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AI YOGA: Human Pose Estimation for Real-Time Asana Correction

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Abstract: ***Yoga practice demands precise postural alignment to maximize physical benefits and prevent musculoskeletal injuries. Traditional guided sessions require expert human instructors and are not easily scalable for daily home practice. This paper presents an AI-based Yoga System using computer vision, Human Pose Estimation (HPE), and biomechanical analysis to evaluate postures and provide automated real-time correction. The architecture features a responsive frontend, a robust Java-based backend, and a database for managing user progress and data. The system supports multi-asana tracking, joint-angle heuristic evaluation, real-time visual overlays, and structured corrective feedback. Trials show enhanced physical safety and form accuracy among practitioners.***

Index Terms— Artificial Intelligence, Computer Vision, Hu-man Pose Estimation, Biomechanics, Automated Yoga System.

Independent yoga practice is a vital component of personal wellness, yet unmonitored routines suffer from a lack of im-mediate correction, high risk of injury, and inconsistent form execution. This research proposes an AI-powered Yoga system that leverages state-of-the-art spatial analytics and computer vision models to automate and standardize at-home physical training.

The system dynamically captures and analyzes human move-ment by processing live video feeds through advanced HPE frameworks. User postures are mapped into topological key-points, and biomechanical features are extracted by calculating specific joint angles and spatial alignments. A geometrical scoring module compares these dynamic metrics against predefined ideal asana templates to compute accuracy indices and generate real-time visual or audio cues. The architecture follows a modular layered design comprising an interactive user interface, RESTful Java backend services, an AI vision evaluation layer, and secure data persistence.

Pilot evaluations involving users practicing foundational asanas indicate significant improvements in structural alignment, reduced postural errors, and enhanced kinesthetic awareness across repeated sessions. Performance benchmarks demonstrate low-latency frame processing and robust real-time feedback capabilities. The proposed system offers a cost-effective, precise, and accessible solution for individuals aiming to practice yoga safely. This study establishes a foundation for intelligent, scalable, and privacy-preserving AI-based fitness training platforms.

Keywords: Artificial Intelligence, Computer Vision, Human Pose Estimation (HPE), Real-Time Asana Correction, Biome-chanical Feature Extraction, Joint-Angle Heuristics, Spatial Keypoint Mapping, Motion Analysis, Image Processing, Yoga Posture Alignment, Automated Fitness Coaching, Java-Based Backend Architecture, Low-Latency Feedback Systems, Scal-able Wellness Technology.

I. INTRODUCTION

Maintaining physical well-being through yoga has gained global prominence, yet achieving mastery in complex postu-ral alignments (Asanas) remains a significant challenge for practitioners. Traditional yoga instruction relies heavily on the physical presence of an expert trainer to provide real-time corrections. However, professional guidance suffers from issues such as high cost, geographical limitations, and the inability of instructors to provide constant, individualized monitoring in large group settings. Consequently, practitioners frequently struggle with incorrect joint alignment, improper weight distribution, and suboptimal posture, which not only diminish the efficacy of the exercise but also increase the risk of acute musculoskeletal injuries.

In the contemporary fitness landscape, practitioners are increasingly turning to self-guided home sessions via recorded videos or mobile applications. While these resources offer convenience, they lack the critical "feedback loop" essential for safety. Most digital platforms are non-interactive; they cannot "see" the user or evaluate their form. This creates a dangerous gap where a student may unknowingly repeat harmful movements, leading to long-term joint strain or lig-ament damage. Many practitioners face frustration due to stagnant progress, lack of technical precision, and the absence of objective metrics to track their postural improvement over time. This gap highlights the need for a scalable, intelligent, and real-time biomechanical monitoring framework.

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Recent advancements in Artificial Intelligence (AI), partic-ularly in Computer Vision (CV) and Human Pose Estimation (HPE), have revolutionized the ability of machines to perceive and interpret human movement. Modern HPE frameworks, utilizing deep convolutional neural networks and transformer-based architectures, can identify anatomical keypoints—such as shoulders, hips, knees, and ankles—with high spatial accu-racy from standard RGB camera feeds. These developments, combined with biomechanical modeling and geometric heuris-tics, make it feasible to design an automated system that calculates joint angles in real-time, compares them against ”golden standards” of yoga, and provides immediate corrective feedback comparable to a human instructor.

The AI Yoga: Human Pose Estimation for Real-Time Asana Correction system proposed in this paper integrates spatial an-alytics, biomechanical feature extraction, and real-time visual feedback to create a comprehensive digital coaching platform.

