StrideSync -AI Enhanced Workout Tracking and Form Validation

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***Abstract*— AI-powered fitness tracking and nutritional analysis systems enhance health management through advanced AI and computer vision technologies. As personal fitness and dietary management gain significance in promoting health and wellness, existing solutions often lack real-time monitoring and personalized feedback, creating a gap in user engagement and effectiveness. This paper presents a methodology that integrates real-time object detection using a YOLOv8 model to accurately identify food items and calculate their nutritional values based on user input weights. Additionally, it employs advanced pose estimation algorithms like MediaPipe Pose and BlazePose to monitor exercise forms across diverse workouts, providing users with actionable insights to improve performance. The system includes an intuitive web interface, built using Flask and Tkinter, that displays real-time nutritional information and visualizes data through interactive charts, fostering user understanding of their dietary intake and fitness progress. After rigorous testing, the system demonstrated significant accuracy in exercise tracking and food composition analysis, offering a comprehensive health management tool. Future enhancements will focus on expanding exercise databases, incorporating holistic health metrics such as heart rate and sleep tracking, and developing a mobile application to increase accessibility. Ultimately, the system aims to empower users to achieve their fitness and nutritional goals, contributing to a healthier lifestyle through technology-driven solutions.**

***Keywords*— Pose Estimation, Computer Vision, YOLO, Body Mass Index (BMI), Nutritional Analysis.**

I. INTRODUCTION

The intersection of technology and personal health management is revolutionizing how individuals approach fitness and nutrition. With advancements in computer vision and interactive interfaces, a significant opportunity exists to elevate personal wellness through sophisticated, user-friendly tools. Effective health management demands a multifaceted approach that combines accurate nutritional analysis, precise body metric tracking, and personalized exercise regimens. Recent developments in computer vision technologies allow for precise food identification and nutritional analysis. At the same time, real-time exercise monitoring helps users maintain correct form, making workouts safer and more effective.

In today's fast-paced world, many people struggle with maintaining the correct form during workouts, leading to injuries and diminishing exercise effectiveness. Counting repetitions manually can be distracting, leading to errors and impacting focus. Furthermore, hiring a personal trainer for guidance is often costly and inconvenient. These challenges indicate a need for an accessible and affordable solution that can provide real-time feedback and ensure proper workout execution, allowing users to maximize the benefits of their exercise routine.

The proposed system in [1] uses MediaPipe Pose and BlazePose for real-time exercise form evaluation via webcam, though its accuracy is impacted by webcam quality and lighting conditions. In [2], the system utilizes MediaPipe for real-time movement tracking to improve workout form but may face usability and privacy challenges in camera-restricted environments. The AI personal trainer, developed with OpenCV and Flask [3], provides real-time feedback and personalized plans but is limited by camera quality and internet dependency. The fitness tracker offers customized feedback on form and reps, aiming to boost home workouts, yet it struggles with tech reliance, exercise variety, privacy, and adaptability issues [4]. In [5], the system combines OpenCV, MediaPipe, ChatterBot, and Flask for pose detection and workout plans but lacks real-time query support and motivational features. [8] The system leverages libraries such as OpenCV for computer vision tasks, TensorFlow or PyTorch for machine learning-based pose estimation, and Mediapipe for accurate pose detection, identifying key body landmarks, and providing feedback on form during exercise.[6] The system utilizes the Kinect sensor to track 20 body joints during exercises and employs machine learning algorithms to provide real-time feedback for correcting exercise performance and improving posture. [9] The system uses a deep learning model to estimate 3D human pose from images and video, leveraging a novel architecture that balances high accuracy with performance for on-device processing.[7] The study focuses on detecting and analyzing body landmarks to assess human poses accurately in various environments. The authors explore algorithms and models that can process image data to estimate posture, aiming to support health monitoring and fitness applications.

The fitness systems reviewed face challenges like dependency on camera quality and stable environments, raising privacy and usability issues. Limited adaptability to diverse exercises, reliance on specific hardware and internet, and lack of user engagement features reduce their effectiveness. Improving these aspects is crucial to making AI-based fitness solutions more reliable, accessible, and adaptable for many users. To address these challenges, this paper presents an AI-based gym trainer that leverages computer vision to provide real-time feedback on exercise form, automatically count repetitions, and analyze food composition. Our solution integrates various tools, including a BMI calculator, a food composition calculator powered by a YOLOv8 model, and customized workout plans for weight loss and weight gain. Additionally, we have included seven exercises with pre-defined standard positions and joint angles, enabling accurate rep counting and form assessment.

We developed a GUI that displays a food composition calculator, real-time pose detection for counting reps, and a BMI calculator.

- Designed a BMI calculator that takes height and weight as inputs and calculates the BMI index.
- Integrated a food composition calculator using a YOLOv8 model, optimized and embedded in the front end with JavaScript, HTML, and CSS.
- Added a section with workout plans for weight loss and weight gain.
- Incorporated seven exercises with predefined standard positions in the GUI. By defining joint angles, the system accurately counts reps. A help section with GIFs guides users on the correct exercise form.
- Included a pose accuracy progress bar that shows how close the user is to completing the current rep.

