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AI Based Body Mapping and Exercise Monitoring System

Kashvi Ranpise, Aditya Sukhadev Jadhav, Shruti Dok
Arpita Wani, Abolee Kokate
Department of Computer Engineering
Pimpri Chinchwad Polytechnic, Pune, India
kashviranpise@gmail.com, jadhavadi0030@gmail.com, shrutidok22@gmail.com
arpitawani0501@gmail.com, kokateabolee0509@gmail.com

Abstract: *This paper presents an AI-based body mapping and exercise monitoring system that performs real-time posture analysis using computer vision techniques. The system employs deep learning–based human pose estimation to detect skeletal landmarks from a live camera feed without the use of wearable sensors. Joint angles are computed from selected landmarks to evaluate body movements and identify exercise-specific postures. The proposed framework supports exercises such as squats and push-ups by analyzing critical joint angles and classifying movements into upward and downward stages using predefined thresholds. Accurate repetition counting is achieved while minimizing false detections. Additionally, the system provides real-time visual and textual feedback to guide users toward correct exercise form. The approach is marker-less, cost-effective, and hardware-independent, requiring only a standard camera. Experimental results indicate reliable real-time performance, making the system suitable for home fitness training and preliminary rehabilitation monitoring applications.*

Keywords: Human Pose Estimation, Body Mapping, Exercise Monitoring, Computer Vision, Joint Angle Analysis, Real-Time Posture Analysis

I. INTRODUCTION

Regular physical activity plays a crucial role in maintaining overall health and preventing lifestyle-related disorders. However, the increasing prevalence of sedentary habits and the lack of access to professional fitness supervision have created a need for intelligent, automated exercise monitoring solutions. Traditional fitness guidance methods often rely on human trainers or wearable sensor–based systems, which can be costly, intrusive, and inconvenient for everyday use. Recent advancements in artificial intelligence and computer vision have enabled the development of non-invasive, vision-based systems capable of analyzing human movement in real time.

Human pose estimation has emerged as a key technology for understanding body posture and motion by detecting anatomical landmarks from visual data. By mapping the human body into a skeletal representation, pose estimation techniques allow precise analysis of joint movements without requiring specialized hardware. This capability has opened new possibilities for applications such as fitness training, rehabilitation, and sports performance analysis.

In this work, an AI-based body mapping and exercise monitoring system is proposed to provide real-time posture evaluation and exercise repetition tracking using a standard camera. The system employs deep learning–based pose estimation to extract body landmarks and computes joint angles to assess exercise form. Exercises such as squats and push-ups are monitored by analyzing critical joints and classifying movement stages based on angular thresholds. Additionally, the system delivers immediate visual and textual feedback to assist users in maintaining correct posture.

The proposed approach is marker-less, cost-effective, and easy to deploy, making it suitable for home-based fitness environments. This research demonstrates the effectiveness of vision-based body mapping for intelligent exercise monitoring and establishes a foundation for future enhancements, including multi-exercise support, personalized training, and rehabilitation-oriented applications.

Ease of Use

Ease of use is a fundamental design consideration in the proposed AI-based body mapping and exercise monitoring system, as the effectiveness of fitness applications largely depends on user engagement and accessibility. The system is designed to function using a standard camera, thereby eliminating the need for wearable sensors, external devices, or complex calibration procedures. This marker-less approach significantly reduces setup time and lowers the entry barrier for users with limited technical expertise. The application offers an intuitive and visually informative interface, where the user's skeletal structure is overlaid on the live video feed. Key joint angles are displayed in real time, enabling users to understand their body posture during exercise execution. Exercise modes can be selected through simple keyboard controls, allowing seamless switching between supported activities such as squats and push-ups without restarting the system.