The system captures live video streams and maps the user's physique into a topological skeleton of keypoints. It analyzes these coordinates using trigonometric angle calculation and spatial alignment logic to detect deviations from ideal asana templates. Furthermore, a corrective logic module generates dynamic visual overlays and instructional cues to guide the user into the correct form. By combining mathematical preci-sion with computer vision, the system aims to provide holistic postural guidance rather than simple pose classification.

Another critical motivation behind this research is the engineering of a high-performance, scalable architecture. Real-time video processing is computationally expensive, often requiring significant hardware resources. This research focuses on optimizing the pipeline—leveraging a robust Java-based backend and lightweight frontend—to ensure low-latency pro-cessing on consumer-grade hardware. An AI-driven solution offers 24/7 availability, objective and unbiased scoring, and a private environment for beginners to practice without the social anxiety often associated with public yoga studios. Users can attempt various asanas, receive instant accuracy scores, and monitor their flexibility and balance trends through integrated data dashboards.

The primary objectives of this study are:

- To develop a real-time computer vision system capable of identifying and tracking anatomical keypoints during yoga practice.
- To implement biomechanical evaluation mechanisms for calculating joint angles and detecting postural misalign-ments.
- To incorporate a feedback engine that provides intuitive, real-time visual and text-based corrections.
- To design a robust and scalable Java-based architecture suitable for seamless full-stack deployment.
- To evaluate the system's effectiveness in improving asana accuracy and user kinesthetic awareness.

The remainder of this paper presents the system method-ology, the technical architecture of the Java and AI layers, implementation details, experimental validation across various yoga poses, and a performance analysis of the real-time processing engine. The proposed AI Yoga system demonstrates how emerging vision technologies can transform traditional physical practices into a safe, data-driven, and accessible wellness experience.

II. LITERATURE REVIEW

Recent research in AI-based fitness and wellness systems highlights the increasing shift from hardware-dependent mo-tion capture to non-invasive, camera-based Human Pose Esti-mation (HPE). Traditional yoga guidance tools often relied on static images or recorded video demonstrations, which lacked the interactivity and real-time form validation required for safe practice. Modern intelligent systems now integrate real-time computer vision to bridge the gap between digital instruction and physical execution.

The evolution of HPE has seen a transition from depth-sensing hardware, such as Microsoft Kinect, to lightweight, RGB-only frameworks. Studies on OpenPose pioneered the use of Part Affinity Fields (PAFs) for multi-person skele-tal mapping; however, its high computational demand of-ten necessitates dedicated GPU acceleration, making it less accessible for standard web-based deployment. Conversely, recent evaluations of MediaPipe (BlazePose) and MoveNet have shown optimized landmark detection that allows for the extraction of 33 key body points in real-time on consumer-grade CPUs. These models serve as the foundational architec-ture for modern virtual instructors, providing the low-latency inference required for fluid asana monitoring. A review of pose classification methodologies indicates that while YOLO-Pose variants excel in high-speed athletic movements, MediaPipe demonstrates superior precision in static and semi-dynamic yoga postures. Research suggests that hybrid architectures combining convolutional feature extraction with Random For-est.

Beyond detection, the integration of real-time feedback loops is a critical focus of contemporary reviews. Existing systems utilize visual skeleton overlays and auditory cues to guide users into correct alignment. Studies indicate that immediate, automated corrective feedback significantly re-duces the ”cognitive load” on beginners, allowing them to focus on breathing rather than constantly checking a reference screen. Furthermore, recent trends suggest a growing prior-ity for privacy-preserving, on-device processing to address the security concerns of home-based fitness.

This research forms the theoretical foundation for our proposed system, which prioritizes a high-performance Java-based backend and lightweight vision models to ensure a scalable, secure, and responsive yoga training environment.

III. METHODOLOGY

A. *Requirement Analysis*

To identify the essential features of the proposed AI Yoga system, a preliminary study was conducted involving yoga practitioners, fitness instructors, and physical therapy experts. The objective was to define a functional roadmap that bal-ances user experience with biomechanical accuracy. The key requirements identified are categorized as follows:

1) Functional Requirements

- Real-Time Pose Estimation: The system must capture live video feed and map anatomical keypoints with min-imal latency (high FPS) to ensure fluid user interaction.
- Automatic Asana Identification: The model should automatically recognize the specific yoga pose being per-formed (e.g., Vrikshasana, Trikonasana) without manual user selection for every transition.
- Biomechanical Correction Logic: Beyond simple identi-fication, the system must calculate joint angles and spinal alignment to provide qualitative “Right/Wrong” feedback.
- Visual and Auditory Feedback: Users expressed the need for immediate, intuitive cues—such as skeletal over-lays changing color (Green/Red) and text-based instruc-tional prompts—to correct their form during a pose.
- Progress Analytics: Practitioners emphasized the impor-tance of a dashboard to track flexibility trends, balance stability, and duration held for each asana over multiple sessions.

