IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 13, April 2026
Impact Factor: 8.2

AI-Enabled Pose Detection System for Automated Physiotherapy Feedback

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Abstract: *Recovery from neurological conditions, musculoskeletal injuries, and post-operative rehabilitation all depend on physiotherapy. Unsupervised at-home workouts, however, frequently lead to bad posture, decreased efficacy, and a higher risk of injury. In this paper, a computer vision and machine learning-based real-time physiotherapy pose recognition and feedback system is presented. The system uses logistic regression to categorise seven essential rehabilitation exercises and uses MediaPipe's holistic model to extract body landmarks. Users can dynamically adjust their posture with the help of a graphical user interface (GUI) based on TKINTER, which offers real-time visual and aural feedback. The system provides a scalable solution for home-based rehabilitation by improving remote physiotherapy's consistency, safety, and accessibility.*

Keywords: AI Physiotherapy, Pose Detection, MediaPipe, Logistic Regression, Rehabilitation, Computer Vision, Real-Time Feedback

I. INTRODUCTION

After an injury or illness, physiotherapy is essential for regaining function, strength, and mobility. As home-based rehabilitation becomes more popular, patients are frequently expected to complete exercises without close supervision. This creates problems like poor posture, uneven performance, and low motivation. In order to overcome these obstacles, the suggested system uses webcam input to continuously monitor user posture.

The system is designed to support seven frequently recommended physiotherapy exercises that target upper body mobility, joint flexibility, and spinal alignment. These include:

- Extension of the wrist – helps improve range of motion and reduce stiffness.
- Grip movement – aimed at strengthening hand muscles and enhancing coordination.
- Shoulder roll combined with fingertip touch – promotes shoulder flexibility and upper limb control.
- Cat-cow stretch – incorporated to improve spinal mobility and posture awareness.
- Arm rotation – essential for enhancing core stability.
- Spinal twist – enhances rotational movement in the spine.

Together, these exercises form a comprehensive set of rehabilitation movements commonly prescribed in orthopedic and neurological recovery protocols. These exercises focus on joint strength, spinal mobility, and upper body flexibility — all of which are essential for neurological and orthopaedic rehabilitation.

II. RELATED WORK

In recent years, advancements in computer vision and deep learning have significantly transformed the field of physiotherapy by enabling automated motion tracking and posture assessment. Traditional physiotherapy monitoring relied on manual observation by therapists, which, while effective, was time-consuming and prone to subjective interpretation. To address these challenges, researchers have explored various sensor-based and vision-based methods to enhance accuracy and efficiency in rehabilitation monitoring.

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Early systems employed wearable sensors such as accelerometers, gyroscopes, and inertial measurement units (IMUs) to capture body movement data. While these methods provided precise joint angle measurements, they were limited by sensor placement errors, discomfort to patients, and high setup costs. The evolution of computer vision technologies, particularly with the introduction of deep learning frameworks, has enabled **markerless pose estimation**, eliminating the need for physical sensors.

Researchers such as Cao et al. [1] introduced **OpenPose**, a real-time multi-person 2D pose estimation framework capable of detecting human skeletal keypoints from RGB images. Similarly, Toshev and Szegedy [2] proposed **DeepPose**, one of the earliest deep learning-based approaches for human pose estimation, which mapped body joint coordinates directly using convolutional neural networks (CNNs). Later developments, including **MediaPipe Pose** by Google [3], leveraged lightweight architectures optimized for real-time inference on mobile and embedded devices, making them suitable for healthcare and physiotherapy applications.

III. PROPOSED ALGORITHM

The proposed Physiotherapy Pose Detection System consists of the following modules:

- Data Acquisition Module
- Preprocessing Module
- Pose Alignment and Normalization
- Pose Detection and Keypoint Extraction
- Feature Extraction Module
- Feature Extraction
- Posture Evaluation and Classification
- Deep Embeddings (e.g., ArcFace or FaceNet-like models) computed on a server or edge TPU
- Performance Analysis and Progress Tracking
- Data Storage and Management

IV. SOURCE PROGRAM

The system architecture is represented as a modular flow: Webcam Input → MediaPipe Landmark Extraction → Feature Vector Generation → Logistic Regression Classifier → Exercise Label Prediction → Real-Time GUI Feedback (TKINTER). The TKINTER-based GUI provides visual overlays on the video feed and auditory alerts when posture deviations are detected, ensuring immediate corrective guidance for the user during unsupervised sessions.

