Yoga Pose Detection and Correction Application using AI & ML

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Abstract—Yoga is a traditional Indian way of keeping the mind and body fit, through physical postures (asanas), voluntarily regulated breathing (pranayama), meditation, and relaxation techniques. The recent pandemic has seen a huge surge in numbers of yoga practitioners, many practicing without proper guidance.This paper presents a novel application for yoga pose detection and correction leveraging artificial intelligence (AI) and machine learning (ML) techniques. As the popularity of yoga grows, the need for effective instructional tools to ensure correct postures has become paramount. Our application employs computer vision algorithms to analyze users' body positions in real-time, providing instant feedback on alignment and pose accuracy. By utilizing deep learning models trained on a diverse dataset of yoga poses, the system identifies key landmarks and assesses deviations from optimal alignment. We implement a user-friendly interface that offers personalized corrections and suggests modifications to enhance practice. The effectiveness of the application is evaluated through user studies, demonstrating significant improvements in pose accuracy and user engagement. This work contributes to the intersection of technology and wellness, promoting safe and effective yoga practices through innovative AI solutions. Future research directions include expanding the dataset for enhanced model robustness and integrating additional wellness metrics for a holistic user experience.

Index Terms—Artificial intelligence, deep learning, machine learning techniques, pose estimation techniques, skeleton and yoga

I. INTRODUCTION

In recent years, the practice of yoga has gained significant traction worldwide, not only as a form of physical exercise but also as a holistic approach to mental well-being. With its roots in ancient philosophy, yoga emphasizes alignment, balance, and mindfulness, making proper technique essential to maximize benefits and prevent injury. However, in traditional settings, personal feedback on postures often depends on instructors' availability and expertise, leading to variability in practice quality.

The advent of artificial intelligence (AI) and machine learning (ML) offers promising solutions to this challenge. By leveraging computer vision and real-time data analysis, AI-powered applications can facilitate accurate detection and correction of yoga poses. This not only democratizes access to quality instruction but also enhances the learning experience for practitioners of all levels.

This paper presents an innovative application that integrates AI and ML technologies to analyze users' yoga postures through video input. By employing advanced algorithms, our system detects deviations from ideal postures and provides personalized feedback, thus fostering a deeper understanding of alignment and technique. We discuss the architecture of the application, the methodologies employed for pose detection and correction, and the implications for enhancing yoga practice in various settings. Through rigorous evaluation, we demonstrate the potential of this technology to empower individuals in their yoga journey, promoting safety, efficiency, and a richer engagement with the practice.

II. PROCESS FLOW

1.Login and Registration System:

Login: Users can log in using their email and password. If they forget their password, an option for password recovery should be provided.

Registration: During registration, users provide basic information such as:Name,Email,Age,Gender,Weight and Height (for BMI calculation),Previous knowledge of Yoga,Health conditions (e.g., back pain, knee issues, high blood pressure, etc.). This data is crucial for suggesting appropriate yoga poses.

Security: Password encryption should be implemented using libraries like bcrypt for securely storing credentials.

Database Integration: User information, health conditions, and preferences can be stored in a cloud database (e.g., Firebase, MySQL, MongoDB).

2. Pose Suggestion System:

Personalized Recommendations: Based on the user's health conditions and profile data, the app should suggest a list of yoga poses that suit their needs. For example:If a user has back pain, the system might suggest poses like *Child's Pose (Balasana)*, *Cat-Cow (Marjaryasana-Bitilasana)*, and avoid poses like *Wheel Pose (UrdhvaDhanurasana)*.

Pose Library: A pre-built library of poses with images, videos, and descriptions should be maintained. The backend should handle filtering and suggesting relevant poses.

Machine Learning Integration: Using health conditions, the system can predict or classify the user's suitability for specific poses using algorithms like decision trees or k-nearest neighbors (KNN).

3. Pose Detection: Using Computer Vision (OpenCV or TensorFlow):

The app should detect the user's pose using the device's camera. You can implement pose detection using models like *MediaPipe Pose*, *OpenPose*, or *TensorFlow Lite PoseNet*.

Real-time Feedback: The system analyzes live camera footage to map the user's skeleton and joints using keypoint detection, comparing it to the correct yoga pose.