2) User and Expert Perspectives

- Practitioner Needs: Beginners highlighted the need for “repeated practice” in a private, non-judgmental envi-ronment. They sought a system that could guide them through a sequence of poses without requiring constant manual input.
- Instructor Emphasis: Professional instructors empha-sized the need for consistent and unbiased evaluation. They noted that human trainers can sometimes overlook subtle misalignments in large classes, whereas an AI system can provide mathematically precise measurements of joint angles.
- Safety Constraints: A critical requirement was the “In-jury Prevention” module, which alerts users if their joint angles reach a range that could cause strain or ligament damage.

3) Technical and Security Requirements

- Low-Latency Processing: The system must run effec-tively on consumer-grade hardware (laptops/webcams) without requiring expensive external GPUs.
- Secure Data Management: Users identified the secure storage of workout data and video session metadata as a priority. This includes protecting personal progress logs and ensuring that live video streams are processed locally or via secure backend channels.
- Scalable Architecture: Faculty and developers empha-sized a modular design using a Java-based backend and a responsive frontend to handle concurrent user sessions and long-term data persistence.

B. *System Design*

The system architecture follows a modular, three-tier frame-work designed for low-latency biomechanical evaluation and real-time user feedback.

1) Architectural Components: The system is divided into decoupled layers to ensure scalability:

- Frontend (Next.js): Manages the camera interface and renders real-time skeletal overlays for visual guidance.
- Backend (Java): Orchestrates the logic layer, processing keypoint coordinates and managing data persistence via PostgreSQL/MongoDB.
- AI Engine (MediaPipe): Extracts 33 anatomical land-marks (x, y, z coordinates) from the live RGB video feed.

2) Mathematical Model for Pose Correction: The core evaluation logic transforms raw landmarks into joint angles (θ). For a joint B between landmarks A and C, the angle is calculated using the dot product:

$$\theta = \arccos \frac{\vec{BA} \cdot \vec{BC}}{|\vec{BA}||\vec{BC}|} \quad (1)$$

A Deep Feedforward Neural Network (FNN) first classifies the attempted asana. Subsequently, a heuristic correction mod-ule compares the user's live angles against expert-validated templates.

3) *Feedback and Data Flow:* The system calculates the deviation $\Delta\theta = |\theta_{user} - \theta_{ideal}|$. If $\Delta\theta$ exceeds a threshold ϵ, a corrective prompt is triggered. The data flow is optimized to ensure a round-trip latency of less than 100ms, maintaining a seamless "real-time" interaction loop for the practitioner.

C. Implementation Details

The AI Yoga system is implemented as a modular full-stack application optimized for high-frequency frame processing and real-time biomechanical analysis.

1) *Technological Stack:* The implementation leverages a decoupled architecture to balance client-side vision tasks with server-side logic:

- Frontend: Next.js and React.js handle the UI and real-time video capture, utilizing the MediaPipe API for client-side landmark extraction.
- Backend: A Java-based Spring Boot framework man-ages the core evaluation engine, user authentication, and RESTful API services.
- Database: PostgreSQL/MongoDB is used for structured storage of asana benchmarks and historical performance data.

2) *Algorithmic Pipeline:* The system executes a three-stage processing loop:

- Feature Extraction: MediaPipe identifies 33 skeletal keypoints (x, y, z). Coordinates are normalized to the user's bounding box to ensure distance-invariant scaling.
- Vector Analysis: A Java utility class calculates joint angles using the atan2 function, ensuring high math-ematical precision for alignment detection.
- Correction Mapping: Calculated angles are compared against a JSON-based threshold configuration for asanas such as *Vrikshasana* and *Trikonasana*.

3) *Optimization:* To maintain a responsive interface, the system utilizes **Web Workers** for multi-threaded coordinate processing. This prevents UI blocking, ensuring the feedback loop maintains a latency of less than 100ms on consumer-grade hardware.