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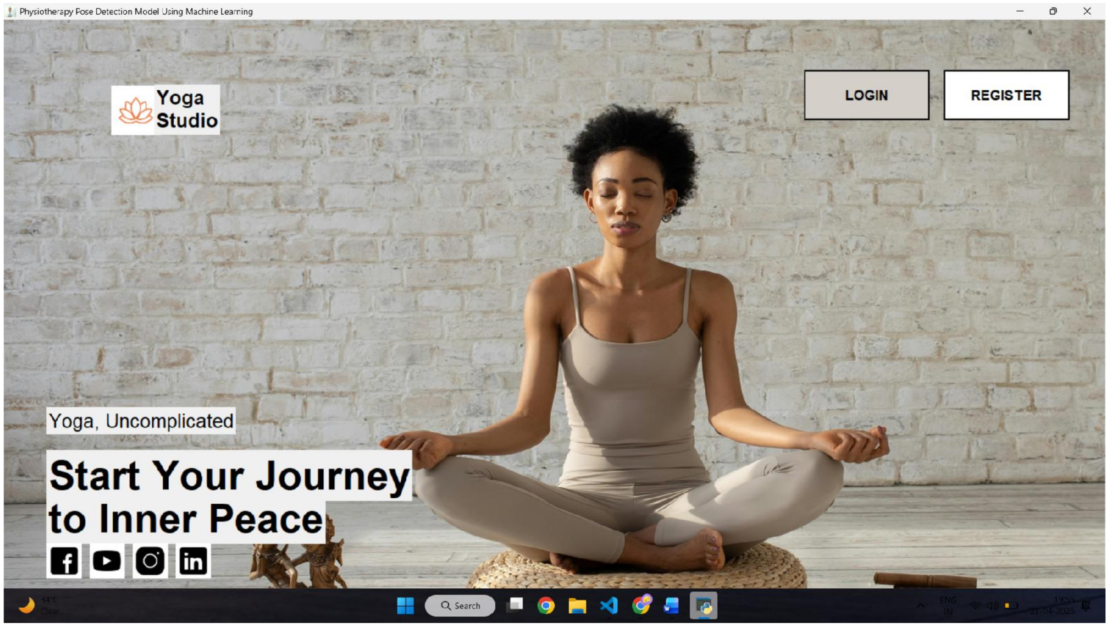
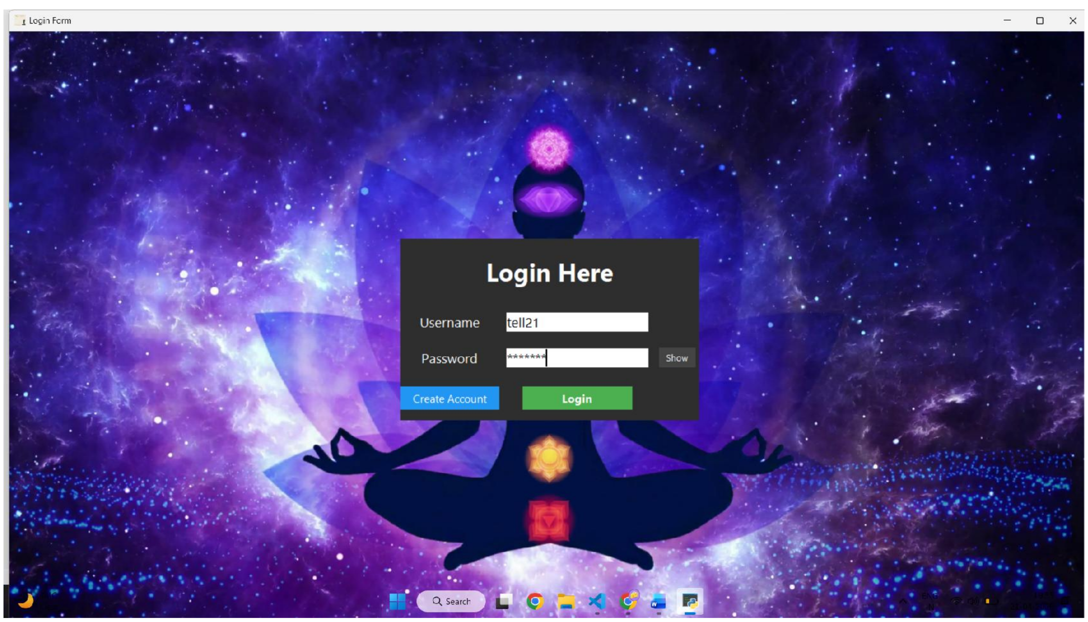
V. SIMULATION RESULTS