Accuracy: The detection can be fine-tuned using models trained on datasets like the *Yoga-82 Dataset*, which consists of different yoga postures.

4. Pose Correction:Real-time Correction: After detecting the user's pose, the app should compare the angles of joints (e.g., knees, elbows, hips) with the correct pose data. If a pose is incorrect, the system should provide:

Visual Feedback: Highlighting body parts that need adjustment.

Voice Assistance: Using text-to-speech (TTS) to guide the user, e.g., "Raise your left arm a little higher," "Straighten your back," etc.

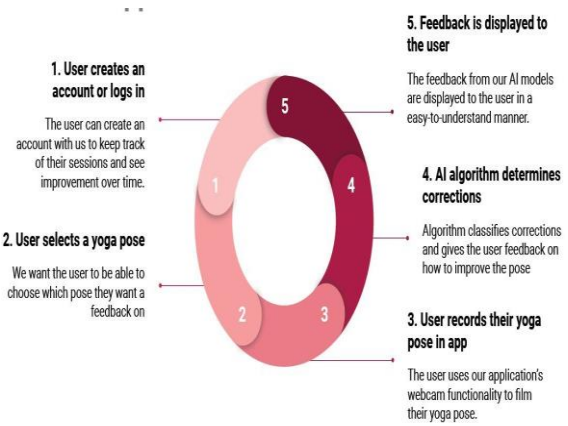
Accuracy Thresholds: Define tolerable ranges for correct poses. If the angles of body joints deviate from the correct pose beyond a certain threshold (e.g., 10°), the app provides corrective guidance.

5. Information About the Pose and Its Benefits:

Pose Overview: Each pose should have a detailed description that appears when selected from the suggestion list, including: Name of the pose (both in English and Sanskrit). A high-quality image or short animation of the pose. Step-by-step instructions to perform the pose correctly.

Benefits of the Pose: For each suggested pose, the app should list the physical and mental health benefits (e.g., improving flexibility, relieving stress, strengthening core, etc.).

Precautions: Include a list of health conditions that might contraindicate the pose (e.g., avoid certain poses if pregnant or suffering from a slipped disc).



III. TECHNICAL IMPLEMENTATION

1. Front-end: Use *Android Studio* with *Java* or *Kotlin* for building the user interface. Integrate Python using the *Chaquopy plugin* (to run Python code within Android). Alternatively, use *Flutter* for a cross-platform app and integrate with Python using APIs.

2. Backend: For pose detection, train models using *TensorFlow* or *MediaPipe Pose*. Store user data and pose history in cloud databases like Firebase or AWS RDS. Use *RESTful APIs* to connect the app to the backend for user authentication, pose suggestions, and health data storage.

3. Machine Learning Models: Use pre-trained models like *PoseNet* or *MediaPipe* for pose detection. For pose suggestions and corrections based on health conditions, create classification or recommendation models using libraries like *scikit-learn* or *Tensor Flow*.

IV. PERFORMANCE EVALUATION METRICS

To assess the effectiveness of the yoga pose detection and correction application powered by the algorithm, we can utilize several performance evaluation metrics. These metrics help gauge the model's accuracy, efficiency, and overall impact on user experience. Below are the key metrics that can be employed:

1.Accuracy

-Definition: The ratio of correctly identified poses to the total number of poses detected.

-Formula:

$$\text{Accuracy} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Positives} + \text{False Negatives}}$$

2.Precision

-Definition: The ratio of true positive detections to the total detected poses, reflecting the model's ability to avoid false positives.

-Formula:

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Positives}}$$

3. Recall (Sensitivity)

-Definition: The ratio of true positive detections to the total actual poses, indicating how well the model identifies all relevant instances.

- Formula:

$$\text{Recall} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$$

4.F1 Score

-Definition: The harmonic mean of precision and recall, providing a balance between the two metrics. It is particularly useful when dealing with imbalanced classes.

- Formula:

$$F1 \text{ Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

5. Mean Average Precision (mAP)

-Definition: A metric that summarizes the precision-recall curve by calculating the average precision across multiple classes (different yoga poses). It considers both precision and recall at different thresholds.

- Usage: This is particularly useful for evaluating the model on a set of poses rather than a single class.