The rest of the paper is organized as follows: Section II details the implementation of our proposed solution, including its technical components and integration into the user interface. Section III presents some key results and observations from testing the system. Section IV concludes the paper with our plans for future work, highlighting areas for improvement and potential extensions to enhance user experience and effectiveness further. Finally, Section V deals with the acknowledgment.

II. IMPLEMENTATION

The system architecture is designed to integrate multiple components to track exercise repetitions, provide workout recommendations, calculate BMI, and analyze food composition. The architecture can be divided into three main sections: User Interface, Exercise Tracking and Analysis, and Food Composition Analysis, as shown in Figure 6.

A. User Interface (GUI)

The system's User Interface (GUI), as shown in Fig 3, serves as the central hub where users interact with the application's various functionalities. This interface provides seamless navigation between features, such as real-time video capturing for exercise tracking, BMI calculation, diet recommendations, and food composition analysis. The GUI displays real-time video captured through OpenCV and provides an intuitive environment for users to monitor their exercise form and repetition count. Additionally, it includes input fields where users can enter their height and weight for BMI calculation, and based on the calculated BMI, the system generates personalized diet and workout recommendations. The GUI also integrates with a web interface where users can view detailed nutritional breakdowns of food items detected by the system. This integration ensures a user-friendly experience that combines multiple functionalities in one coherent interface.

B. Real-time Video Capturing

Real-time video capturing is a critical system component, supporting exercise tracking and food composition analysis. Using OpenCV, a powerful computer vision library, the system captures live video from the user's camera. This feed enables different modules to analyze exercise movement and detect food items for nutritional calculation. The real-time aspect ensures instant feedback for tracking repetitions or analyzing food composition, allowing the system to respond dynamically to user actions.

C. Exercise Tracking

The exercise tracking subsystem is built on top of Mediapipe, a framework specialized in real-time detection of human joints, which plays a critical role in ensuring proper exercise form and accurate repetition counting. This subsystem enables precise pose estimation by detecting key joints such as shoulders, elbows, hips, and knees from the video feed, essential for real-time exercise monitoring and feedback.

1. Logic and Implementation:

- Pose Estimation and Joint Detection: Mediapipe identifies and tracks the user's key joints. This is done through a real-time video feed processed by OpenCV, where each frame is analyzed to extract the joint positions needed out of the 33 points in the media pipe, as shown in Fig 1. For example, in a shoulder press, Mediapipe identifies the positions of the shoulder, elbow, and wrist, which are crucial for evaluating the correctness of the movement.

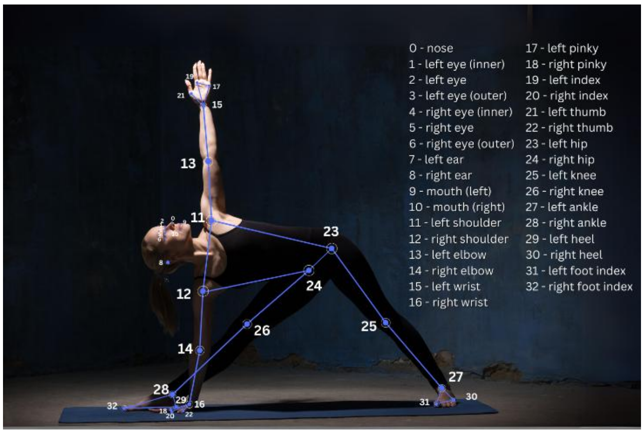


Fig 1.Mediapipe 32 key points detected

- Angle Calculation: The system calculates the angles between key joints to assess whether the user performs the exercise correctly. This is achieved using the calculate_angle() function, which takes three points ((x1,y1),(x2,y2),(x3,y3)(joints)) as inputs and computes the angle formed between them using the trigonometric equation as in (1). The formula used is:

$$Angle = (\arctan 2(y_3-y_2, x_3-x_2)-\arctan 2(y_1-y_2, x_1-x_2)) *180/\pi \quad (1)$$

- Repetition Counting Logic: The counter operates based on detected angles. For example, in lateral raises, the system monitors arm angles. When arms are fully extended (angle > 170 degrees), it registers an "up" stage. When arms return to a lower position (angle < 140 degrees) and the previous stage is "up," the counter increments, marking a complete repetition. The counter is continuously updated and displayed on the GUI. This ensures that users complete full repetitions with proper form before incrementing the count.

- Form Validation: The system checks for proper form by ensuring that certain angle thresholds are met. For instance, in a shoulder press, the system verifies that the arm angles are consistent with the correct form throughout the movement. This form validation mechanism helps users avoid incorrect posture, which could lead to injury or ineffective exercise.

