

A Real-Time Computer Vision Framework for Yoga Posture Analysis Using Coordinate Geometry

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ABSTRACT:

Yoga is widely practiced without direct supervision from qualified instructors because of the growing popularity of at-home physical fitness activities. Unsupervised practice is convenient, but it frequently results in incorrect posture execution, which lowers efficacy and raises the danger of injury. The real-time vision-based posture analysis framework presented in this study is intended to support users during yoga practice by offering prompt feedback on posture accuracy. Key body joints are identified by the proposed system using MediaPipe-based skeletal landmark detection, and posture alignment is assessed using coordinate geometry-based angle computation. The framework uses lightweight geometric reasoning to enable effective real-time execution on common consumer devices, in contrast to data-intensive deep learning approaches that demand massive training datasets and significant processing resources. Through visual and audio signals, the system provides corrective feedback, assisting users in making dynamic posture adjustments. Usability and user engagement are further improved by a simple and interactive user interface. Experimental findings show that the proposed method improves posture accuracy and practice safety by successfully detecting posture variations and offering practical advice. The framework provides an approachable and dependable solution for unsupervised yoga instruction, which is especially helpful for learners and persons practicing on their own, including users who benefit from accessible, voice-guided assistance.

Keywords: Computer vision, Human posture analysis, Skeletal landmark detection, Coordinate geometry, Real-time posture evaluation.

1. Introduction

Yoga is a holistic practice combining physical postures (asanas), breathing exercises (pranayama), and meditation techniques to promote overall health, and has existed for thousands of years in India. In addition to flexibility, strength, and balance, yoga is proven to enhance cardiovascular and respiratory health, decrease stress, and increase mental concentration and emotional regulation (Büssing et al., 2012). When performed regularly, yoga may also improve posture, prevent musculoskeletal problems, and make practitioners more conscious of their lifestyle. Beyond physical fitness, yoga has lasting positive effects on the body, mind, emotions, and self-awareness, which makes it a vital practice in modern life. However, the efficacy of yoga is based on good alignment, and a slight deviation may decrease the benefits or raise the chance of injury. Conventional learning techniques—face-to-face instruction or video guides—can be informative but lack real-time, customized feedback and can be inadequate for self-practice, particularly among novices.

To overcome these limitations, several digital solutions have emerged to automate yoga instruction. Many of these systems use machine learning (ML) or deep learning (DL) models to detect and classify human poses. While these can achieve high accuracy on complex postures, they require large annotated datasets, significant computational resources, and dedicated model training. Moreover, ML-based systems can be less interpretable, making it difficult for users to know exactly which part of their posture needs correction. These limitations make traditional ML-based solutions less accessible and less scalable for devices with limited processing power or for users in home environments without specialized hardware.

This paper presents a Digital Yoga Assistance System that overcomes these limitations by combining coordinate geometry with MediaPipe Pose to detect and correct yoga postures in real time without using ML models. MediaPipe Pose, a lightweight and pre-trained computer vision framework developed by Google, detects 33

body landmarks from a standard webcam feed, including joints such as shoulders, elbows, wrists, hips, knees, and ankles (Bazarevsky et al., 2020; Lugaresi et al., 2019). Using the x, y coordinates of these landmarks, the system applies coordinate geometry to assess body alignment. For example, the angle at the knee or elbow is computed from three joint coordinates using the angle-between-vectors formula, while the distance between the hands, or between the raised foot and the supporting leg, is computed using the Euclidean distance formula. Through the analysis of these geometric parameters, the system senses deviations from the ideal poses and provides accurate corrective feedback. Such a geometry-based approach does not require the collection or training of datasets and is rapid, interpretable, and computationally inexpensive, making it especially well-suited for real-time execution on commodity consumer hardware.

The system is deployed as a Progressive Web Application (PWA) so that it can be accessed in real time using any modern browser on desktop, laptop, or mobile devices without installing software. Visual instructions are displayed as live pose overlays of the detected body landmarks and alignment indicators, while text-to-speech (TTS) audio feedback gives users live instructions like a real instructor. The audio feedback increases engagement and allows users to spend less time looking at the screen. In addition to posture correction, the system also offers dietary recommendations, personalized wellness advice, and progress tracking, making it a holistic digital assistant that supports not only proper yoga practice but the wider lifestyle of the user. By integrating posture guidance with dietary and health advice, the system helps promote a more balanced and healthy routine for users of any age. This emphasis on low-cost, device-independent access aligns with public-health guidance encouraging regular physical activity across all populations (World Health Organization, 2020) and with inclusive approaches to physical education that aim to make movement instruction available to learners of differing abilities, including those with limited access to in-

person instruction (Lieberman & Houston-Wilson, 2018).