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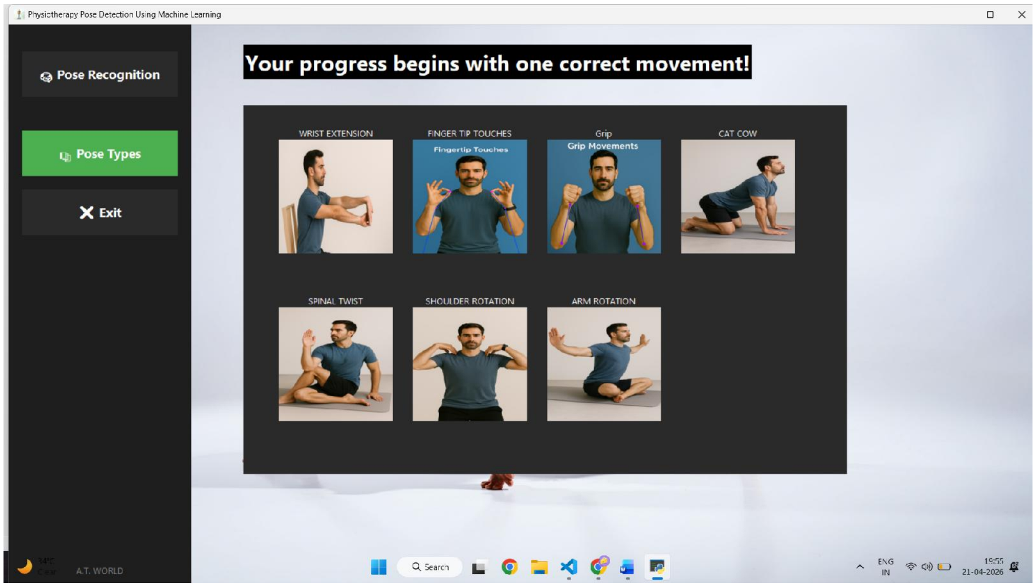