In addition to visual cues, the system provides immediate textual feedback to guide users toward correct movement patterns. Feedback messages such as posture corrections or successful repetition indicators allow users to self-correct in real time, minimizing the need for external supervision. The repetition counter and exercise status are clearly displayed, ensuring transparency and ease of interpretation. By prioritizing minimal interaction, real-time feedback, and hardware independence, the proposed system achieves a high level of usability. These design choices make the system suitable for diverse users, including beginners, fitness enthusiasts, and individuals seeking guided home-based exercise solutions.

II. LITERATURE SURVEY

The Evolution of Vision-Based Fitness Monitoring

The field of automated fitness monitoring has evolved significantly with advancements in computer vision and artificial intelligence. Traditionally, exercise assessment and posture correction relied on in-person supervision by professional trainers or physiotherapists, making personalized guidance expensive and geographically limited. Early digital fitness solutions primarily focused on static video tutorials and wearable sensor–based tracking systems, which required specialized hardware and often restricted natural movement. As the demand for accessible and cost-effective fitness solutions increased, research shifted toward vision-based systems capable of analyzing human movement using standard cameras. This transition marked a fundamental change from sensor-dependent tracking to marker-less body mapping, enabling real-time exercise analysis without physical constraints.

Dominance of Deep Learning in Human Pose Estimation

Recent literature highlights the widespread adoption of deep learning–based human pose estimation techniques for understanding body posture and motion. Convolutional Neural Networks (CNNs) and keypoint detection models have demonstrated high accuracy in identifying skeletal landmarks under varying conditions. These models analyze spatial relationships between joints to generate a structured representation of the human body. Research has shown that pose estimation frameworks trained on large-scale datasets can reliably detect joint coordinates in real time, forming the foundation for applications such as fitness coaching, sports analytics, and rehabilitation monitoring. The ability to extract precise joint-level information has enabled the development of exercise-specific evaluation systems based on biomechanical principles..

Interpretability and Accuracy Challenges in Vision-Based Systems

Despite their effectiveness, many deep learning–driven fitness monitoring systems face challenges related to interpretability and robustness. Complex neural networks often function as black-box models, making it difficult to explain how specific posture assessments or exercise decisions are derived. In fitness and rehabilitation contexts, the lack of transparent decision logic can reduce user trust and limit clinical applicability. Furthermore, variations in camera angle, lighting conditions, and body orientation can introduce inaccuracies in joint detection, leading to incorrect posture evaluation. These limitations highlight the need for systems that combine reliable pose estimation with interpretable, rule-based movement analysis.

Computational Constraints and Real-Time Deployment

Another significant concern identified in existing research is the computational complexity associated with advanced pose estimation models. Many state-of-the-art systems require high-performance GPUs and cloud-based infrastructure to operate efficiently, restricting their deployment in low-resource environments. This dependency poses challenges for real-time applications intended for home-based fitness training or mobile platforms. Consequently, recent studies emphasize lightweight architectures that balance accuracy and computational efficiency, enabling real-time performance on consumer-grade hardware while maintaining responsiveness and usability.

Rule-Based Exercise Analysis and Hybrid Approaches

Parallel to purely data-driven methods, earlier research explored rule-based and kinematic approaches for exercise evaluation. These systems utilize predefined joint angle thresholds and movement patterns derived from biomechanical knowledge to assess exercise correctness. Unlike end-to-end deep learning models, rule-based methods offer greater transparency and interpretability, making them suitable for posture correction and repetition counting. Recent literature suggests that hybrid systems—combining pose estimation with deterministic angle-based logic—can achieve reliable performance while ensuring clarity in decision-making. Such approaches are particularly effective for structured exercises like squats and push-ups, where joint movements follow well-defined patterns.

Bridging the Gap Between Detection and User Guidance

Beyond posture detection, several studies identify a gap between exercise recognition and actionable user guidance. While many systems successfully classify exercises or count repetitions, they often fail to provide meaningful feedback for posture correction. Effective fitness monitoring requires not only identifying movements but also guiding users toward proper form in real time. Systems that integrate visual cues, textual feedback, and repetition tracking are better positioned to enhance user engagement and exercise effectiveness. Addressing this gap is essential for developing intelligent fitness solutions that support safe, independent training.