6. Intersection over Union (IoU)

-Definition: A metric that measures the overlap between the predicted bounding box and the ground truth bounding box. It helps assess the localization accuracy of detected key points.

- Formula:

$$\text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$

-Threshold: A common threshold for IoU is 0.5, meaning the prediction is considered correct if IoU $\geq$ 0.5.

7. Processing Time

-Definition: The time taken for the model to process a frame and provide feedback. This metric is crucial for real-time applications.

-Measurement: Recorded in milliseconds per frame.

8. User Satisfaction Metrics

-Definition: Subjective measures collected through user surveys or feedback forms that assess the perceived usefulness, ease of use, and overall satisfaction with the application.

-Metrics: Likert scale ratings (1-5 or 1-7) on various aspects such as clarity of feedback, impact on practice, and usability.

9. Engagement Metrics

-Definition: Metrics that evaluate how actively users are using the application.

- Examples:

- Session Duration: Average time spent per session.

-Frequency of Use: Number of times users engage with the app over a specified period.

V. WORKING AND METHODOLOGY

1. Problem Definition

Objective: Develop an application that detects yoga poses in real-time through video input and provides feedback for corrections.

2. Data Collection

Dataset:Collect a diverse dataset of yoga poses. This can be achieved using:Publicly available datasets (e.g., Yoga-82, YogaPose Dataset).Creating a custom dataset by recording various individuals performing yoga poses.

Annotations:Each image/video should be annotated with:Pose labels (e.g., Downward Dog, Warrior I).

Keypoint annotations for different body parts (e.g., shoulders, elbows, knees).

3. Data Preprocessing

Image Processing: Resize images, normalize pixel values, and apply data augmentation techniques (e.g., rotation, flipping) to increase the robustness of the model.

Keypoint Extraction: Use pose estimation techniques to extract keypoints from images. Libraries like OpenPose, MediaPipe, or PoseNet can be used.

4. Model Selection

Pose Detection Models:Use pre-trained models for pose estimation (e.g., OpenPose, MediaPipe Pose, PoseNet).

Fine-tune these models on the collected dataset to improve accuracy for yoga poses.

5. Pose Classification

Architecture: Implement a classification model (e.g., CNN, LSTM, or hybrid models) to identify yoga poses based on the keypointdata.Loss Function: Use categorical cross-entropy for multi-class classification.Training: Train the model using labeledkeypoint data.

6. Real-time Detection

Video Input: Capture video from the camera, and use the pose detection model to process each frame in real-time.Inference: Extract keypoints from each frame, input them into the classification model, and predict the yoga pose.

7. Correction Feedback

Feedback Mechanism:Compare the detected pose with a reference pose.Calculate angles between keypoints to assess alignment and provide specific corrective feedback (e.g., "your left knee is bent too much").User Interface: Create a simple and intuitive interface that displays:

Detected pose.Corrective suggestions (textual feedback, visual overlays).Progress tracking (e.g., number of poses practiced, improvement metrics).

8. Evaluation and Testing

Performance Metrics: Evaluate the model using metrics such as accuracy, precision, recall, and F1-score.User Testing: Conduct user testing to gather feedback on the effectiveness of pose detection and correction suggestions.

9. Deployment

Platform: Decide on the platform (mobile, web, desktop) and implement the application accordingly.

Frameworks: Use frameworks like TensorFlow or PyTorch for model training and inference, and Flask or Django for web applications.

10. Continuous Improvement

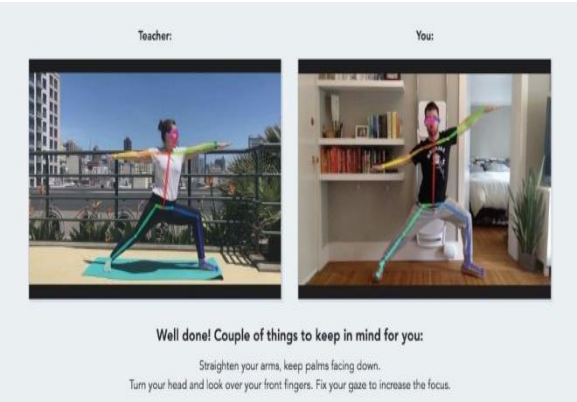
User Feedback: Regularly collect user feedback to improve the model and user experience.

