

AI FITNESS TRAINER: A COMPREHENSIVE REVIEW OF HUMAN POSE ESTIMATION AND INTELLIGENT MOBILE EXERCISE MONITORING SYSTEMS

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ABSTRACT

The rapid growth of mobile fitness applications has increased the demand for intelligent systems capable of providing real-time exercise guidance without professional supervision. Recent advances in Artificial Intelligence (AI), Computer Vision (CV), and Human Pose Estimation (HPE) have enabled the development of camera-based fitness solutions that can automatically detect body posture, analyze movements, count exercise repetitions, and provide corrective feedback. This review paper presents a comprehensive analysis of existing research on AI-based fitness trainer systems, focusing on human pose estimation techniques, pose detection models, joint angle calculation methods, exercise recognition, repetition counting, and posture evaluation approaches. The review also examines the role of mobile development frameworks and cloud technologies in supporting intelligent fitness applications. Furthermore, the applications, challenges, and future research directions of AI-assisted fitness systems are discussed. The reviewed literature indicates that lightweight pose estimation models combined with mobile computing have significantly improved the accessibility, efficiency, and practicality of sensor-free fitness training, while personalized feedback, adaptive learning, and robust real-time performance remain important areas for future research.

KEYWORDS: AI Fitness Trainer, Human Pose Estimation, Computer Vision, Deep Learning, Exercise Recognition, Pose Detection, Flutter, Google ML Kit, Firebase.

1. INTRODUCTION

The rapid advancement of Artificial Intelligence (AI), Computer Vision (CV), and Deep Learning (DL) has significantly transformed the healthcare and fitness industries. Traditionally, individuals relied on professional trainers, physiotherapists, or sports coaches to learn and perform exercises correctly. However, the increasing demand for home-based fitness solutions, coupled with the widespread availability of smartphones and affordable computing devices, has accelerated the development of intelligent fitness applications. Modern fitness systems have evolved from simple workout timers and instructional videos to intelligent platforms capable of monitoring body movements, evaluating exercise performance, and providing personalized feedback in real time.

Fitness automation refers to the use of intelligent technologies to automate exercise monitoring, posture assessment, repetition counting, and performance evaluation with minimal human intervention. Recent developments in computer vision have enabled camera-based systems to estimate human body posture without requiring wearable sensors or specialized equipment. Deep learning-based pose estimation models such as OpenPose, PoseNet, BlazePose, and MoveNet have demonstrated remarkable performance in detecting human body keypoints from images and videos, making automated fitness coaching more practical and accessible.

The COVID-19 pandemic further accelerated the adoption of virtual fitness platforms and home workout applications. As users increasingly perform exercises without direct supervision, there is a growing demand for systems that can automatically assess exercise form, detect incorrect postures, and provide immediate corrective guidance. Consequently, Smart Pose Trainer systems have emerged as an important research area that integrates AI, machine learning, and human pose estimation to deliver intelligent, real-time fitness assistance.

1.1 Need for AI-Based Pose Correction

Performing exercises with improper body posture can significantly reduce workout effectiveness and increase the risk of muscle strain, joint injuries, and long-term musculoskeletal disorders. Conventional fitness applications primarily provide prerecorded instructional videos or textual exercise descriptions but lack the capability to observe user

movements and verify whether exercises are performed correctly. As a result, users exercising independently often receive no guidance regarding incorrect body alignment or incomplete range of motion.

Artificial Intelligence addresses these limitations by enabling automatic analysis of human movement using computer vision algorithms. AI-based pose correction systems continuously capture body movements through cameras, estimate anatomical keypoints, calculate joint angles, and compare the observed posture with predefined or learned reference poses. When deviations from the ideal posture are detected, the system generates corrective feedback in the form of visual indicators, voice instructions, or textual suggestions.

Such intelligent systems eliminate the dependency on continuous human supervision while improving exercise safety, training accuracy, and user engagement. Furthermore, AI-driven pose correction is increasingly being adopted in physiotherapy, sports performance analysis, yoga training, rehabilitation, elderly care, and occupational ergonomics. The integration of deep learning and real-time pose estimation has therefore become a critical component in the development of modern intelligent fitness solutions.

1.2 Applications of Smart Pose Trainer

The application of Smart Pose Trainer systems extends far beyond conventional fitness coaching. In fitness and gym training, these systems assist users in maintaining correct exercise posture, automatically counting repetitions, and tracking workout progress. In yoga, intelligent pose analysis helps practitioners achieve accurate body alignment while reducing the likelihood of injuries caused by improper stretching. Healthcare and physiotherapy have also benefited significantly from AI-assisted pose analysis. Rehabilitation exercises require patients to perform movements with high precision, and Smart Pose Trainers can continuously monitor patient progress while providing corrective guidance remotely. In sports science, coaches utilize pose estimation technologies to analyze athlete performance, optimize movement techniques, and reduce injury risks through biomechanical assessment.

Additional applications include dance training, martial arts instruction, ergonomic posture monitoring in workplaces, elderly fall detection, virtual reality fitness environments, human-computer interaction, and motion analysis for gaming and animation. The versatility of Human Pose Estimation has therefore expanded Smart Pose Trainers into multiple interdisciplinary domains involving healthcare, education, entertainment, and sports technology.