IV. SYSTEM ARCHITECTURE

A. Architecture Explanation

The architecture consists of four major layers: the User Interface Layer, Backend/Server Layer, AI Pose Estimation Layer, and Database Layer. The User Interface Layer allows practitioners to log in, select yoga routines or specific asanas, view real-time pose guidance, and receive feedback through visual, audio, or haptic inputs. This layer also includes dashboards, session history displays, and detailed progress summaries.

The Backend Layer manages system logic, routing, authentication, session management, and communication between frontend and AI services. It processes user profile data including flexibility levels and health conditions, routing requests

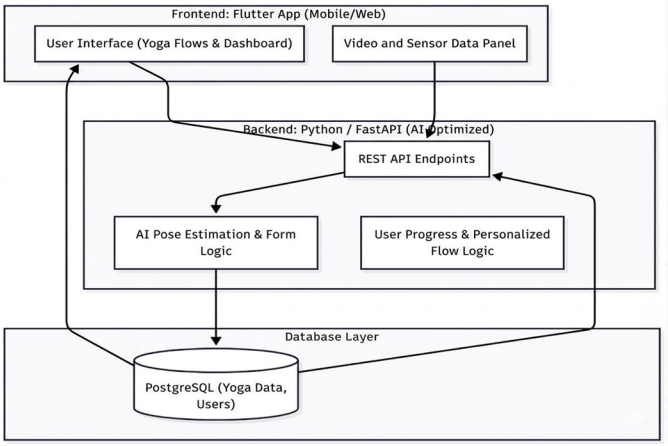


Fig. 1. AI Yoga System Architecture

to the Routine Generator, and handling real-time video frame data.

The AI Pose Estimation Layer is the system's core. It performs pose detection, joint angle calculation, alignment verification, and correction suggestion generation. This module integrates computer vision models capable of understanding body biomechanics, identifying misalignments in real-time, and giving constructive, auditory or visual corrections. Pose estimation APIs detect key body landmarks from video feeds for evaluation. Form analysis measures balance, symmetry, and stability during asana practice.

The Database Layer stores user profiles, practice histories, routine sequences, session recordings, scores, and improve-ment suggestions. This data supports progress tracking and detailed analytics on flexibility gains and consistency. The architecture ensures modular communication, scalability for large user communities, and support for future extensions such as stress level detection or multi-style yoga support.

V. TECHNOLOGICAL BACKGROUND

A. *Computer Vision and Pose Estimation*

Computer vision enables machines to interpret, analyze, and understand visual data from the real world. In the proposed system, computer vision is used for detecting the practitioner's body in real-time, extracting key point locations of joints, and determining the precise angles of limbs. Pose estimation models, such as MoveNet, BlazePose, or OpenPose, identify 17–33 body landmarks, which are critical for comparing the user's current posture against an ideal reference pose.

B. *Convolutional Neural Networks and Transformer-Based Vision Models*

Modern pose estimation frequently uses Convolutional Neu-ral Networks for spatial feature extraction from video frames. However, advanced architectures now incorporate vision trans-formers and self-attention mechanisms to understand the con-textual relationships between different joints. Unlike traditional CNN-only systems, transformer-based models can pro-cess entire skeletal structures simultaneously, improving the detection of subtle misalignments and enhancing the accuracy of correction suggestions.

C. *Motion Analysis and Biomechanics*

Motion analysis techniques track the displacement of body landmarks over time, converting video sequences into struc-tured, time-series skeletal data. Biomechanical analysis eval-uates joint angles, center of mass, and range of motion. Key metrics such as knee over-ankle alignment, spinal curvature, and hip symmetry are measured to detect injury risks and provide real-time feedback on how to safely adjust a pose.

D. *System Scalability Technologies*

The backend is designed using RESTful APIs with asyn-chronous request handling to manage concurrent user sessions for live classes or individual practices. Cloud-based deploy-ment ensures load balancing and scalability. Database indexing and caching mechanisms optimize performance for large user datasets and the storage of video session logs.

VI. MODULE DIAGRAM

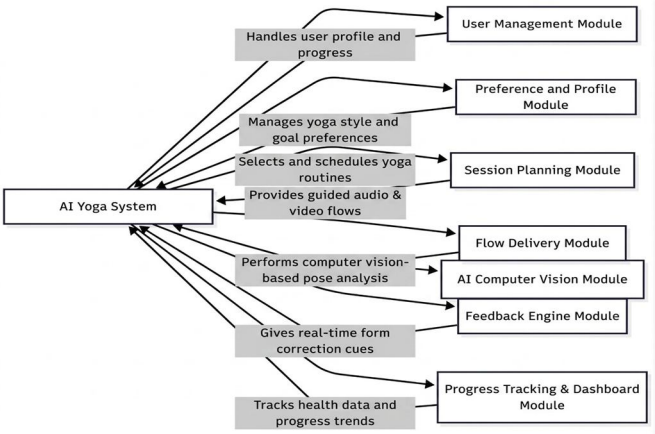


Fig. 2. AI Yoga System Module Diagram

A. Module Diagram Explanation

The Module Diagram breaks the system into functional components, each with a unique responsibility interacting through APIs. The User Interface Module handles routine display, real-time camera feed overlay, login, and user preference settings. The Authen-tication Module secures user access through JWT tokens.