Model Retraining: Update the model with new data to enhance performance over time.

11. Future Enhancements

Integration of AR/VR: Consider integrating augmented or virtual reality for a more immersive experience.

Personalization: Use AI to tailor sessions based on user progress and preferences.



VI. WORKFLOW ALGORITHMS

Posenet:

PoseNet is a deep learning model for real-time human pose estimation. It can detect key points in a human body, such as the eyes, ears, nose, shoulders, elbows, hips, knees, and ankles. PoseNet is available in several environments, including TensorFlow and TensorFlow.js, allowing integration with web and mobile platforms.

How PoseNet Works:

PoseNet works by detecting a person's key body joints and their corresponding positions in an image or video. It can handle multiple people in an image and provides a set of key points for each person.

Keypoint Detection: PoseNet detects 17 keypoints on the human body (e.g., head, shoulders, elbows, knees, and ankles).

Confidence Scores: For each keypoint, PoseNet provides a confidence score, which indicates how likely the point was detected correctly.

Skeleton Construction: By connecting these keypoints, PoseNet constructs the skeleton and gives a visual representation of the person's pose.

PoseNet Workflow:

The model inputs an image or video frame.

It detects and outputs the location of key body points in the frame.

The model then calculates the skeletal structure and compares it to a reference pose (e.g., yoga pose).

You can apply corrections by comparing the detected pose to the standard or ideal pose and provide real-time feedback to the user.

Key Features:

Single-person & Multi-person Mode: PoseNet can handle both single-person and multi-person pose detection.

Platforms: Available in TensorFlow Lite (for Android/iOS) and TensorFlow.js (for web).

Lightweight Model: PoseNet is fast and can run on a mobile device or browser.
Pre-trained Model: No need for extensive training. It's ready-to-use and pre-trained on a large dataset of human poses.

Pros:

Lightweight and fast: PoseNet can run in real-time even on mobile devices.

Cross-platform: Available in TensorFlow Lite for mobile apps, TensorFlow.js for web, and standard TensorFlow for backend servers.

Good Accuracy: PoseNet provides decent accuracy for applications like yoga pose detection.

Cons:

Limited Keypoints: PoseNet detects 17 keypoints, which might not be enough for very fine-grained correction in complex yoga poses.

Lower Flexibility in Edge Cases: The accuracy can degrade when body parts are obscured or when detecting poses with extreme stretching.

MediaPipe Pose

MediaPipe is a framework developed by Google that provides cross-platform libraries for various vision tasks, including pose detection. MediaPipe Pose is a high-fidelity solution for real-time pose estimation and tracking that works well on mobile devices andweb applications.

How MediaPipe Pose Works:

MediaPipe Pose detects and tracks the human skeleton by identifying 33 keypoints across the human body, which is more detailed than PoseNet. This makes MediaPipe particularly suitable for applications that require detailed posture tracking, like yoga.

Keypoint Detection: MediaPipe detects 33 keypoints (as opposed to PoseNet's 17). These include not only common joints like knees, elbows, and shoulders but also finer points like wrists, ankles, and hips.

3D Estimation: MediaPipe offers 3D pose estimation, meaning it can provide depth information, which can be helpful in yoga applications for detecting misalignments in poses.

Real-time: MediaPipe Pose is optimized for real-time pose detection and tracking, even on mobile devices with lower computational power.

MediaPipe Workflow:

The model inputs an image or video frame.

MediaPipe detects 33 keypoints and estimates their 3D coordinates.
It tracks the pose over time, allowing you to assess the accuracy and correctness of the pose.

You can provide real-time feedback on misalignments based on the 3D positions of joints and limbs.

Key Features:

33 Keypoints: MediaPipe detects a more detailed set of keypoints than PoseNet, making it more suitable for precise pose corrections.

2D and 3D Pose Detection: MediaPipe provides both 2D and 3D pose estimation.

Cross-Platform: It works on mobile, web, and desktop platforms with native support.

Highly Optimized: Runs efficiently on mobile devices, including iOS and Android, and can provide real-time feedback.

Pros:

Highly Detailed Keypoints: 33 keypoints give finer control for detecting and correcting yoga poses.

