.
2. Created sections for live video feed, posture feedback, BMI calculator, and meal plans.
3. Integrated webcam access and model communication via JavaScript.

C. Backend & Real-time Integration:

1. Set up Python backend scripts using OpenCV and TensorFlow.
2. Streamed webcam input, processed frames, and returned predictions.
3. Used WebSockets or API calls (depending on setup) to communicate with the frontend.

D. Testing & Debugging:

1. Tested the system with different users performing exercises.
2. Validated model predictions and feedback accuracy.
3. Debugged UI responsiveness and ensured seamless webcam integration across browsers.
4. Fine-tuned posture detection thresholds to reduce false positives and negatives.

V. RESULTS

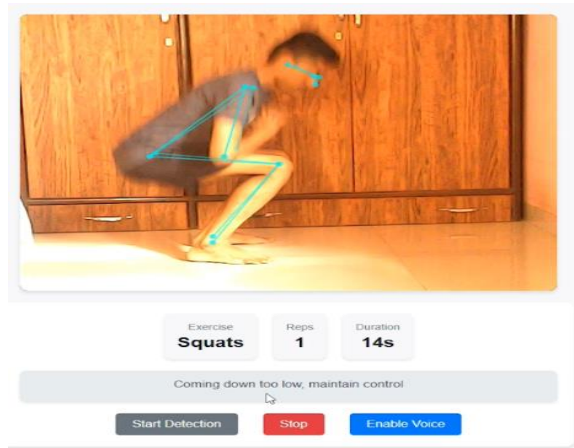

FIGURE. 4. Form Correction

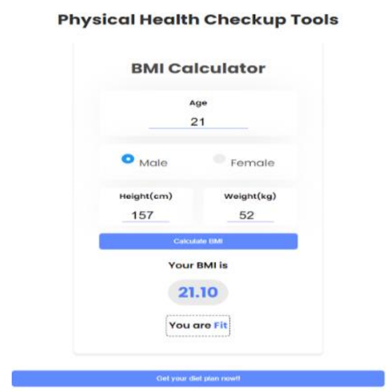

FIGURE. 5. BMI Calculation

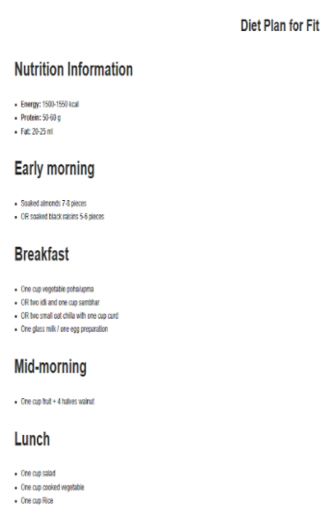

FIGURE. 6. Meal Plan

VI. CHALLENGES

1. Interpretability of Models: Advanced models like artificial neural networks often operate as "black boxes," meaning their decision-making processes are not easily understood or interpreted, which can make debugging, trust-building, and refinement challenging.
2. Dataset Limitations: A limited dataset size and lack of diversity pose significant obstacles for training machine learning models. These limitations can lead to overfitting (where the model performs well only on training data but poorly on new data) and hinder the model's ability to generalize effectively to unseen scenarios.

VII. CONCLUSION

This research explores how machine learning (ML) and deep learning (DL) are transforming exercise form correction and pose estimation. While existing technologies have made significant progress, challenges like limited datasets, real-world adaptability, and model interpretability still need to be addressed. To bridge these gaps, we developed an AI-powered Exercise Form Corrector that analyzes video input to provide real-time posture feedback, helping users perform exercises safely and effectively. Additionally, our system includes a BMI calculator that suggests personalized meal plans, making it a well-rounded fitness tool. Although our current dataset has some limitations, future improvements could involve expanding data sources, integrating wearable sensors, and refining deep learning models for even greater accuracy. This research contributes to the growing field of AI-driven fitness solutions, promoting safer workouts and encouraging healthier lifestyles.

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