The tracking subsystem supports multiple exercises, each with specific logic for form validation and repetition counting, as shown in Fig 2. For the Lateral Raise, it tracks shoulder and arm angles to count reps accurately. Alternative Dumbbell Curls monitor arm flexion to validate the curling motion, while Barbell Curls focus on elbow and wrist joint alignment. The system analyzes elbow and shoulder positions in Push-Ups to ensure complete push-up execution. Squats involve calculating hip and knee angles to confirm a full squat. The Shoulder Press monitors shoulder and arm alignment for proper presses, and Triceps Dips track elbow extension to ensure correct dip form.

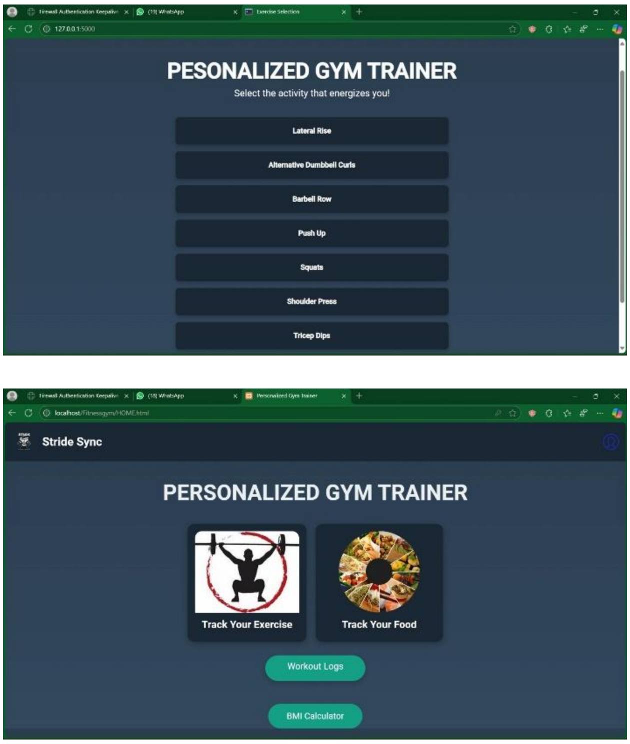


Fig 2.Exercise list and GUI demonstration

D. BMI Calculator and Workout Recommendation

The system includes a BMI (Body Mass Index) calculator, as shown in Fig 3, allowing users to input height and weight. Based on these inputs, BMI categorizes users as underweight, normal weight, overweight, or obese. This serves as the basis for personalized diet and workout recommendations. Depending on the BMI category, the system advises on suitable exercises (e.g., strength training for underweight or cardio for overweight, as seen in Fig 4). This integration of BMI calculation and tailored guidance makes the system a comprehensive fitness assistant, supporting users in achieving health goals.