The system has been tested on several yoga poses such as Vrikshasana (Tree Pose), Garudasana (Eagle Pose), and Hasta Uttanasana (Raised Hands Pose). The experimental results show that the system is highly effective at detecting deviations in posture and providing corrective feedback, and the geometric approach ensures that the corrections are easily comprehensible and easy to implement. Although lighting conditions, background clutter, and camera position may affect the accuracy of landmark detection, the performance of the system remains robust, lightweight, and efficient overall. The system thus provides an affordable, accessible, and scalable digital solution for yoga instruction by relying on coordinate geometry, MediaPipe landmark identification, TTS audio, and PWA deployment.

2. Related Work

Because of the rising popularity of yoga and the broader interest in fitness and personal health, considerable attention has been paid to applying computer vision and machine learning to yoga support systems. Many research works consider the use of these technologies to provide real-time guidance, posture correction, and feedback to yoga practitioners. This section reviews important activity in this area and concentrates on the approaches, challenges, and advances that have influenced the design of the Digital Yoga Assistance project.

A study employing Geometric Coordinate Feature Point Estimation presented a method for measuring yoga postures with the help of geometric coordinate feature points, considering joint-angle prediction and muscle activity in postures such as Adho Mukha Svanasana. This aligns with the Digital Yoga Assistance approach of using joint-angle computation and geometric modelling to assess the importance of good posture for preventing injuries (Guan, 2024). A 2024 paper examined how MediaPipe could be used to assess human posture in real time to enhance alignment and reduce injury risk during a yoga session; the key point detection in that

work relies on pre-trained AI models, whereas the present project advances this strategy by introducing coordinate geometry to determine posture accurately without resource-intensive pre-trained models (Radha et al., 2024). A 2023 study proposed an 87%-accurate real-time yoga posture recognition and correction system based on Support Vector Machines (SVMs), illustrating how machine learning can assist in yoga; the Digital Yoga Assistance project instead applies coordinate geometry and mathematical modelling to simplify the system and avoid large training datasets (Mane et al., 2023). A more recent study introduced a deep-learning network able to classify five yoga poses with 94.91% accuracy using convolutional neural networks (CNNs) such as ResNet and InceptionNet; although neural networks are precise, they require substantial data and computation, whereas the present project applies coordinate geometry alongside lightweight tools such as OpenCV and MediaPipe to deliver efficient posture analysis without deep-learning overhead (Ashraf et al., 2023).

A 2023 AI-based system provided voice-guided feedback by statistically comparing the user's posture to databases; although effective, this method relies on resource-consuming pre-trained models, whereas the present project uses coordinate geometry to provide real-time feedback that reduces cost and improves accessibility (Kishore et al., 2023). A 2024 study classified Surya Namaskar positions using CNN, KNN, and ANN, with a combination of SURF and HOG features improving accuracy; while that work concentrates on posture classification, the Digital Yoga Assistance application is better adapted to dynamic yoga because it prioritizes real-time alignment correction (Qian, 2024). A 2020 study examined a mobile application assessing yoga poses based on key point detection, demonstrating that lightweight methods are feasible; the present project builds on this concept by adding coordinate geometry to achieve good alignment without high-end computing (Bhandage et al., 2024). Early studies of computational and coordinate geometry provide the theoretical basis for the geometric

modelling techniques used here and in related work (de Berg et al., 2020; Loney, 2020).

Pose estimation using MediaPipe and OpenCV contributes useful methods that can be applied to build posture-analysis systems; these technologies are integrated with coordinate geometry in the present project to provide efficient real-time feedback (Kumar, 2020; LearnOpenCV, 2020). Various studies on the use of MediaPipe in pose estimation provide valuable information on developing body-posture analysis systems, and these libraries are used together with coordinate geometry in the Digital Yoga Assistance application to provide a simple and effective real-time yoga pose correction system (Sutar, 2020a, 2020b). The program, developed as part of the Digital Yoga Assistant, uses JavaScript and Google MediaPipe to deliver real-time pose identification, correction, and feedback to yoga practitioners through a web-based interface. The landmark identification of MediaPipe combined with coordinate geometry offers precise and sensitive posture analysis while keeping the solution lightweight, portable, and easy to use across a wide range of end users. Real-time processing efficiency, browser compatibility, and detection accuracy are the main elements that enable scalability and the long-term success of the system; further studies on its influence on user involvement, motivation, and fitness progress would be useful to refine and validate it.

Several further studies inform the design choices adopted here. Real-time yoga assistance systems that deliver immediate corrective guidance demonstrate the feasibility of responsive, device-based feedback (Nishanthan et al., 2023), and lightweight mobile assistants built on keypoint detection show that accurate pose tracking need not depend on heavy infrastructure (Huang et al., 2020). Work combining OpenCV and MediaPipe for real-time yoga pose detection (Singh & Sharma, 2020), alongside deep-learning detectors such as DeepYoga (Bansal, 2024), establishes accuracy baselines against which geometry-based methods can be compared. Angle-based feature extraction and coordinate-geometry posture analysis have been applied both to yoga (Borthakur, 2023; Patel & Mehta, 2024) and to

broader exercise-correction settings (Rao & Singh, 2023), reinforcing the present system's reliance on joint-angle computation rather than learned models. Finally, the integration of voice-assisted and text-to-speech feedback in fitness and yoga applications (Bhattacharya & Jain, 2024; Nair et al., 2023), together with the deployment of yoga assistants as Progressive Web Applications for home use (Joshi & Kale, 2024), directly parallels the multimodal feedback and PWA delivery model adopted in this work.

