IRJCS: International Research Journal of Computer Science
Volume 12, Issue 08, October 2025
ISSN: 2393-9842
https://www.irjcs.com/archives
https://doi.org/10.26562/irjcs.2025.v1208.06

AI-Driven Posture Assessment and Feedback System for Remote Fitness Coaching Using MediaPipe

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Publication History
Manuscript Reference: IRJCS/RS/Vol.12/Issue08/OCCS10085
Research Article | Open Access | Double-Blind Peer Reviewed Article ID: IRJCS/RS/Vol.12/Issue08/OCCS10085
Received:23,October 2025, Revised: 09, October 2025, Accepted: 31October 2025 Published Online: 21November 2025
https://www.irjcs.com/volumes/Vol12/iss-08/06.OCCS10085.pdf
Article Citation:M.Ramya,Vasant,Srinivas,Vinayaka,Vishal(2025), AI-Driven Posture Assessment and Feedback System for Remote Fitness Coaching Using MediaPipe**,**IRJCS: International Research Journal of Computer Science, Volume 12, Issue 08 of 2025 pages 321-325 **doi:>** https://doi.org/10.26562/irjcs.2025.v1208.06
BibTeX M.Ramya@2025AI-Driven
IRJCS papers should be cited as IRJCS (International Research Journal of Computer Science, AM Publications, India 2025, ISSN 2393-9842, https://doi.org/10.26562/ijrcs.2025.v1208.06 The journal's official abbreviation is IRJCS.
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Abstract: This project is a fitness management system designed as a RESTful API backend, providing facilities such as personalized workout and diet plan, exercise guidance, and user progress tracking. It includes many modules such as user authentication, profile management and workout session management (start, end and history of the workout), exercise catalog with instructional content, diet planning and history of the exercise and the diet plan and it also provides the analytical progress reports on key fitness metrics such calories burnt, reps count and the accuracy trends after the workout. The system protects user and administrator privacy by providing secure connections and access through role-based restrictions and authentication middleware It aims to improve customers' fitness journeys by providing personalised meal planning, comprehensive exercise instructions, and educational exercise and health progress that is accessible through certified API endpoints.
Keywords: RESTful API, torsion angle computation, real-time posture monitoring, OpenCV, MediaPipe, tracking of health data, personalised workout regimens, tracking and planning diets, tracking fitness progress, backend of a fitness app.

1. INTRODUCTION

In order to increase exercise effectiveness and user safety, this project presents FormFit, a cutting-edge AI-driven virtual fitness trainer that provides real-time posture feedback during exercises. This approach is required since one of the most common issues that contemporary fitness enthusiasts have is maintaining adequate activity without the direct supervision of a trainer or coach, which frequently leads to ineffective exercises or damage to body parts. Unlike traditional fitness applications that focus mainly on repetition counting and calories tracking, FormFit project emphasizes accurate form detection and personalized correction, aiming to bridge the gap between self-guided workouts and professional trainers.

By implementing real-time AI analysis of 33 body keypoints and torsion angle calculations between the joints, the system delivers audio, video and text feedback to increase the performance and provide safe exercise habits without any injuries. This novel strategy lowers the risk of accidents and encourages users to regularly and confidently work out at home.

2. LITERATURE SURVEY

The development of web application frameworks, computer vision, and real-time intelligent fitness technology has advanced more quickly thanks to communication protocols. Previous systems maintained track of basic user data and mainly monitored exercise methods and posture instead of providing thorough feedback.In order to overcome this, more modern platforms have included pose estimation algorithms like MediaPipe BlazePose and MoveNet, which allow precise identification of human skeletal keypoints from consumer cameras. This increases the benefits that were previously exclusive to expert trainers by enabling the evaluation of form and alignment during exercises. From simple data storage to intricate designs, backend systems have developed. Their frequent use of Node.js, Express.js, and secure authentication using JWT enable data collection and real-time WebSocket communication. On the front end, responsive interfaces for user interaction and real-time feedback display are created using design tools like Tailwind CSS and frameworks like Nextjs and Reactjs.