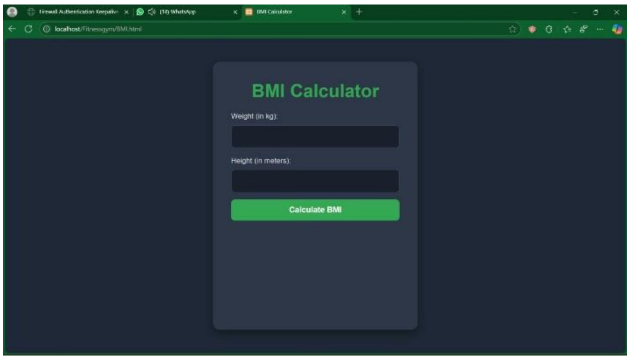


Fig 3:BMI calculator

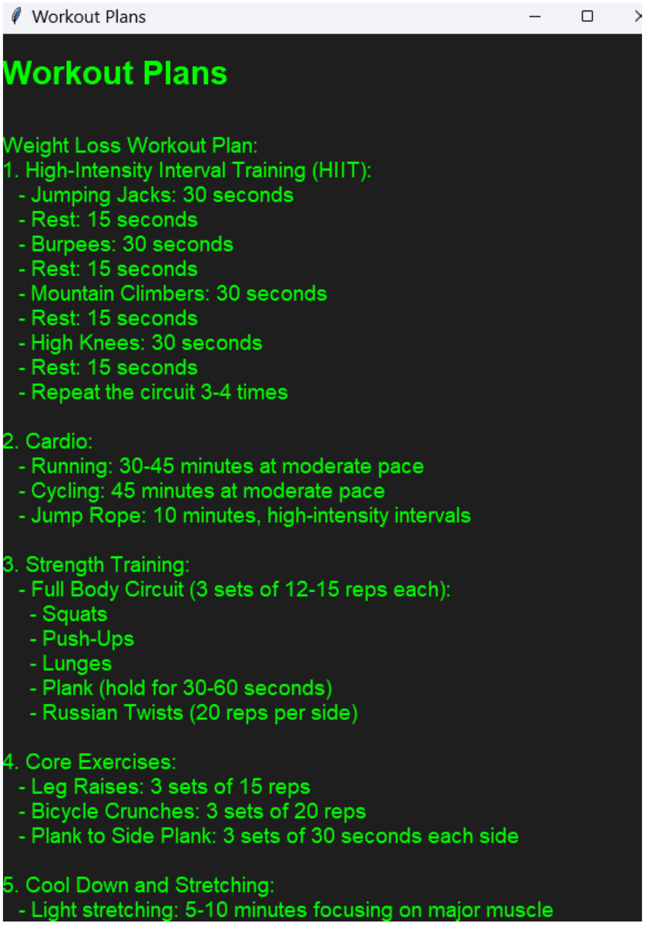


Fig 4. Workout plans

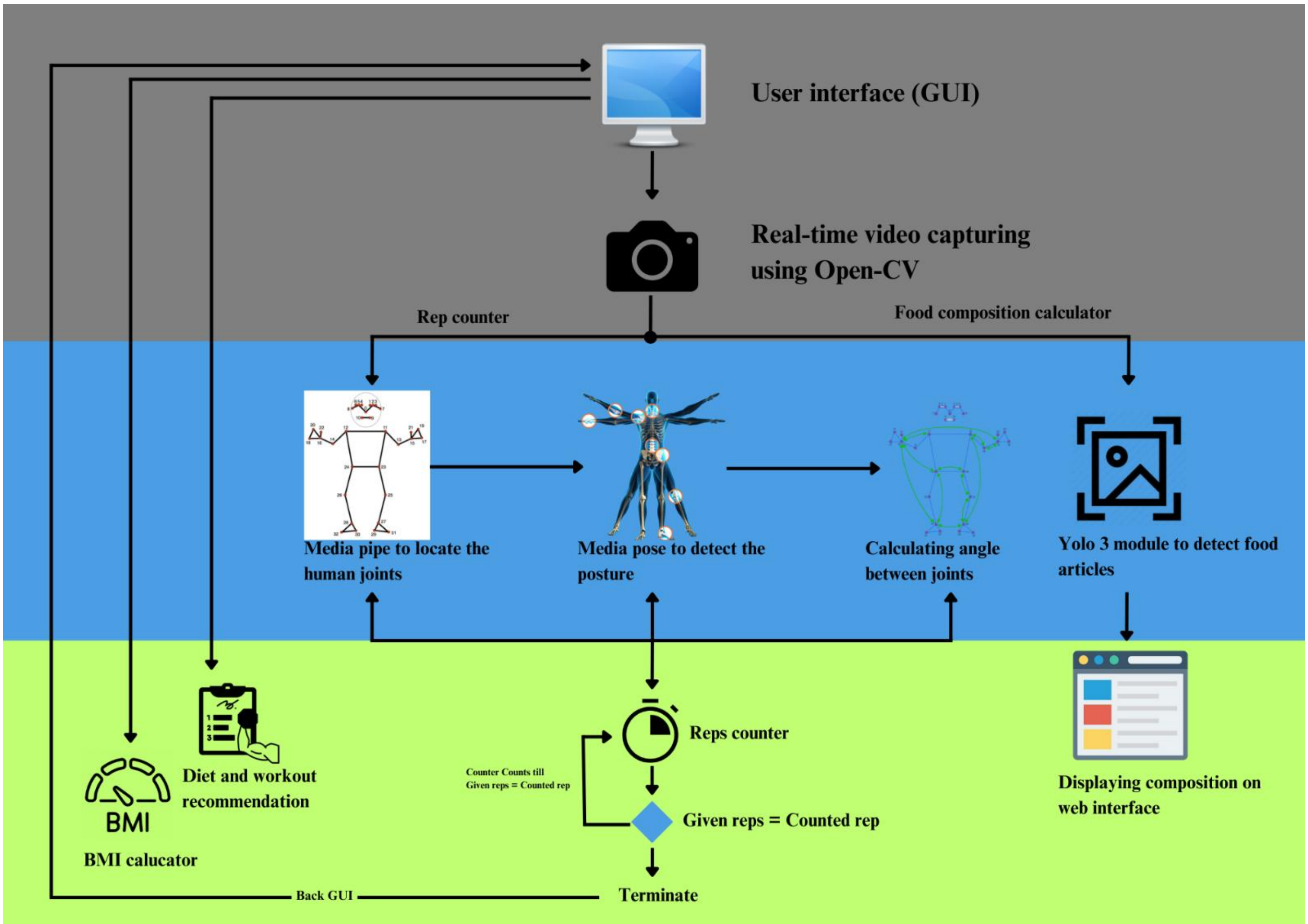


Fig 5: System architecture

E. Food Composition Analysis

The food composition calculator seamlessly integrates real-time object detection to provide accurate nutritional information for various food items. This system combines a robust web interface with an advanced object detection backend.

1. Real-Time Object Detection: The system employs a YOLOv8 (You Only Look Once version 8) model for real-time object detection, which is ideal for its accuracy and speed. YOLOv8 can identify various food items and processes each frame from the live video feed, detecting objects with high precision and marking them with bounding boxes and labels.