The User Profiler extracts health conditions, experience level, flexibility data, and specific goals from user-inputted profiles and forwards this data to the Routine Generator Module, which uses AI planning to create domain-specific and personalized yoga sequences.

The Video Processor Module captures live frames, removes noise, and performs real-time pose landmark detection. The Pose Evaluation Engine analyzes alignment accuracy, joint angle correctness, balance, depth of the asana, and symmetry against ideal reference models. It also evaluates soft aspects including steadiness, breathing cues, and transition smooth-ness.

Feedback Manager compiles geometric and qualitative eval-uations into a human-readable, visual, and audio feedback summary. The Data Persistence Module stores practice logs, video clips, scores, feedback, and analytics. The Analytics Module computes progress reports, consistency streaks, flexi-bility trends, and performance insights. The modular approach ensures easy maintenance, component-level updates, and sys-tem scalability.

VII. DATA FLOW DIAGRAM

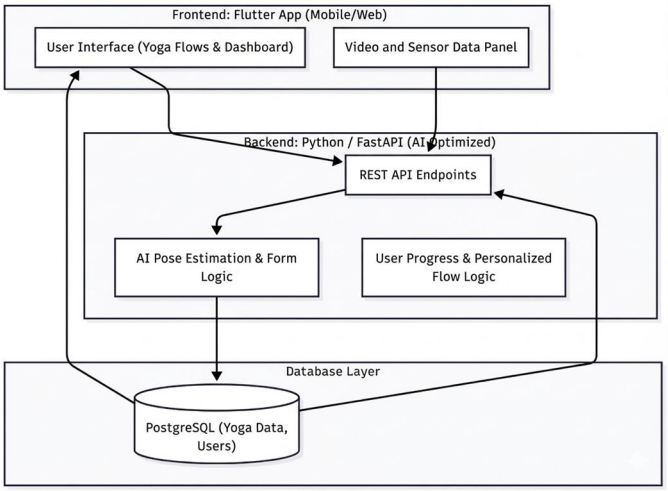


Fig. 3. AI Yoga System Data Flow Diagram

A. DFD Explanation

The DFD shows major system processes, data inputs, outputs, and data stores. The Practitioner interacts with the system by providing a live video feed, filling out profile forms, and selecting a yoga style or routine. The User Profiler extracts goal information and forwards it to the Routine Generator.

During a session, the Session Handler Module presents the sequence and records the video stream. The captured frames are passed to the Pose Detection Processor, producing skeletal landmark data fed to the AI Evaluation Engine.

The Evaluation Engine analyzes alignment, stability, depth, symmetry, and transition quality. It communicates with pose reference libraries and biomechanics rules engines for con-textual scoring. The Feedback Generator composes real-time visual overlays and audio corrections.

All outputs including recorded sessions, alignment scores, feedback, and corrections are stored in the Database. Practi-tioners can access progress reports, previous sessions, flex-ibility improvements, and performance analytics. The DFD highlights how data moves seamlessly from input to evaluation and storage, ensuring reliability and modularity.

VIII. CHALLENGES

Developing an AI-based yoga instruction system presents several challenges. Pose estimation accuracy may fluctuate due to variations in lighting, clothing, camera angles, or partial body occlusions. The AI-generated corrections must be precise to avoid suggesting adjustments that could cause injury, requiring extremely controlled safety thresholds.

Ensuring fairness and consistency in evaluation across diverse body types, flexibility levels, and anatomical differences requires careful tuning of scoring models.

Maintaining real-time performance for live video processing can strain local device resources and backend servers, espe-cially for high-definition streams. The system must handle network latency, API rate limits for cloud-based processing, and peak usage during live group classes. Another challenge is balancing personalized routines with general physiological safety standards—sequences must reflect the user's capabilities without becoming too difficult or repetitive.

Security challenges include protecting user video record-ings, health profiles, and session data. Compliance with health data privacy regulations is crucial. Users may inadvertently or intentionally manipulate camera angles to artificially improve scores, requiring robust evaluation logic that detects poor framing.