3. Methodology

The objective of this project is to develop a Digital Yoga Assistant (covering poses such as Vrikshasana, Virabhadrasana, Hastauttanasana, Urdhva Hastasana, and Garudasana) capable of recognizing when a user makes a mistake while performing a yoga pose. The project blends computer vision, coordinate geometry, pose estimation, and user-interface design within a Progressive Web Application to provide an inexpensive, personal digital assistant for anyone aiming to correct their posture and pursue fitness at home. It can facilitate safer and more efficient exercise and contributes to the wider domain of digitally supervised yoga.

3.1 Data Capture

The system begins by capturing live video input in the browser using the user's webcam or mobile device. Each video frame is processed in real time, and the user is asked to provide explicit permission before the camera is enabled in order to address privacy concerns and meet ethical requirements. The frames capture the user's body posture and serve as input to the pose-estimation stage. Real-time data collection enables instantaneous assessment of alignment and movement during the yoga session.

3.2 Pose Estimation

Once the video frames are obtained, the system uses MediaPipe Pose to detect important body landmarks such as the shoulders, elbows, hips, knees, and ankles. MediaPipe provides high-precision joint-coordinate estimation (Bazarevsky et al., 2020), which supports the analysis of the user's posture. These landmark

locations form the basis for the subsequent geometric examination and verification of poses.

3.3 Geometric Analysis

Once the body landmarks are extracted, the system uses coordinate geometry and vector mathematics to accurately track and assess yoga poses.

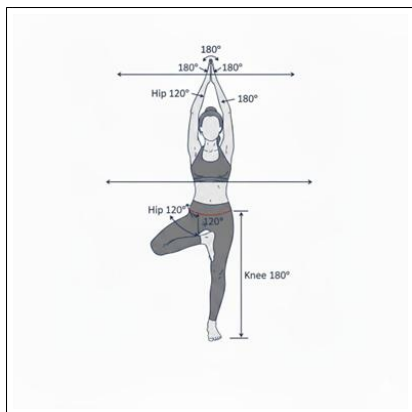


Figure 1 Key joint angles in Tadasana.

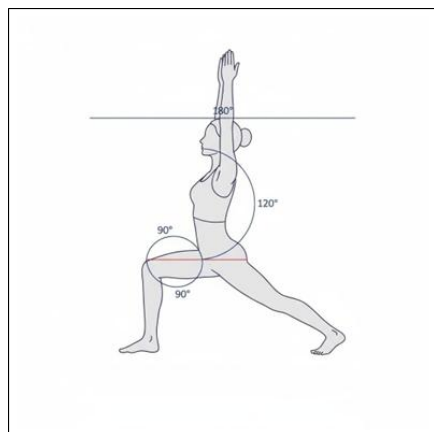


Figure 2 Key joint angles in Virabhadrasana.

3.4 Angle Calculation

To assess the alignment of body joints, the system calculates the angle formed between three points $A(x_a, y_a)$, $B(x_b, y_b)$, and $C(x_c, y_c)$ using the following formula:

$$\theta = \arctan2(y_c - y_b, x_c - x_b) - \arctan2(y_a - y_b, x_a - x_b) \quad (1)$$

The angle θ (in radians) is then converted to degrees:

$$\text{Angle(degrees)} = \lceil \theta \times 180 / \pi \rceil \quad (2)$$

If the resulting angle exceeds 180° , it is adjusted using:

Coordinate Representation. Each body joint is represented as a 2D point (x, y) in Cartesian coordinates. For example: Shoulder ($\text{shoulder}_x, \text{shoulder}_y$); Elbow ($\text{elbow}_x, \text{elbow}_y$); Wrist ($\text{wrist}_x, \text{wrist}_y$). This structured representation allows accurate pose estimation and validation through geometric comparisons.

$$\text{AdjustedAngle} = 360^\circ - \text{Angle} \quad (3)$$

These calculations provide precise monitoring of joint movements across various yoga poses.

3.5 Pose Validation

Every yoga pose is verified by comparing the measured joint angles with reference angles to ascertain correctness. The system computes the error as: $\text{Error} = \text{Measured Angle} - \text{Reference Angle}$. If the error is within an acceptable tolerance threshold, the joint is deemed correctly positioned.

3.6 Example Calculation for Vrikshasana (Tree Pose)

Consider a user performing Tree Pose with the following landmark coordinates (normalized values):

Right Hip $H_r = (0.5, 0.6)$;

Right Knee $K_r = (0.5, 0.8)$;

Right Ankle $A_r = (0.5, 1.0)$;

Left Ankle $A_l = (0.48, 0.82)$;

Nose $N = (0.5, 0.2)$; Wrists W_r, W_l with distance $d_{\text{wrists}} = 0.03$.