2. Nutritional Information Calculation: After a food item is detected, the system calculates its nutritional content based on a predefined database. For each detected item, the system provides detailed dietary information such as: • Carbohydrates (g) • Proteins (g) • Fats (g) • Lipids (g) • Cholesterol (mg) • Calories

3. Users input the weight of the detected food item, and the system scales the nutritional values proportionally to this weight. This ensures accurate dietary information based on the actual quantity of food being analyzed.

4. Web Interface and Visualization: The web interface, developed using HTML, CSS, and JavaScript, offers an intuitive user experience by displaying the detected food item's name and description, providing real-time nutritional details such as carbohydrates, proteins, fats, lipids, cholesterol, and calories, and visualizing this data through an interactive Chart.js bar chart that updates dynamically to reflect the latest information, enabling users to quickly analyze and understand the nutritional composition of the detected food item.

5. Backend Integration: The backend, powered by the Flask web framework, efficiently manages data flow between the object detection system and the web interface by handling routes for updating detected food items and retrieving the latest data. It operates concurrently in a separate thread to maintain responsiveness. It facilitates real-time communication through HTTP requests, ensuring the web interface remains current and accurately reflects the most recent detected food information.

III. RESULT

The StrideSync system was rigorously evaluated to assess its effectiveness in real-time exercise tracking, BMI calculation, and food composition analysis. The results from the implementation and testing phases highlight the system's capabilities and performance across its core functionalities.

A. *Workout window*

1. barbell curls

A curl counter logic is implemented to track the user's repetitions based on the angles formed by the arms. A "down" state is registered when the arm is fully extended (angle > 160 degrees), and an "up" state is registered when the arm is fully curled (angle < 30 degrees)—the transition from "down" to "up" increments the repetition counter.

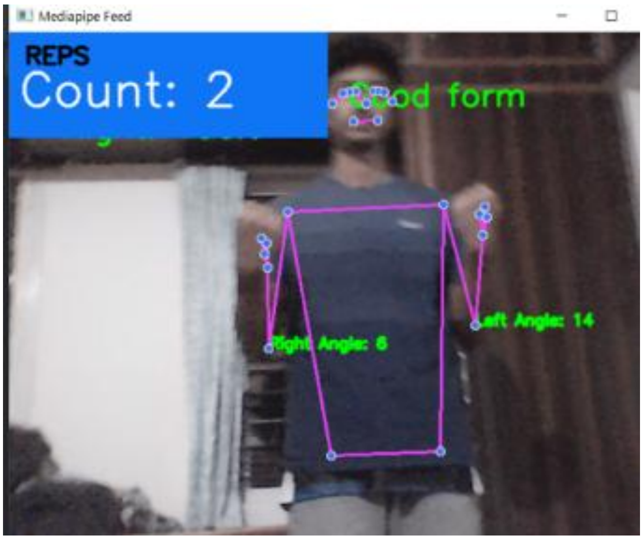


Fig 6. Correct form detection of barbell curls

The system provides real-time feedback to the user about their form. If the difference between the angles of the left and right arms exceeds a certain threshold, a "Correct your form" message is displayed, as shown in Fig 7. Otherwise, a "Good form" message is provided, as shown in Fig 6, encouraging the user to maintain the correct posture.

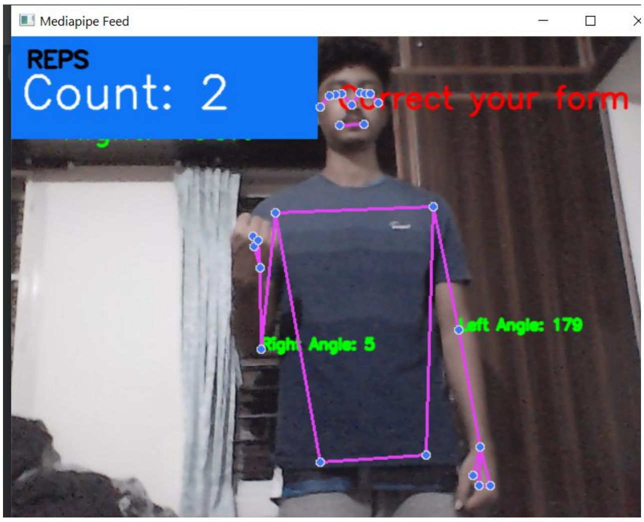


Fig 7. Feedback for Incorrect form detected in barbell curls

2. Shoulder press

The shoulder press in Fig 8 component tracks arm movements by measuring the angles at the elbow joints. It detects when the arms are in the "up" position (full extension) with an angle greater than 160 degrees and in the "down" position (lowered) with an angle less than 90 degrees. The joints considered are the shoulder, elbow, and wrist. A repetition is counted when both arms are simultaneously in the "up" position.