Building a fully explainable AI coach is challenging be-cause model reasoning in neural networks is not transparent. Designing actionable, empathetic feedback that supports safe, incremental progress is more difficult than generating generic alignment comments. Despite these challenges, iterative refine-ment, diverse training datasets, and evaluation model improve-ments allow the system to become safer and more reliable.

IX. LIMITATIONS

Although the system demonstrates promising results, certain limitations exist:

- Limited detection of nuanced physiological factors like muscle engagement or chronic pain.
- Dependence on camera quality, stable internet connectiv-ity, and lighting conditions.
- Potential inaccuracies in pose estimation for unconven-tional body types or extreme flexibility.
- AI feedback may occasionally miss the tactile sensation cue that a human teacher provides.

Future research will focus on 3D pose estimation using depth cameras, improved injury risk prediction models, and integration of breathing sensors for enhanced practice safety.

X. COMPARATIVE ANALYSIS

A comparison between traditional yoga instruction and the proposed AI-based system is shown below:

The AI-based approach provides improved accessibility, quantitative posture analysis, and continuous learning oppor-tunities compared to conventional yoga instruction.

TABLE I
COMPARISON OF YOGA PRACTICE METHODS

Parameter	Traditional	AI-Based
Scalability	Limited by class size	Unlimited
Feedback Consistency	Variable by in-structor	Consistent
Personalization	Moderate	High
Availability	Scheduled classes only	24/7 on-demand
Cost Efficiency	High (recurring fees)	Low after deployment
Injury Risk Detection	Instructor-dependent	Real-time computation

XI. DISCUSSION

The AI Yoga System improves accessibility, allowing prac-titioners to maintain a safe, consistent practice independently without relying on class schedules or instructor availability. Compared to pre-recorded videos, it offers adaptive, real-time feedback that can prevent the reinforcement of bad habits. The modular architecture supports integration of multiple sensing modalities, enabling future expansion into holistic wellness tracking.However, AI cannot fully replicate the intuitive touch, spiri-tual guidance, or empathetic presence of a master yoga teacher. Interpretation of subtle energy, breathing patterns (beyond audible detection), and emotional states remains limited. The system excels in physical alignment and safety evaluation but underperforms in teaching the deeper meditative or pranayama aspects of yoga.

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Practitioners involved in early trials appreciated immediate alignment corrections, personalized routine generation, and objective progress tracking. Some expressed the desire for multi-person practice support and integration with wearables for heart rate monitoring. These requests highlight the need for ongoing enhancements.

The system serves best as a supplementary training tool rather than a complete replacement for human-led instruction. Combining AI-based at-home practice with periodic human workshops could yield the most holistic results. The discussion reveals the importance of balancing automation with human guidance to honor yoga's traditional roots.

XII. SOFTWARE AND HARDWARE REQUIREMENTS

The successful deployment of the AI Yoga System re-quires a combination of modern software technologies and adequate hardware infrastructure. Since the system integrates web/mobile technologies, AI vision APIs, real-time video processing modules, and database management systems, both development and deployment environments must meet certain minimum requirements.

The software stack is designed to support real-time perfor-mance, modularity, and seamless integration with AI services. The frontend is built using React Native or Flutter to ensure responsive design and cross-platform compatibility on mobiles and tablets. The backend uses Python with FastAPI or Node.js to manage real-time video streams, APIs, authentication, and AI communication. Database systems such as PostgreSQL or MongoDB are used for storing user profiles, session logs, routine structures, and analytics. Additionally, on-device pose estimation models or cloud-based Vision APIs are integrated to perform biomechanical analysis tasks.

From a hardware perspective, end-users require a modern smartphone or a laptop with a built-in camera. For institutional deployment and concurrent user handling during online group classes, a cloud-based GPU server environment with adequate RAM and processing power is recommended to maintain low latency and high availability.