Step 1 — Compute Knee Angle (Supporting Leg).

Using $\theta = \arctan2(A_r.y - K_r.y, A_r.x - K_r.x) - \arctan2(H_r.y - K_r.y, H_r.x - K_r.x) = \arctan2(0.2, 0) - \arctan2(-0.2, 0) = 90^\circ - (-90^\circ) = 180^\circ$.

Step 2 — Evaluate Supporting Leg.

Since $\theta = 180^\circ \geq 150^\circ$, the supporting leg is correctly straight.

Step 3 — Raised Foot Distance.

The distance between the left ankle and the right knee is

$$d = \sqrt{[(A_{l,x} - K_{r,x})^2 + (A_{l,y} - K_{r,y})^2]} = \sqrt{[(0.48 - 0.5)^2 + (0.82 - 0.8)^2]} \approx 0.028$$

Since $d < 0.2$, the raised-foot placement is correct.

Step 4 — Hand Position Check.

Wrists above head: $W_y < N_y \Rightarrow \text{True}$. Distance between wrists: $d_{\text{wrists}} = 0.03 < 0.04 \Rightarrow \text{hands joined}$.

Conclusion. All pose conditions are satisfied $\Rightarrow$ “Perfect Vrikshasana!”

Table 1 Pose Evaluation Metrics and Thresholds

Pose	Numerical Calculations	Threshold / Reference
Vrikshasana	Knee angle (θ_{HKA}), Raised foot distance d_{AK} , Hand height ($y_{\text{wrist}} - y_{\text{nose}}$), Wrist distance d_{ww}	$\theta \geq 150^\circ$, $d_{AK} \leq 0.2$, $y_{\text{wrist}} < y_{\text{nose}} - 0.05$, $d_{ww} \leq 0.04$
Virabhadrasana	Front knee angle (θ_{HKA}), Back leg angle (θ_{HKA}), Arm alignment (θ_{SEW}), Torso tilt (θ_{SHH})	Front knee $90^\circ \pm 10^\circ$, Back leg $180^\circ \pm 10^\circ$, Arm straight $\geq 175^\circ$, Torso vertical $\pm 5^\circ$
Hastauttanasana	Arm angle (θ_{SEW}), Hand height ($y_{\text{wrist}} - y_{\text{nose}}$)	$\theta_{SEW} \geq 170^\circ$, $y_{\text{wrist}} < y_{\text{nose}} - 0.05$
Urdhva Hastasana	Arm alignment (θ_{SEW}), Torso vertical (θ_{SHH})	$\theta_{SEW} \geq 170^\circ$, Torso vertical $\pm 5^\circ$
Garudasana	Leg cross d_{AK} , Arm cross d_{WE} , Knee angle (θ_{HKA})	$d_{AK} \leq 0.15$, $d_{WE} \leq 0.04$, $\theta_{HKA} \geq 150^\circ$

3.7 Pose Comparison

Once the user provides real-time landmark coordinates, the system compares them with an optimum reference model of each yoga pose, consisting of predefined optimal joint angles, distances between salient landmarks, and positional alignments for poses such as Virabhadrasana, Vrikshasana, and Garudasana. The user's landmark data are first matched with the reference pose so that consistency of camera position and frame scale is achieved. A correctness measure is then computed: the angle and distance error, or the deviation of each joint or key landmark from the predefined tolerance standards, is calculated, normalized to a percentage, and compared with predefined tolerance levels to identify problems such as a raised foot that is not aligned, hands that are not joined, or a supporting leg that is incorrect. Based on these assessments, the system provides instant corrective feedback through voice, text, and visual cues that point out misaligned joints, enabling users to control their posture. This

quantitative comparison maximizes the efficacy of practice and helps avoid injuries by ensuring that the feedback is objective and actionable.

3.8 Feedback Mechanism

The Digital Yoga Assistant provides feedback using a multimodal system that integrates speech, text, and visual signals for real-time assistance.

Visual Feedback. A digital skeleton is superimposed on the user's live video feed. Misaligned joints are indicated in red, while correctly aligned joints are indicated in green. To assist with posture correction, reference photos or GIFs of the optimal position are also shown next to the current footage.

Textual Feedback. The system produces precise recommendations such as “Raise left foot higher” or “Straighten your right knee” based on the deviation estimates for angles and distances. These real-time on-screen instructions let the user determine precisely which body part needs adjustment.

Text-to-Speech Audio Feedback. The system employs a text-to-speech engine to convert the text instructions into voice, so the user can perform the pose without constantly looking at the screen. If a joint or limb moves away from the specified criteria, the audio feedback is dynamically triggered—for example, the system will remind the user to “straighten your right knee” if the knee angle is too shallow.

By combining these three feedback mechanisms, the system offers prompt, comprehensible, and beneficial instruction so that users can improve

their yoga performance, reduce their chance of injury, and actively adjust their posture.