Together with scalable databases like MongoDB, these technologies enable applications to offer both real-time guidance and progress statistics. Despite these developments, research reveals shortcomings in systems that provide precise, adaptive correction for a variety of workout kinds, particularly in unsupervised or home environments. Platforms like the one discussed in this study aim to close these gaps and provide users with useful, professional-grade exercise feedback even outside of the gym setting by using AI pose estimation, custom rule engines for posture evaluation, and modular, real-time API connection.

3. METHODOLOGY

This project combines computer vision, artificial intelligence, and contemporary web development to create a sophisticated virtual fitness trainer that provides real-time posture feedback.In order to concentrate on problems with improper workout form without supervision, user demands and fitness barriers were first examined. Using webcam video streams processed with OpenCV, sophisticated pose estimation models such as MediaPipe BlazePose and TensorFlow Js MoveNet were utilised to identify 33 body landmarks. MongoDB provides scalable data storage, while the Node.js and Express.js backend handles workout data, user authentication, and real-time communication using SocketIO. The frontend creates a responsive UI with exercise feedback and real-time position overlays using Reactjs, Nextjs, and Tailwind CSS. A rule-based system instantly provides visible and audio correction indications to improve user safety and workout efficiency by comparing joint angles to thresholds; performance optimization, cloud deployment, and integration testing guarantee a reliable, low-latency experience across devices. By combining scalable web services with AI-driven pose detection, this all-encompassing approach creates an accessible digital fitness assistant that successfully connects at-home workouts with expert coaching.