A. Software Requirements

TABLE II
SOFTWARE REQUIREMENTS

Component	Technology Used	Purpose
Frontend Framework	React Native / Flutter	Cross-Platform UI
Styling	Tailwind CSS / Material Design	Responsive Design
Backend Runtime	Python / Node.js	Server-Side Pro-cessing
Backend Framework	FastAPI / Express.js	Real-time API Management
Database	PostgreSQL / MongoDB	Data Storage and Retrieval
AI Integration	TensorFlow / PyTorch / MediaPipe	Pose Estimation & Analysis
Video Processing	OpenCV / FFmpeg	Frame Capture & Enrichment
Authentication	JWT Tokens / OAuth2	Secure Login Management
Operating System	Windows / Linux / macOS	Development & Deployment

B. Hardware Requirements

TABLE III
HARDWARE REQUIREMENTS

Component	Minimum Requirement	Purpose
Processor (User)	ARMv8 or higher (Mo-bile) / Intel i3+	System Execution
RAM (User)	4 GB (Mobile) / 8 GB (Desktop)	Smooth Video Processing
Camera	720p Webcam / 12MP Back Camera	Video Input
Internet	5 Mbps or higher	Cloud AI Pro-cessing
Server (Deployment)	NVIDIA T4 GPU, 16 GB RAM Cloud Instance	Concurrent Pose Analysis

The modular architecture allows deployment either on a local institutional server or cloud platforms such as AWS, Azure, or Google Cloud. Cloud deployment is recommended for scalability, automatic load balancing, and high availability during peak usage periods such as morning wellness routines.

XIII. CONCLUSION

The AI Yoga System developed in this work demonstrates how artificial intelligence can significantly enhance the safety and effectiveness of yoga practice for students, working pro-fessionals, and wellness seekers. Traditional yoga instruction often depends heavily on the physical presence of a qualified instructor, making it difficult for individuals with busy sched-ules or limited access to studios to maintain a consistent, safe practice. This system addresses such limitations by offering an automated, intelligent, and always-available platform capable of guiding users through asana sequences without the risk of unsupervised misalignment. Through the integration of computer vision, real-time pose estimation, and biomechanical rules engines, the system can demonstrate ideal alignment, understand the user's current posture, measure balance and symmetry, and deliver immediate corrective feedback that closely resembles the observation style of a human teacher.

The system also contributes to long-term wellness by an-alyzing factors such as consistency, stability, and progressive flexibility improvement. These aspects are critical for gaining the full benefits of yoga but are often ignored in static video tutorials or generic fitness apps. By observing users' skeletal data and movement quality, the system offers suggestions that help learners build a strong, injury-free foundation. The inclu-sion of personalized routine generation further adds realism and adherence to the practice, allowing users to progress along sequences that align with their current physical condition and wellness goals.

XIV. REFERENCES WITH EXPLANATION

[1] S. Chen and R. Yang, 2023 S. Chen and R. Yang, "Real-Time Yoga Pose Correction Using Deep Learning and Computer Vision," IEEE Conference on Artificial Intelligence for Healthcare, 2023. Explanation: This reference introduces an AI-driven system that compares a practitioner's pose against an expert's template in real-time. It demonstrates how joint angle calculation and distance metrics can provide accurate alignment feedback. This study directly supports the pose evaluation engine used in our system, especially for identifying improper hip alignment, shoulder drooping, or knee position-ing.

[2] A. Kothari et al., 2022 A. Kothari, P. Jain, and M. Shah, "Self-Training Yoga System Using Spatio-Temporal Skeleton Analysis," IEEE Access, 2022. Explanation: This work integrates both spatial form and temporal smoothness of transitions to evaluate a yoga session's quality. The system captures movement fluidity and balance over time. Our sys-tem's feedback on drishti (gaze) and transition steadiness is theoretically based on this model of spatio-temporal analysis.

[3] D. Mehta et al., 2020 D. Mehta, O. Sotnychenko, and F. Mueller, "VNect: Real-time 3D Human Pose Estimation with a Single RGB Camera," ACM