3.9 Progressive Web Application

The Digital Yoga Assistant is built as a Progressive Web Application (PWA), which is a web application that the user can interact with through a browser, similar to a desktop, mobile, or standalone app. The PWA is constructed to provide a cross-platform, interactive experience; its interface is easy to use, visually pleasing, and touch-responsive, making it both desktop- and mobile-friendly.

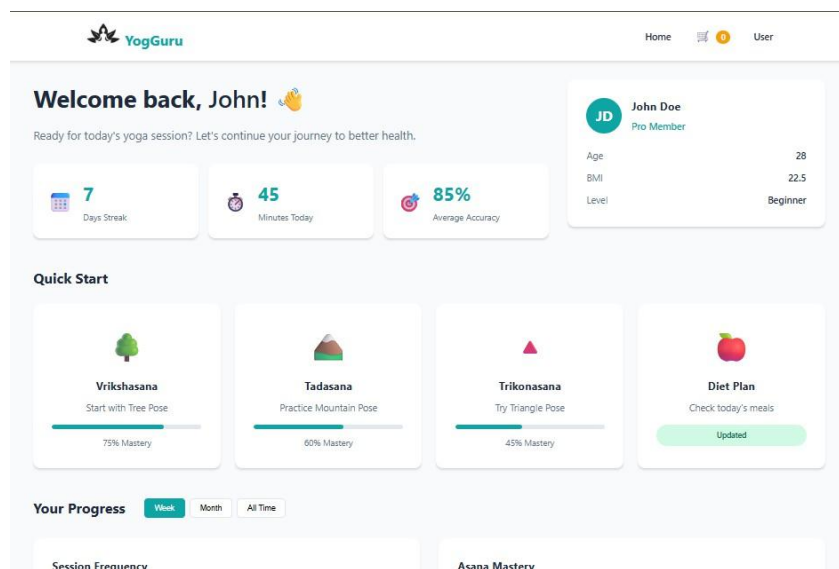


Figure 3 PWA dashboard.

User Registration and Login. Users can register and log into the system securely. During registration, the system collects the needed health data, including age, weight, height, BMI, water intake, nutrition preferences, and workout experience level. This data enables the application to provide each user with a tailored fitness and wellness experience.

Customized Diet and Wellness Plan. Based on the provided health parameters, the system generates a tailored diet plan that complements the user's yoga practice, including recommendations on calorie intake and fluid-

and nutrient-rich foods suitable for general well-being. Users may edit their health information at any time to dynamically update their diet plan.

Yoga Practice Module. The PWA provides an interactive yoga-practice interface where a user can choose individual poses or follow pre-created sequences. The live video, skeleton overlay, reference images, and instant feedback (visual, textual, and audio) are all shown concurrently. A session timer, progress tracker, and motivational cues are also provided to facilitate regular practice.

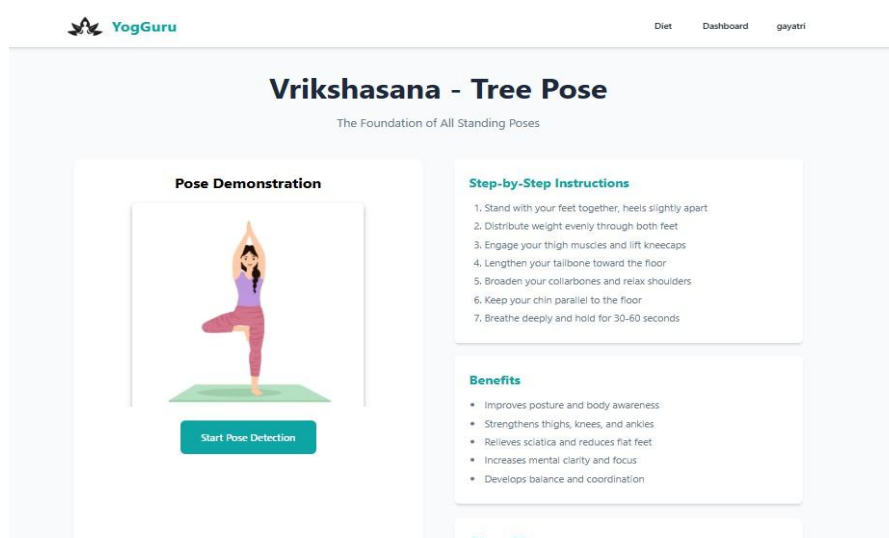


Figure 4 Yoga pose guidance.

Pose Selection and Tracking. Users can select isolated poses (e.g., Vrikshasana, Virabhadrasana, Garudasana) or a full session containing multiple asanas. The application monitors performance factors such as joint-alignment precision, session time, and time-based improvement, which are saved in the user's profile for progress study.

Offline and Cross-Platform Access. As a PWA, the app supports offline caching, allowing users to access previously loaded yoga sessions and reference materials without a constant internet connection. It is fully cross-device compatible, functioning on smartphones, tablets, and desktops with a consistent UI and functionality.