Real-Time 3D Pose Detection: This feature is extremely useful for evaluating depth and angles in poses.

Cross-Platform: Available across mobile, web, and desktop.

High Performance: Can run efficiently on both high-end and low-end devices.

Cons:

Complexity: MediaPipe's higher number of keypoints and 3D pose detection might make the integration slightly more complex than PoseNet.

Resource Intensive: Slightly heavier than PoseNet, although still optimized for real-time applications.

VII. CONCLUSION

The development of a yoga pose detection and correction application using AI and machine learning represents a significant advancement in the intersection of technology and wellness. By leveraging advanced computer vision techniques and deep learning models, this application offers real-time feedback to users, enhancing their yoga practice and ensuring proper alignment and safety.

Key takeaways from this project include:

Enhanced User Experience: The application provides personalized, immediate feedback, allowing users to improve their poses, avoid injuries, and deepen their practice.

Accessibility: By making yoga guidance accessible through a mobile or web platform, individuals can practice at their convenience, accommodating various skill levels and learning styles.

Continuous Learning: The model can evolve over time through continuous data collection and user feedback, ensuring that the application remains effective and relevant.

Integration of AI Technologies: Utilizing pose estimation and machine learning techniques highlights the potential for AI to transform traditional practices, making them more interactive and informative.

Future Opportunities: This technology opens avenues for further enhancements, such as incorporating augmented reality for immersive experiences or personalized training regimens based on user performance.

Overall, the yoga pose detection and correction application embodies a fusion of fitness and technology, empowering users to achieve their wellness goals while promoting safe and effective yoga practices. As AI continues to evolve, the potential for further innovation in this field remains vast, promising even more sophisticated and user-friendly solutions in the future.

APPENDIX

A. References

Datasets:

Yoga-82 Dataset: A large dataset containing diverse yoga poses with annotations.

YogaPose Dataset: Another comprehensive dataset useful for training and validating pose detection models.

1.Pose Estimation Libraries:

OpenPose: A popular library for real-time multi-person pose estimation.

MediaPipe: Google’s framework for building cross-platform applied ML pipelines, including pose detection.

PoseNet: A lightweight model for pose detection in real-time applications.

Machine Learning Frameworks:

TensorFlow: An open-source library for machine learning and deep learning projects.

PyTorch: Another powerful framework, particularly popular for research and experimentation.

Computer Vision Libraries:

OpenCV: A library that provides tools for image processing and computer vision tasks.

User Interface Development:

Flask or Django: Python frameworks for building web applications.

React Native: For developing cross-platform mobile applications.

B.Tools and Technologies

Development Tools:

Jupyter Notebook: For interactive coding and experimentation with data and models.

Visual Studio Code: A versatile code editor for software development.

Hardware Requirements:A computer with a dedicated GPU for model training (e.g., NVIDIA with CUDA support).A camera or smartphone for capturing real-time video input.

Deployment Platforms:

AWS or Google Cloud: For deploying machine learning models and hosting the application.

Heroku: A platform for deploying web applications easily.

C. Technical Implementation

Model Training Steps:Preprocess the dataset (resize, normalize).Use transfer learning with pre-trained models for faster training.Fine-tune the model based on validation performance.

Real-Time Processing:Implement video capture using OpenCV.Extract frames, process them through the pose detection model, and output predictions.

Feedback Mechanism:Calculate joint angles using keypoint data to assess alignment.Develop algorithms for generating corrective feedback based on pose deviations.

D. User Testing and Feedback

Testing Phases:Alpha Testing: Internal testing with a small group of users to identify bugs and issues.Beta Testing: Wider user testing to gather feedback and improve user experience.

Feedback Collection:surveys and interviews to assess user satisfaction and usability.Analytics to track user engagement and effectiveness of feedback.

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Thank you all for your support and encouragement in this endeavor.

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Online Resources
Kaggle Datasets: Various datasets related to yoga and pose estimation can be found on Kaggle. Link
GitHub Repositories: Explore repositories related to yoga pose detection projects. GitHub

These references provide a strong foundation for understanding the methodologies, technologies, and datasets relevant to the development of a yoga pose detection and correction application using AI and ML.