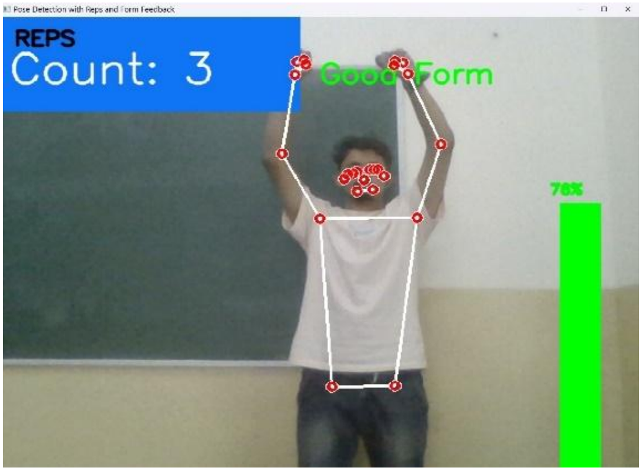


Fig 8. Shoulder press demonstration

3. Lateral raises

The lateral raises in the Fig 9 component tracks arm movements by measuring the angles at the elbow joints. It detects when the arms are in the "up" position (fully extended) with angles greater than 170 degrees and in the "down" position (lowered) with angles less than 140 degrees. The joints considered are the shoulder, elbow, and wrist. A repetition is counted when both arms are in the "down" position after being in the "up" position.

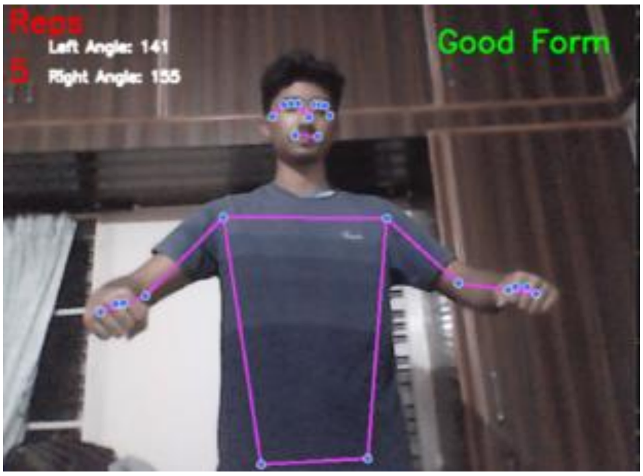


Fig 9. Lateral raises demonstration

4. Alternative dumbbell curls

In the alternate dumbbell curls in Fig 110, the component tracks arm movements by measuring the angles at the elbow joints. It detects when the arm is in the "up" position (full flexion) with an angle less than 30 degrees and in the "down" position (extended) with an angle greater than 160 degrees. The joints considered are the shoulder, elbow, and wrist. A repetition is counted for each arm when transitioning from the "down" to the "up" position. The exercise alternates between left and right arms, ensuring that each arm's movement is counted individually.

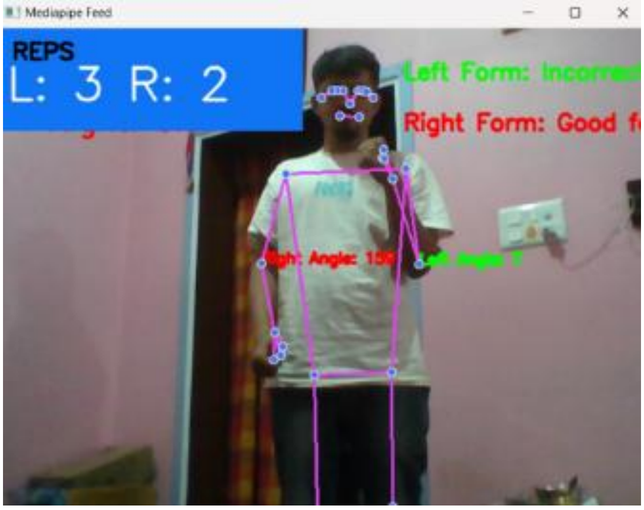


Fig 10. Alternative dumbbell curls

5. Push-ups

The push-up in Fig 11's tracking system calculates the angle of the left arm at the elbow joint to determine if the arm is in the "up" (fully extended) or "down" (bent) position. It counts a repetition when the arm transitions from the "down" to the "up" position and displays real-time feedback on the number of push-ups completed, the percentage of arm extension, and the frames per second.

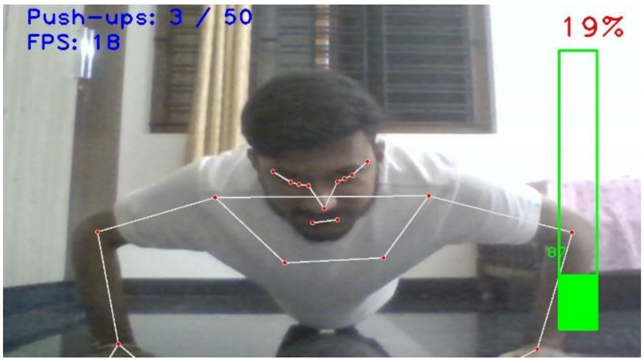


Fig 11. Push up demonstration

6. Squats

In the squat in Fig 12, the tracking system monitors leg movement by measuring the angle at the knee joint, counts a repetition when transitioning from an entirely "down" (bent) to a fully "up" (extended) position, and provides real-time feedback on the number of squats completed, the percentage of leg extension, and the frames per second.