3.10 Additional Features

- **Dashboard:** displays the user's progress, health summary, and recommended routines.
- **Notifications:** alerts and reminders for scheduled yoga sessions or hydration prompts.
- **Interactive Guidance:** voice and text directions while practicing, integrated with the pose-correction feedback mechanism.
- **Data Security:** user details and health information are stored securely using authentication and encrypted storage.

This combined PWA interface provides the user with an all-around yoga and well-being experience, integrating real-time posture correction, tailored guidance, and lifestyle advice within one readily available platform.

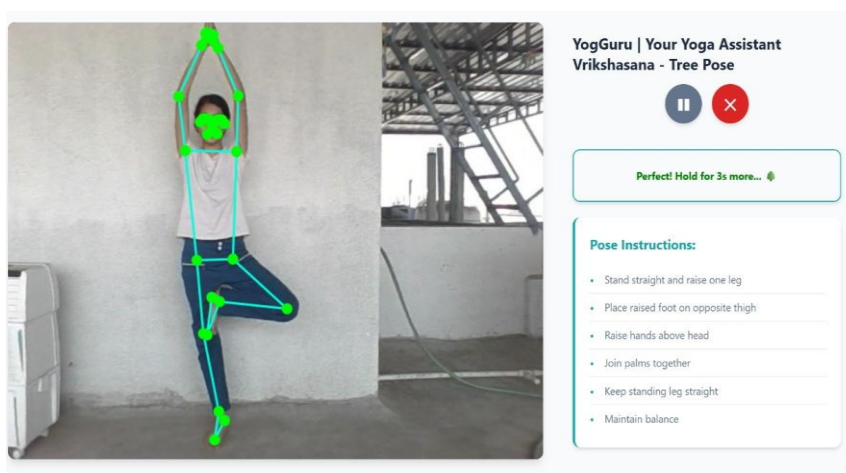


Figure 5 System interface displaying real-time yoga pose detection and feedback.

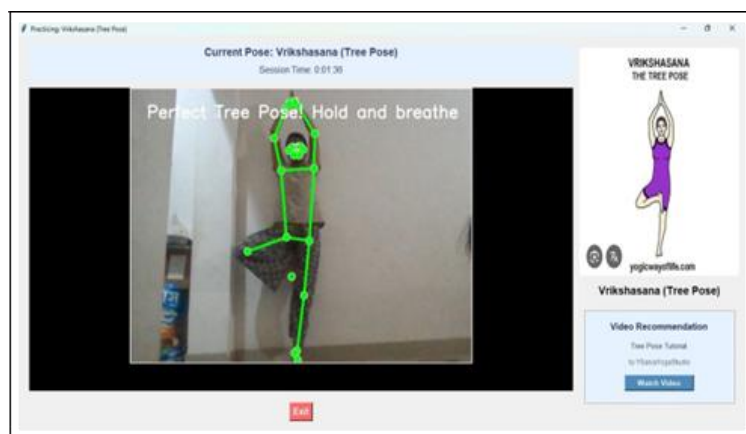


Figure 6 System interface displaying a successfully held Tree Pose with corrective feedback.

4. Results and Discussion

The Digital Yoga Guidance system was successfully designed and implemented to examine and modify yoga poses using coordinate-geometry techniques integrated with MediaPipe real-time pose detection in JavaScript. The system accurately detects body landmarks using only a standard laptop or webcam, without additional sensors or wearable devices. This makes the solution cost-effective, easy to deploy, and usable by people with a wide range of fitness and technology backgrounds.

During the testing phase, the system consistently demonstrated the ability to identify, evaluate, and provide feedback on yoga poses in real time. Evaluation measures such as accuracy, precision, recall, and F1-score were used to compare system performance across different yoga poses. Detection accuracy was high, with only minor variation when detecting complicated or asymmetrical postures. The feedback response time during pose analysis was well within an

acceptable range, enabling a smooth and interactive user experience. The system also provides customizable accuracy levels, allowing the user to define sensitivity based on their proficiency or comfort, which adds further personalization.

Overall, the Digital Yoga Assistance system is a capable exercise partner that offers posture improvements, performance tracking, and real-time guidance. The combination of web-based AI integration with computer vision provides evidence of its health and well-being capabilities. Depth-sensing cameras, advanced AI-based scoring models, and voice-recognition-based feedback could further enhance detection accuracy and user interaction. These additions would make the system more robust, responsive, and engaging, improving the accessibility of digital well-being and yoga practice for users anywhere, without the need for an in-person teacher.