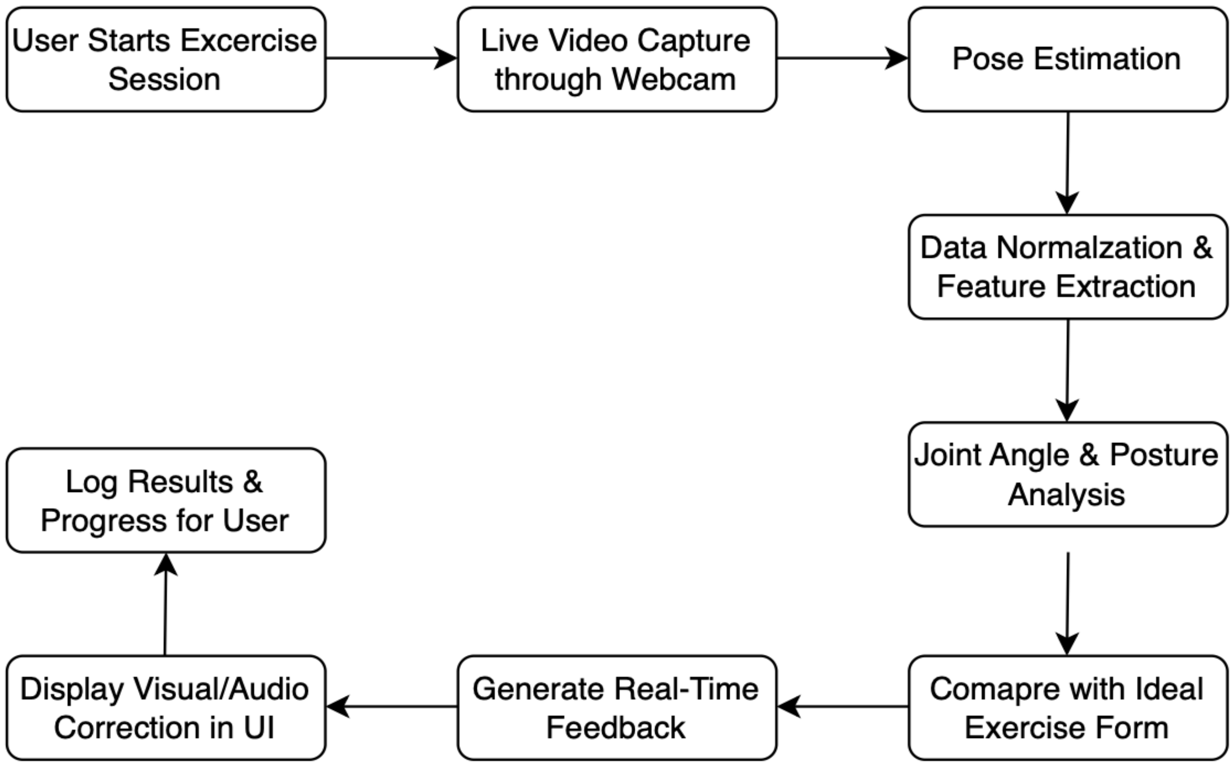

Fig.1 Workflow Diagram of Proposed Methodology

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4. SYSTEM ARCHITECTURE

4.1 User Interface (Web/Mobile Client):

This module captures live video streams from the user's device camera and displays real-time posture correction feedback interactively. It serves as the primary point of interaction, where users can start exercise sessions, view workout analytics, and receive guidance on improving their form.

4.2 Frontend (React.js, Next.js, Tailwind CSS):

The frontend manages all UI components, handles API requests to the backend, and maintains WebSocket connections for instantaneous data communication. It provides a responsive and intuitive interface that adapts seamlessly across desktops and mobile devices, ensuring smooth user experiences.

4.3 Pose Estimation Module (MediaPipe/MoveNet):

This client-side module processes each frame of the live video stream to identify 33 body keypoints essential for accurate posture analysis. The extracted skeletal data forms the basis for subsequent evaluation of exercise form and joint angles

4.4 Backend Server (Node.js, Express.js):

The backend governs core business logic which includes user authentication with JWT, session management, workout data processing, and coordinating real-time feedback. It enforces security using middleware and structures requests through clearly defined API endpoints.

4.5 Real-Time Communication (Socket.IO):

Serving as the communication bridge, Socket.IO enables low-latency bi-directional transmission of pose data and feedback signals, allowing real-time responsiveness between users and the system.

4.6 Database (MongoDB):

This module handles persistent storage of user profiles, workout and diet records, and progress analytics. It supports rapid query handling and scalability to accommodate growing datasets as user activity expands.

4.7 Feedback Engine:

Positioned within the backend, the feedback engine evaluates the pose data against predefined ideal postural models using rule-based algorithms. It generates corrective visual and audio guidance, which is then transmitted back to the user interface to encourage proper exercise technique and prevent injury risks.