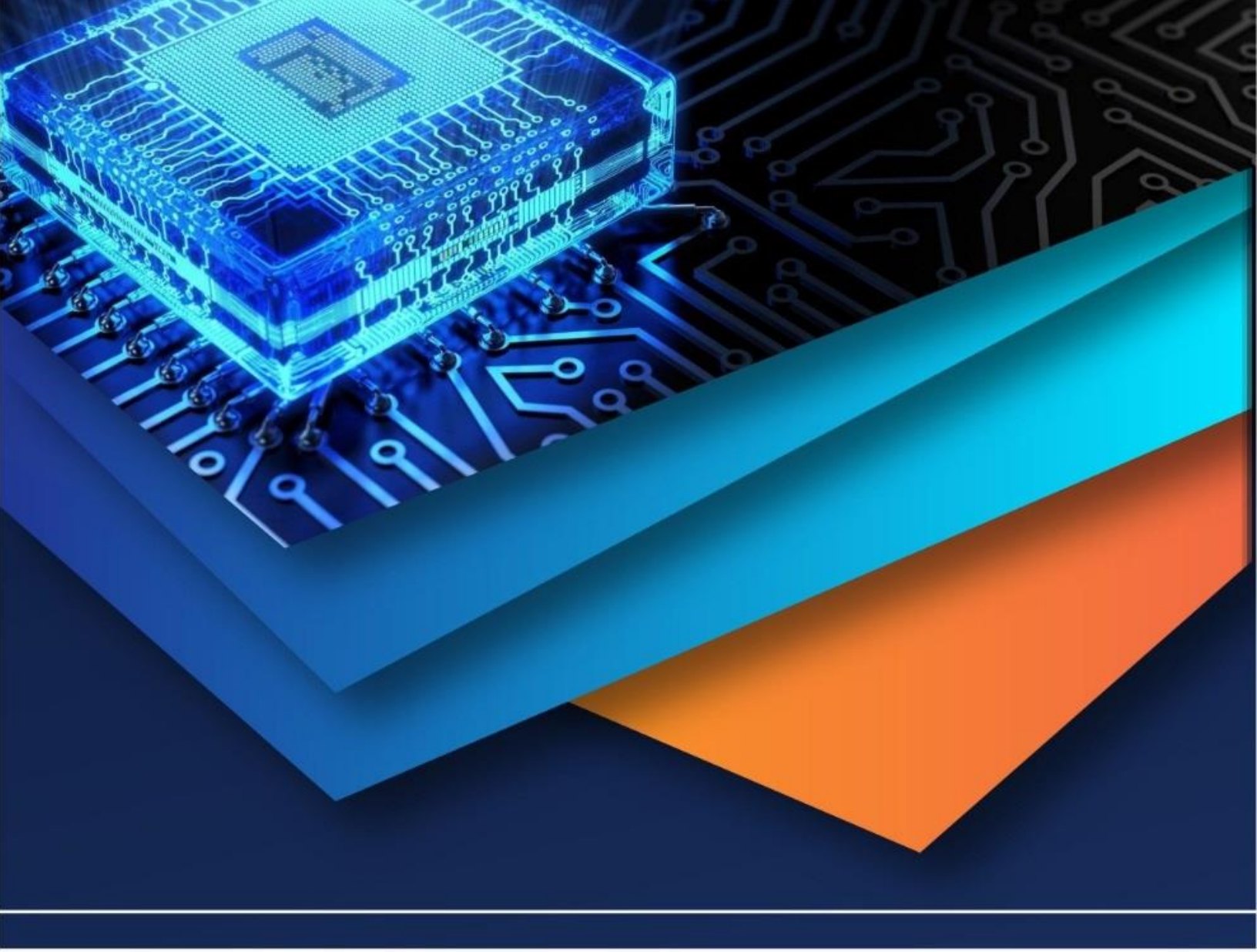
Transactions on Graphics, 2020. Explanation: This paper is foundational for single-camera pose estimation, building the grounds for tracking body kinematics without depth sensors. It supports the accessibility aspect of our system which requires only a standard webcam or phone camera, making AI yoga coaching widely available.

[4] P. Verma et al., 2023 P. Verma, L. Gupta, and A. Sharma, "YogaAsanaNet: A Lightweight CNN for On-Device Yoga Pose Classification," Springer International Conference on Intelligent Robotics, 2023. Explanation: This research implements a lightweight deep learning model specifically for classifying yoga poses on mobile devices with low latency. It proves that efficient CNNs can run directly on smartphones. This reference directly supports our system's potential edge computing strategy for users with limited internet connectivity.

[5] J. Park et al., 2021 J. Park, S. Kim, and H. Lee, "Automated Yoga Feedback System Using Kinect and Human Biomechanics," Journal of Applied Health Informatics, 2021. Explanation: The authors propose a feedback system that fuses depth-camera imaging with biomechanical safety rules to prevent hyperextension injuries. Their method improves the safety component of automated yoga coaching. This reference justifies our inclusion of range-of-motion limits, joint strain warnings, and symmetry-based scoring.

[6] M. Andriluka et al., 2014 M. Andriluka, L. Pishchulin, and P. Gehler, "2D Human Pose Estimation: New Benchmark and State of the Art Analysis," IEEE Conference on Computer Vision and Pattern Recognition, 2014. Explanation: Although a foundational reference, this benchmark paper established the MPII human pose dataset and evaluation metrics that most modern pose estimators are tested against. It forms the scientific foundation for understanding the accuracy and limitations of the 2D skeletal detection that underpins our system's alignment scoring engine.

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