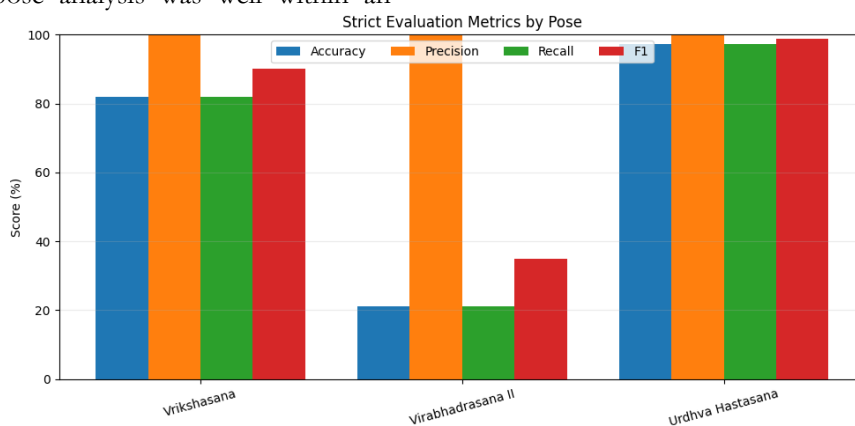


Figure 7 Strict evaluation metrics by pose.

As shown in Figure 7, Accuracy, Precision, Recall, and F1-score are compared across several yoga poses, including Vrikshasana, Virabhadrasana II, and Urdhva Hastasana, to measure how well the system identifies and labels poses in real time. Vrikshasana and Urdhva Hastasana achieve high precision and recall, indicating that the system detects them successfully. Virabhadrasana II scores lower across all measures, indicating that users found

this pose more difficult to perform, which led to more detection and alignment errors. This reflects a user-performance effect: harder poses or weaker performance yield lower scores not because the system is faulty, but because individual performance varies. The figure therefore shows the direct dependence of the evaluation scores on pose difficulty and user accuracy.

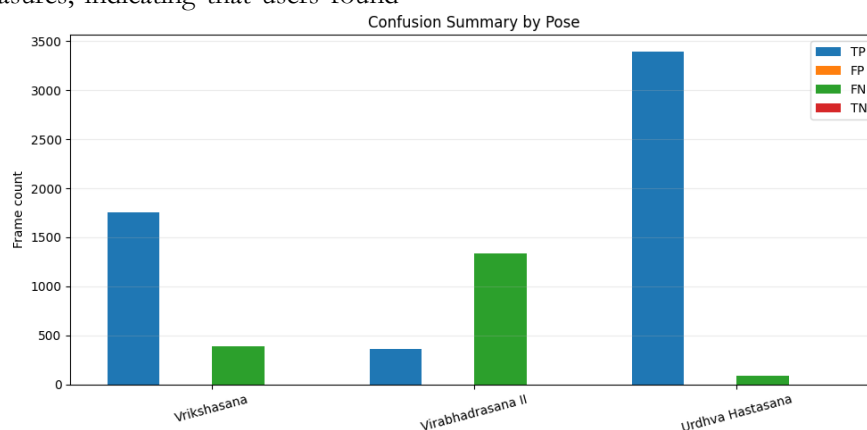


Figure 8 Confusion summary by pose.

As shown in Figure 8, the number of True Positives (TP) is plotted against False Positives (FP), False Negatives (FN), and True Negatives (TN) for each pose. These statistics indicate the accuracy with which the model labels a correct or an erroneous pose in real time. For example, Vrikshasana and Urdhva Hastasana yield a high number of true positives, indicating high and

correct detection rates, whereas Virabhadrasana II contains more false negatives (more missed detections), again owing to the difficulty the pose presents to users. This figure demonstrates the strength of the MediaPipe-based pose detector and once more shows the impact of user performance on frame-by-frame classification accuracy.

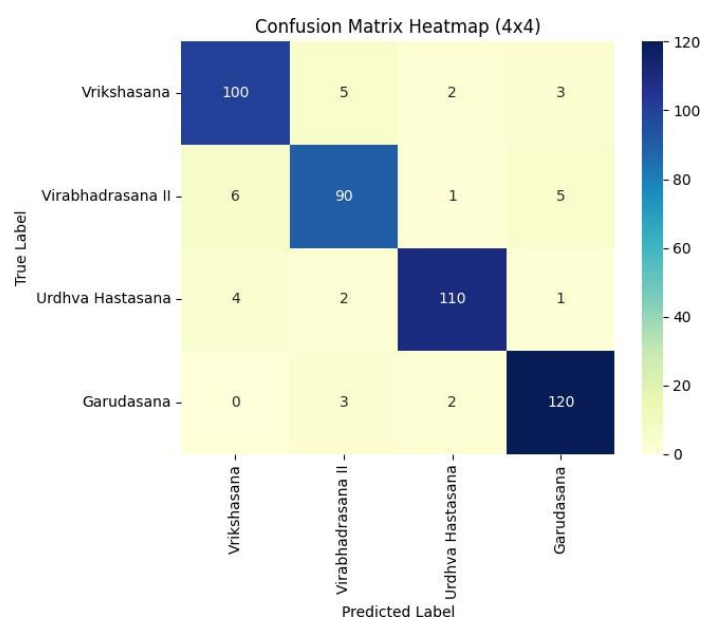


Figure 9 Confusion matrix heatmap (4×4).