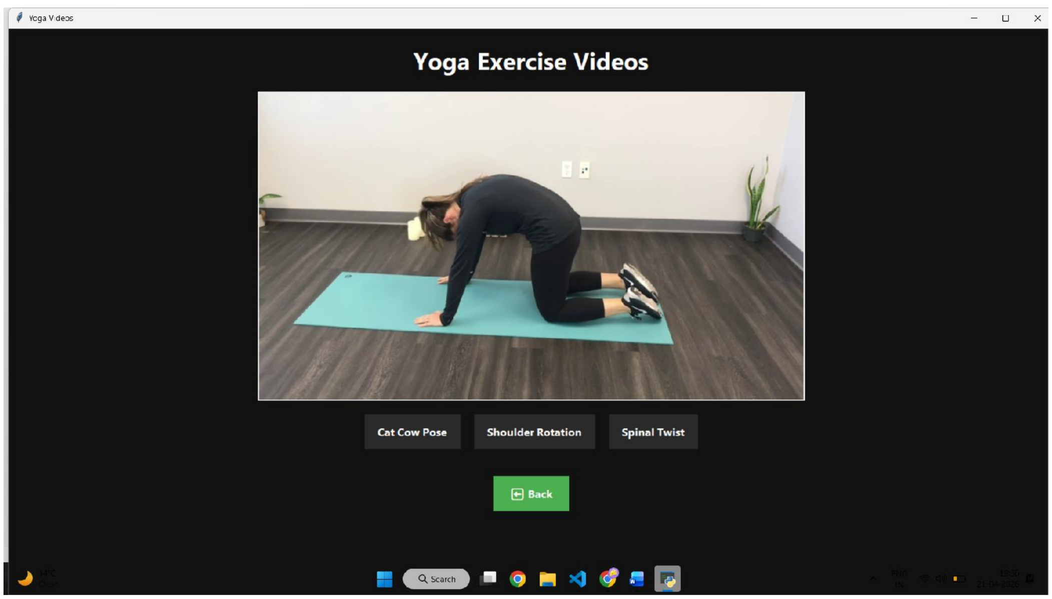
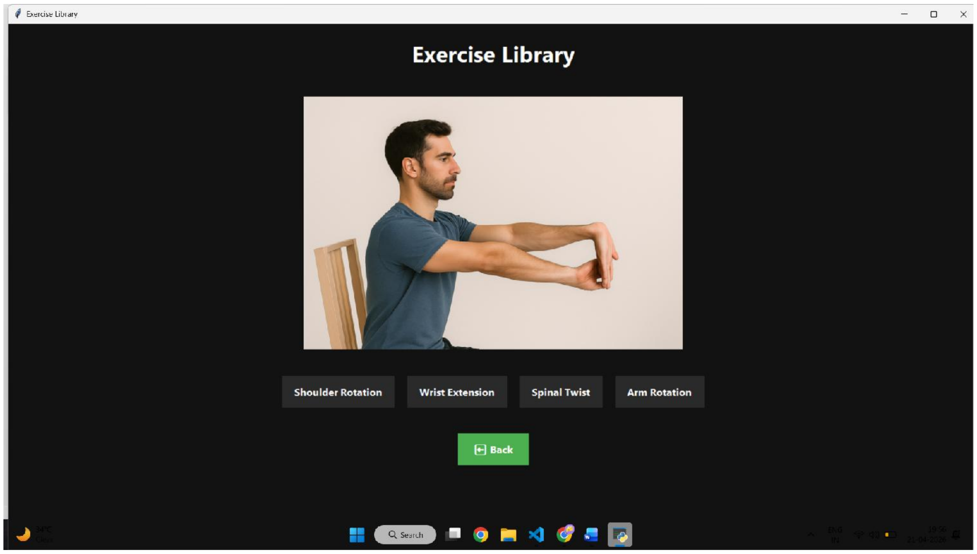
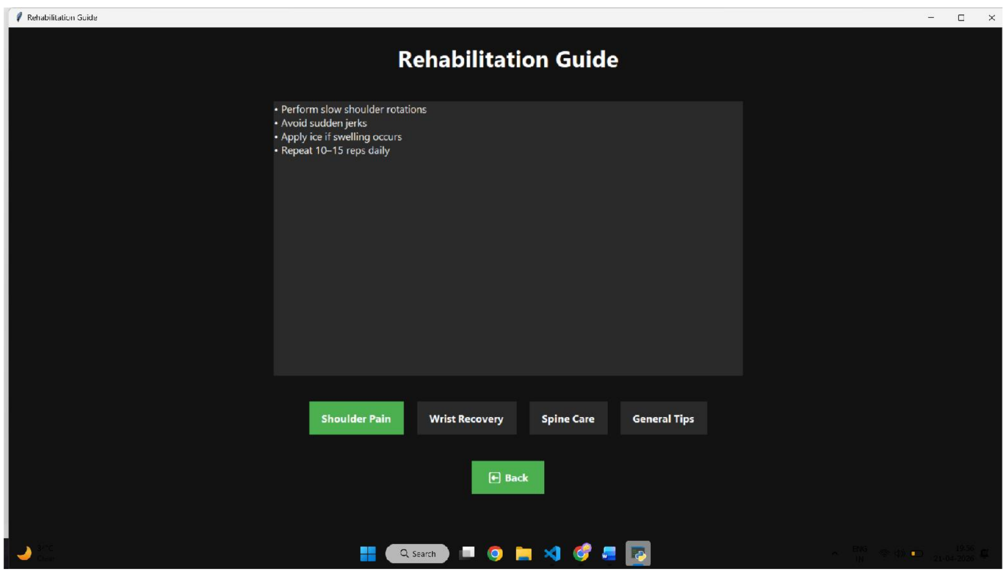