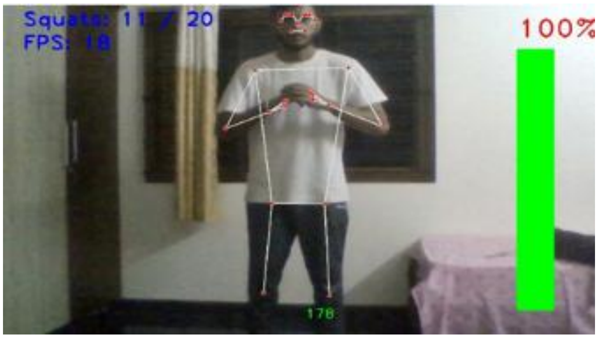


Fig 12. Squat demonstration

7. tricep dips

The tricep Fig 13 dips tracker monitors arm movements by calculating the angles at the elbows. It counts repetitions based on the transition between a fully "down" (angle less than 90 degrees) and a fully "up" (angle greater than 150 degrees) position and provides real-time feedback on the number of dips completed.

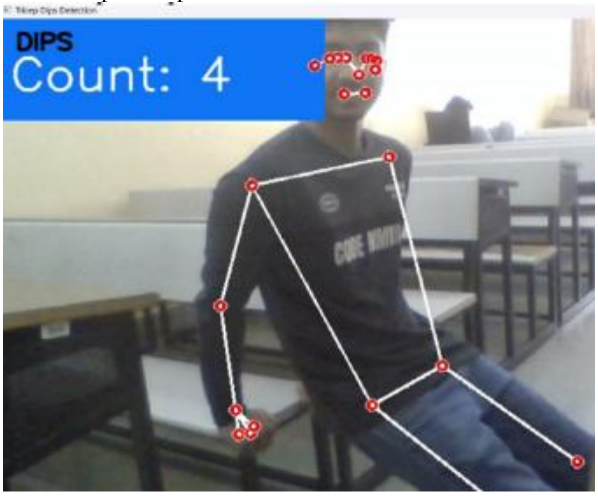
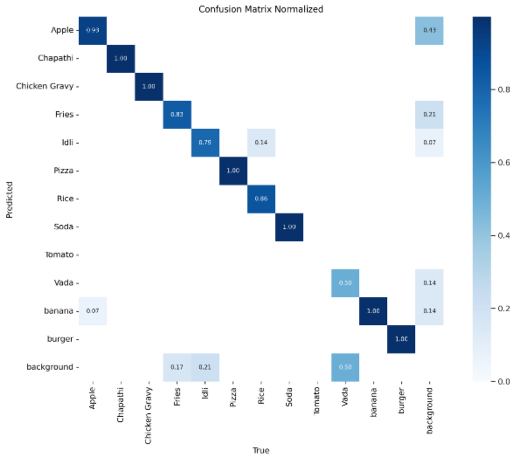


Fig 13. Tricep dips demonstration

B.Food Composition Analysis



When you open the Food Composition Calculator, the interface is divided into two sections: on the left, you see the detected food item and its nutritional breakdown, while the right side features a bar chart displaying the nutritional composition. The system detects the food item in real time, updating the display every few seconds. You can input the weight of the food, and the system recalculates the nutritional values accordingly, updating both the information and the bar chart. This provides an interactive and visual way to explore the food's nutritional content.

The normalized confusion matrix provides an insightful representation of the classification performance across various categories. High classification accuracy is observed for classes such as Chapathi, Chicken Gravy, Pizza, and Burger, each achieving a precision of 1.00. Moderate performance is noted for categories like Idli (0.79), Rice (0.86), and Fries (0.83). However, certain classes exhibit lower precision, such as Banana, which has a true positive rate of only 0.07, with notable misclassifications into categories like Vada and Background. Additionally, there are instances of significant misclassification, such as Fries being confused with Background (0.21) and Idli also misclassified into Background (0.14). These results highlight areas of strength in the classification model while also pointing out categories that require further optimization to improve overall performance.