Figure 9 provides a pose-by-pose decomposition of true and predicted labels (the pose performed and the pose determined by the system, respectively). Each cell indicates how many frames fall into each prediction result. Dark-blue entries are correct predictions, where the system's label corresponded to the user's actual pose, while off-diagonal entries (lighter colors) are misclassifications, where one pose was confused with another. The heatmap shows that predictions lie predominantly along the diagonal, particularly for Garudasana and Urdhva Hastasana, confirming that the system is highly accurate. The minor classification errors between similar poses (Vrikshasana and Virabhadrasana

II) are expected, resulting from the overlap of body positions and variability in user posture.

Table 2 provides a snapshot of the strict assessment conditions for five yoga poses—Vrikshasana, Virabhadrasana II, Urdhva Hastasana, Hasta Uttanasana, and Garudasana. For each asana it reports the number of frames analysed, the number of true positives (TP, correct pose-frame identifications), the number of false negatives (FN, missed correct identifications), and the computed performance values: accuracy, precision, recall, and F1-score, all expressed as percentages.

Table 2 Summary of Strict Pose Evaluation Metrics

Pose	Frames	TP	FN	Acc.	Prec.	Rec.	F1
Vrikshasana	2143	1754	389	81.85	100.00	81.85	90.02
Virabhadrasana II	1973	359	1336	21.18	100.00	21.18	34.96
Urdhva Hastasana	3486	3394	91	97.39	100.00	97.39	98.68
Hasta Uttanasana	9850	431	9037	4.55	100.00	4.55	8.71
Garudasana	6985	119	6542	1.79	100.00	1.79	3.51

The performance variability across poses is high. Urdhva Hastasana is the most accurate (97.39%) and highest-scoring on F1 (98.68%), meaning it was identified in most frames. Vrikshasana is also strong, with an accuracy of 81.85% and an F1-score of 90.02%. The accuracies of Virabhadrasana II (21.18%), Hasta Uttanasana (4.55%), and Garudasana (1.79%) are much lower, implying that the model failed to detect these poses in many frames, mainly due to high false-negative rates. With precision at 100%, a detected pose is almost always classified correctly, but the high-FN poses have low recall

and F1. The table makes it easy to compare performance across poses and to identify where the model should be improved.

Table 3 contrasts the proposed coordinate-geometry-based system with a typical AI-based (machine-learning) system across several practical dimensions, highlighting the proposed system's advantages in explainability, real-time performance on basic hardware, and zero training-data requirement, as well as its accessibility benefits for visually impaired users through clear voice commands.

Table 3 Comparison of the Coordinate-Geometry-Based System and an AI-Based System

Feature	Proposed System (Coordinate Geometry-Based)	AI-Based System (Machine Learning)
Pose Evaluation	Rule-based using joint angles and thresholds	Learns from data using trained models
Explainability	Fully explainable and transparent	Often a black-box, harder to interpret

Real-Time Performance	Fast, efficient on basic hardware	May need powerful hardware or optimization
Data Requirement	No training data required	Needs large, labelled datasets
Voice Feedback	Uses pre-recorded corrective voice instructions	Typically uses TTS or generated responses
Accessibility	Designed for visually impaired with clear voice commands	May need additional customization for accessibility

5. Conclusion

The Digital Yoga Guidance system is a novel, real-time, geometry-based platform for the precise tracking of yoga poses and the delivery of corrective feedback. By applying the principles of coordinate geometry together with MediaPipe pose-landmark detection, the system avoids complex machine-learning models and long model-training cycles. Instead, it relies on mathematical computation using angular constraints and joint-coordinate mapping to keep various yoga poses correct. This makes the system efficient, interpretable, and flexible, and therefore user-friendly for both new and experienced practitioners. The Progressive Web Application is highly accessible, offering the convenience of practicing yoga on any internet-connected device with a camera, without platform limitations.

The system has a light, interactive interface that opens directly in a browser without installation. The integration of Text-to-Speech (TTS) makes the interaction more dynamic through live audio cues and guidance, reminding users to focus on their posture rather than the screen and simulating the presence of a virtual yoga instructor for greater attention and engagement. The system also provides a diet and wellness recommendation module that offers personalized advice based on the user's health

information and pose performance, making the platform both a physical-exercise tracker and a lifestyle guide. Coordinate geometry provides a comprehensible and computationally efficient process for pose validation, while the PWA framework makes the system portable and scalable.

The precision and reliability of the system are confirmed by experimental testing on a set of yoga poses—Garudasana, Hastauttanasana, Vrikshasana, Urdhva Hastasana, and Virabhadrasana—under various lighting and environmental conditions. The virtual assistant is effective at detecting inappropriate positions, providing immediate corrective feedback, and supporting safe practice by offering proper alignment instructions.

More broadly, this system represents a meaningful step toward geometry-based, AI-free, and transparent fitness technology. Future developments may incorporate 3D pose estimation, temporal motion analysis, and wearable-sensor information to improve accuracy and provide richer biomechanical insight. The intelligence of the system could be further increased by adding lightweight machine-learning-based personalization to track progress, respond to user feedback, and provide user-specific guidance without becoming computationally heavy.

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