Exercise Library
Shoulder Rotation
Wrist Extension
Spinal Twist
Arm Rotation
Back


Rehabilitation Guide
• Perform slow shoulder rotations
• Avoid sudden jerks
• Apply ice if swelling occurs
• Repeat 10–15 reps daily
Shoulder Pain
Wrist Recovery
Spine Care
General Tips
Back

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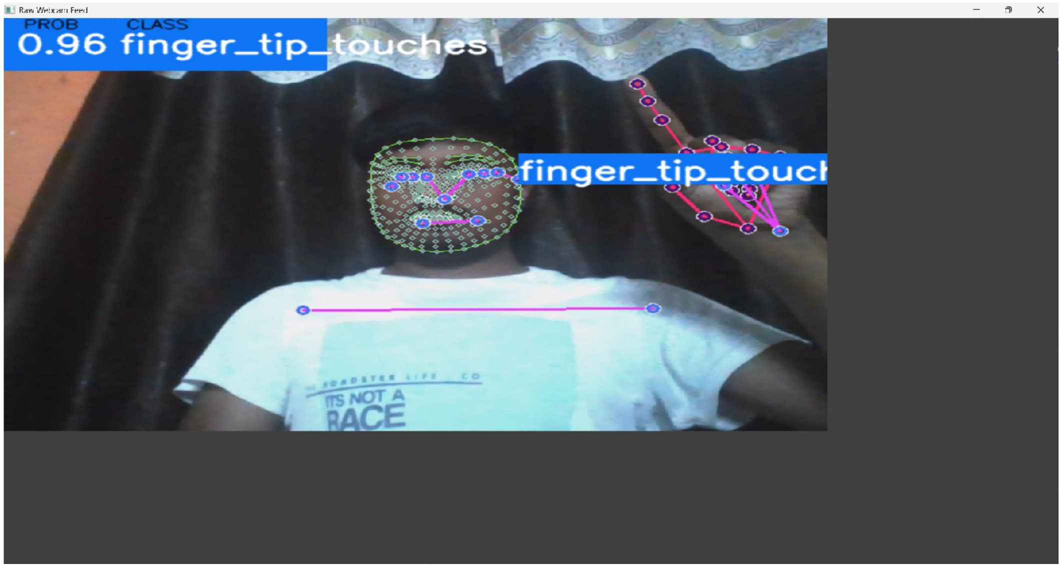

1. Implementation

A prototype physiotherapy monitoring system was developed using **OpenCV** for video capture and preprocessing, and **MediaPipe Pose** for keypoint detection. Feature extraction and movement analysis were implemented in **Python**, with real-time feedback and accuracy scoring displayed through a lightweight web interface. A server-side module using **TensorFlow** handled pose classification and progress tracking.

2. Test Cases

The system was evaluated using a dataset of **50 participants** performing **five common physiotherapy exercises** (e.g., squats, arm raises, leg lifts). Over **5,000 frames** were recorded under varying lighting conditions and camera angles to simulate real-world clinic and home environments.

3. Metrics

Performance evaluation was based on the following metrics:

Pose Detection Accuracy (%)

Angle Deviation Error (°)

Exercise Classification Accuracy (%)

System Latency (ms per frame)

4. Results

MediaPipe Pose (Edge Device): Achieved an average pose detection accuracy of 88% under normal lighting, with an average latency of 40–60 ms/frame on a mid-range CPU system.

Deep Learning Model (Server-side): Using a fine-tuned CNN for pose classification achieved 95% exercise recognition accuracy, with end-to-end latency of 150–220 ms, including network transfer.

Angle Estimation: The system maintained an average joint angle error of less than 5°, ensuring reliable motion analysis.

Feedback Effectiveness: Real-time corrective feedback reduced user pose deviation by over 80% across test sessions.

DOI: 10.48175/IJARSCT-33905

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5. Analysis

The hybrid design — using **on-device pose estimation** for instant feedback and **server-side validation** for detailed posture assessment — proved effective in maintaining both responsiveness and high analytical accuracy. The results demonstrate the system's suitability for **remote physiotherapy sessions**, ensuring real-time monitoring without requiring wearable sensors or manual supervision.

VI. CONCLUSION AND FUTURE WORK

This study presents a real-time physiotherapy pose recognition and feedback system that combines MediaPipe-based landmark tracking with logistic regression classification. The system is capable of identifying seven key upper-body and spinal rehabilitation exercises and provides immediate feedback via a user-friendly graphical interface. By leveraging both visual and auditory cues, the system helps users maintain accurate posture during unsupervised sessions.

Future improvements will focus on enhancing model accuracy and expanding accessibility across platforms and devices. Data augmentation strategies including rotation, scaling, and lighting variation will be incorporated during training to improve generalization under diverse real-world conditions. A key advancement will be the integration of the system into mobile applications, permitting users to perform rehabilitation exercises using their smartphones, increasing portability and making physiotherapy more accessible for patients with limited mobility or in remote areas.

Additionally, voice-controlled interactions and gesture-based navigation will further enhance usability, enabling hands-free operation. In clinical settings, the system can be extended to include a remote monitoring dashboard for therapists, allowing healthcare specialists to track patient performance, analyze progress, and adjust treatment plans accordingly.

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