The system can detect a variety of food items, including Apple, Banana, Chapathi, Chicken Gravy, Fries, Idli, Pizza, Rice, Soda, Tomato, Vada, and Burger. Each food item is identified using the YOLO model, which allows the system to provide real-time nutritional information based on the detected food. The list can be expanded to include more items in the futureList of Foods Supported:

1. **Enhanced Pose Detection**: Integrating high-quality cameras or additional sensors will improve pose detection accuracy, addressing the limitations of standard webcams and ensuring reliable tracking across various conditions.
2. **Advanced Algorithms**: Utilizing more sophisticated pose detection algorithms, such as 3D pose estimation and robust neural networks, will enhance landmark identification and accurate angle calculations for diverse body types and exercises, making the system more adaptable.
3. **Personalized Feedback**: Developing adaptive feedback systems that adjust based on users' performance and progress, driven by machine learning models, would provide personalized guidance, making StrideSync a more customized experience.
4. **Expanded Exercise Database**: Including a broader range of exercises and movements will enhance StrideSync's versatility and effectiveness, allowing it to evaluate and offer feedback on an extended array of workouts.
5. **Holistic Health Metrics**: Adding metrics like heart rate monitoring and calorie tracking will provide a more comprehensive view of users' fitness levels and workout efficiency, contributing to a fuller understanding of their health and performance.

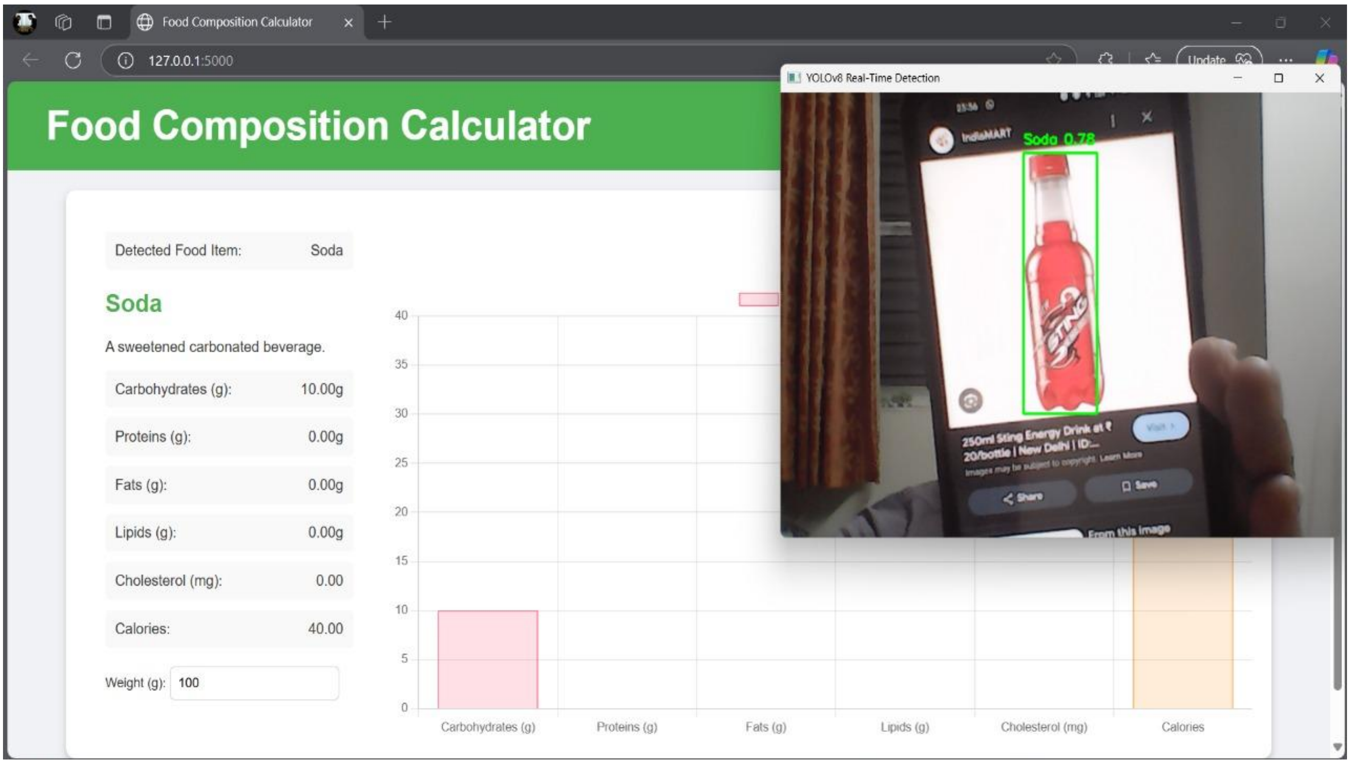


Fig 14.YOLO model integration with web interface

IV. CONCLUSION AND FUTURE WORKS

StrideSync provides a comprehensive workout tracking and form validation solution, leveraging advanced AI and computer vision techniques to deliver real-time exercise monitoring, an intuitive BMI calculator, and a detailed food composition analyzer. By offering actionable insights, StrideSync enhances users' fitness and nutritional practices, promoting overall health and wellness. Future improvements could further amplify StrideSync's capabilities:

V. ACKNOWLEDGMENT

We sincerely thank the Department of Artificial Intelligence and Machine Learning at RV College of Engineering for providing us with the necessary resources and support throughout this project. Special thanks to our guides, Dr. Somesh Nandi for their invaluable guidance, encouragement, and insightful feedback. We also thank our

friends and peers for their continuous support and constructive suggestions.

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