III. METHODOLOGY

The proposed AI-based body mapping and exercise monitoring system follows a real-time computer vision pipeline designed to analyze human movement using a standard camera. The system begins by capturing live video frames, which are processed sequentially to ensure continuous monitoring. Each frame is converted into a suitable color format to enable accurate pose estimation while maintaining real-time performance.

Human body mapping is performed using a deep learning–based pose estimation model that detects key anatomical landmarks representing major joints of the human body. These landmarks are extracted as normalized two-dimensional coordinates, forming a skeletal representation of the user's posture. To improve robustness in side-view exercises, the system allows selective tracking of either the left or right body side, ensuring consistent joint detection even when only one side is clearly visible to the camera.

Once the body landmarks are obtained, joint angles are computed using geometric relationships between three relevant joints. Vector-based trigonometric calculations are applied to determine the internal angle at each target joint. For squat monitoring, the knee joint angle is calculated using hip, knee, and ankle coordinates, whereas push-up monitoring relies on elbow joint angles derived from shoulder, elbow, and wrist positions. These joint angles serve as the primary indicators for evaluating movement quality and exercise progression.

Exercise recognition is achieved through rule-based state classification using predefined angular thresholds. Movements are segmented into upward and downward stages based on joint extension and flexion patterns. A repetition is counted only when a valid transition between these stages occurs, which helps reduce false detections caused by partial or incorrect movements. This deterministic approach ensures transparency and reliability in exercise evaluation.

The system provides real-time feedback by overlaying skeletal landmarks, joint angles, repetition counts, and posture-related messages directly onto the video stream. Textual feedback informs users whether an exercise repetition is performed correctly or requires improvement, enabling immediate posture correction. User interaction is handled

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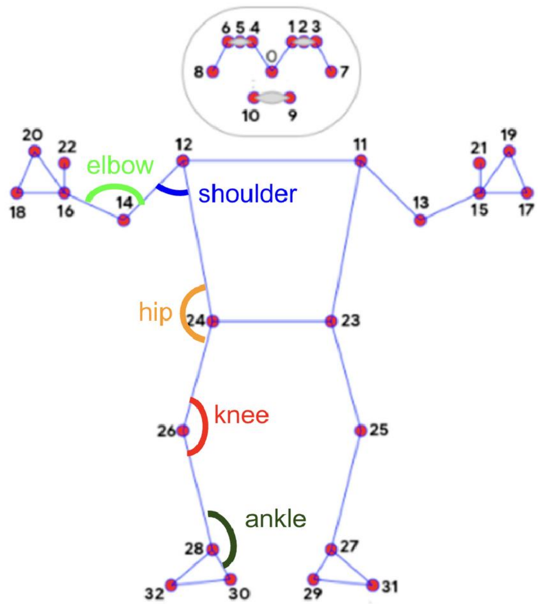
through simple keyboard inputs that allow exercise selection and counter resets without disrupting the monitoring process.



Overall, the methodology combines real-time pose estimation with interpretable, angle-based motion analysis to deliver a marker-less, low-cost, and user-friendly exercise monitoring solution. The lightweight computational design enables smooth execution on consumer-grade hardware, making the system suitable for home fitness and self-guided training environments.

IV. CONCLUSION

This work presented an **AI-based body mapping and exercise monitoring system** for real-time posture analysis using computer vision. The system employs human pose estimation and joint angle analysis to monitor exercises such as squats and push-ups without requiring wearable sensors. Rule-based movement classification enables accurate repetition counting and posture evaluation while maintaining interpretability. Real-time visual and textual feedback assists users in correcting exercise form. The marker-less and lightweight design allows deployment on consumer-grade hardware, making the system suitable for home fitness and self-guided training applications.

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