5. RESULTS

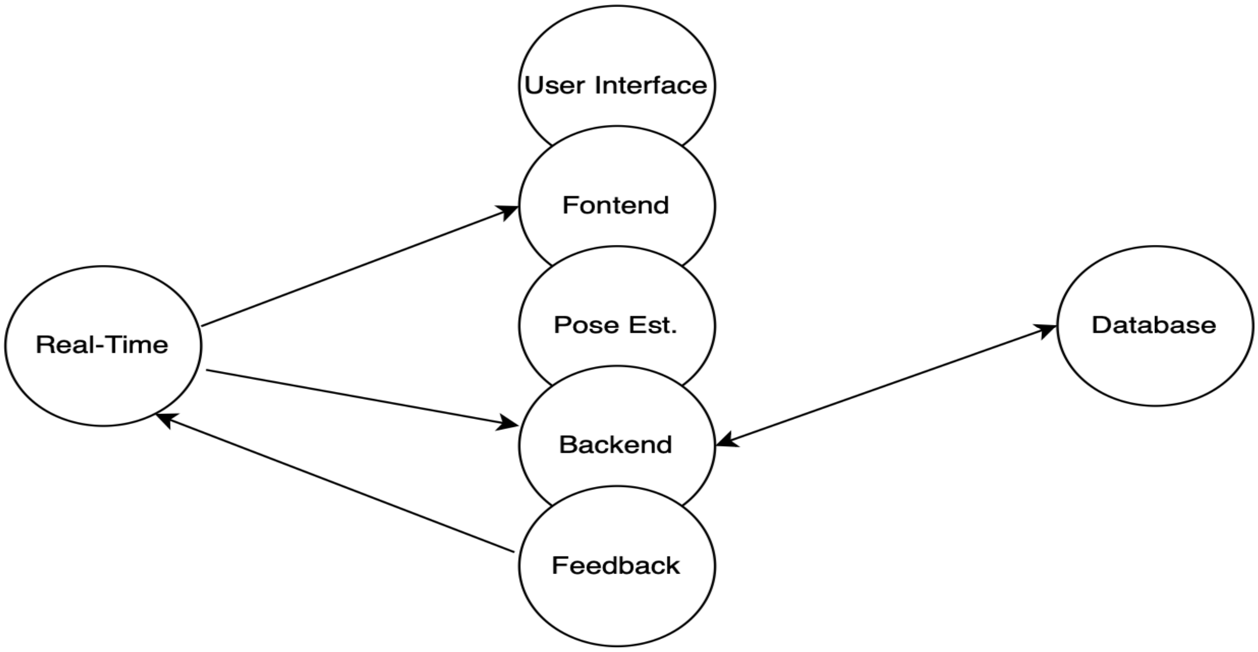

Fig. 2 System Architecture Flowchart

6. FUTURE ENHACEMENT

- Enhanced AI Models: Incorporate more sophisticated deep learning models, including 3D pose estimation and action recognition algorithms, to improve accuracy and support a wider range of exercises and complex movements.
- Mobile and Wearable Integration: Develop native mobile applications and integrate with wearable fitness devices (like smartwatches or fitness bands) to enhance real-time data collection and user engagement.
- Multi-user and Social Features: Add features for group workouts, challenges, social sharing, and community support to increase motivation and adherence.

- Expanded Exercise Library: Increase the repertoire of exercises covered, including specialized workouts such as rehabilitation, yoga, pilates, and fitness for different age groups.
- Advanced Analytics and Reporting: Provide deeper insights with AI-powered analytics, reporting on injury risks, performance trends, and personalized recommendations.

7. ADVANTAGES & DISADVANTAGES

7.1 ADVANTAGES

- Accessibility: Provides users the ability to exercise and receive professional-grade posture correction at home, eliminating the need for in-person trainers.
- Real-time Feedback: Utilizes AI and computer vision to deliver instantaneous visual and audio cues, improving workout effectiveness and reducing injury risk.
- Personalization: Customizes workout and diet plans based on individual user profiles and progress, making fitness guidance more relevant.
- Scalability: Built on modular backend architecture with RESTful APIs and WebSocket communication, allowing easy expansion and integration with other health platforms.
- Data tracking and Analytics: Tracks detailed user fitness data including workout history and diet logs, enabling comprehensive progress monitoring.

7.2 DISADVANTAGES

- Hardware Dependency: Requires users to have a webcam or camera-enabled device with suitable processing power for real-time AI pose estimation.
- Pose Estimation Limitations: Environmental conditions like poor lighting or occlusions can degrade pose detection accuracy, potentially affecting feedback quality.
- Limited Exercise Range: Current AI models may not cover all possible exercises, limiting the system's ability to evaluate certain movements or specialized workouts.
- Internet Reliance: Real-time feedback and data synchronization typically require stable internet connections, which can reduce accessibility in low-connectivity areas.
- User Motivation: Absence of human presence may impact the motivation and adherence levels in some users who benefit from personal trainer interactions.
- Privacy Concerns: Capturing and transmitting video data raises privacy and security issues that require robust encryption and compliance with data protection regulations.

CONCLUSION

The developed AI-powered virtual fitness trainer effectively combines advanced pose estimation technologies such as MediaPipe BlazePose and TensorFlow.js MoveNet with a robust modular full-stack system architecture that ensures real-time posture feedback and personalized workout assistance. The integration of a Node.js, Express.js backend with MongoDB database and WebSocket-based communication enables scalability, security, and seamless exercise session management. The frontend leverages React.js and Next.js to provide an interactive, responsive user interface that facilitates live video processing and instant corrective feedback. This system addresses the growing need for accessible fitness guidance, particularly for users exercising independently at home, and demonstrates promising accuracy in detecting and correcting exercise forms. With further enhancements, including richer exercise libraries, mobile integration, and AI-based personalization, this project is poised to expand the reach and effectiveness of digital fitness coaching, promoting safer exercise habits and better health outcomes.

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