2. Literature Review

Recent advances in Artificial Intelligence (AI), Computer Vision (CV), and Deep Learning (DL) have significantly improved the development of intelligent mobile fitness applications capable of monitoring human movements and providing real-time posture correction. Human Pose Estimation (HPE) has become the fundamental technology behind AI Fitness Trainer systems by enabling accurate detection of body landmarks from camera images. Early deep learning models such as DeepPose (Toshev and Szegedy, 2014) introduced convolutional neural networks for estimating body joint positions, while the Stacked Hourglass Network (Newell et al., 2016) further improved estimation accuracy through multi-scale feature learning.

The development of OpenPose by Cao et al. (2017) represented a major advancement in real-time human pose estimation by introducing Part Affinity Fields for accurate multi-person pose detection. Although OpenPose achieved high accuracy, its computational complexity limited deployment on mobile devices. To address this limitation, Google's MediaPipe framework (Lugaresi et al., 2019) and BlazePose (Bazarevsky et al., 2020) introduced lightweight pose estimation models capable of detecting 33 body landmarks directly on smartphones. Similarly, TensorFlow's MoveNet provides efficient real-time pose detection with low latency, making mobile AI fitness applications more practical.

Beyond pose detection, recent studies have focused on intelligent exercise analysis. Liao et al. (2020) demonstrated the use of deep learning for rehabilitation exercise assessment by analyzing body movements and comparing them with reference exercises. Chen et al. (2020) proposed a mobile-based squat assessment system that computes joint angles from detected landmarks to evaluate posture and provide corrective feedback. These studies highlight the importance of joint angle calculation, posture evaluation, and repetition counting in developing reliable AI-assisted fitness systems.

Modern AI Fitness Trainer applications integrate pose estimation with cross-platform mobile technologies to provide complete workout monitoring solutions. Google ML Kit simplifies on-device pose detection by providing real-time access to body landmarks, while Flutter enables efficient cross-platform mobile application development using a single codebase. Firebase services support user authentication, workout history, cloud synchronization, analytics, and personalized progress tracking. Open-source AI Fitness Trainer implementations demonstrate that combining pose estimation, joint angle calculation, repetition counting, and rule-based posture evaluation can effectively deliver affordable and sensor-free mobile fitness solutions. However, most existing systems still rely on fixed

threshold values and predefined posture rules, limiting their adaptability to different users and exercise variations. Future research should therefore focus on intelligent posture classification, adaptive feedback generation, personalized exercise coaching, and explainable AI-based fitness assistance.

3. Applications of Smart Pose Trainer

Smart Pose Trainer systems have gained significant importance in various domains, including fitness, healthcare, sports, rehabilitation, and elderly care. These systems utilize Artificial Intelligence (AI), Computer Vision (CV), and Human Pose Estimation (HPE) to analyze body movements, detect posture, count exercise repetitions, and provide real-time corrective feedback. In fitness and yoga, they help users maintain proper body alignment and reduce the risk of injuries. In physiotherapy and rehabilitation, they support remote patient monitoring and recovery assessment. Additionally, Smart Pose Trainers are used in sports performance analysis, fall detection, ergonomic posture monitoring, and virtual coaching, making intelligent and personalized training more accessible and effective.

4. Challenges

Despite significant advancements in Artificial Intelligence (AI) and Human Pose Estimation (HPE), Smart Pose Trainer systems continue to face several technical challenges. The accuracy of pose estimation is often affected by poor lighting conditions, body occlusions, complex backgrounds, and varying camera angles. Differences in users' body shapes, clothing, and movement styles also influence posture detection and feedback accuracy. High-accuracy models may require substantial computational resources, limiting their deployment on low-end mobile devices. Furthermore, ensuring real-time performance, user privacy, secure data handling, and personalized feedback remains a major challenge. Addressing these limitations is essential for developing robust, reliable, and widely accessible Smart Pose Trainer systems.

5. CONCLUSION

Artificial Intelligence, Computer Vision, and Human Pose Estimation have significantly transformed the development of intelligent mobile fitness applications. This review examined the evolution of AI Fitness Trainer systems, covering pose estimation models, joint angle calculation methods, exercise recognition, repetition counting, and real-time posture correction techniques. Recent frameworks such as MediaPipe, BlazePose, MoveNet, and Google ML Kit have enabled accurate and efficient on-device pose estimation, making

smartphone-based fitness monitoring practical without requiring wearable sensors or specialized equipment.

The reviewed literature indicates that integrating pose estimation with mobile application frameworks such as Flutter and cloud platforms like Firebase enables the development of scalable, cross-platform fitness applications capable of personalized workout monitoring and analytics. Although existing systems provide reliable posture assessment and exercise guidance, challenges related to lighting conditions, body occlusions, computational efficiency, user diversity, and adaptive feedback remain significant. Future research should focus on developing intelligent AI Fitness Trainer systems using personalized learning, transformer-based pose estimation, multimodal sensing, and explainable AI to improve accuracy, user experience, and accessibility. Such advancements will enable the next generation of affordable, intelligent, and real-time mobile fitness assistants suitable for healthcare, rehabilitation, and home-based exercise environments.

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