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Yoga Pose Detection and Feedback System

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Abstract: Human pose estimation plays a vital role in various domains, including fitness tracking, physiotherapy, sports performance analysis, and human-computer interaction. Accurate posture detection is essential to prevent injuries, improve physical activity performance, and aid rehabilitation processes. This research presents a real-time human pose detection and feedback system leveraging the MoveNet deep learning model and TensorFlow. The system captures live video streams using OpenCV, processes the frames with MoveNet to extract key joint positions, and applies an angle calculation module to evaluate movement accuracy. To enhance accessibility and usability, the system integrates a graphical user interface (GUI) built with Tkinter and a text-to-speech feedback mechanism to provide real-time guidance.

The effectiveness of the system is validated through comparative analysis with standard pose models, ensuring that users receive real-time feedback on their posture deviations. The experimental results demonstrate high detection accuracy, rapid processing speeds, and enhanced user engagement, making it a viable solution for automated fitness coaching, physiotherapy monitoring, and interactive learning applications. Additionally, the system reduces the reliance on human instructors by offering automated posture correction, thereby democratizing access to professional-level movement assessment.

Keywords: Human Pose Estimation, MoveNet, TensorFlow, OpenCV, Real-time Analysis, Deep Learning, Yoga Pose Detection.

I. INTRODUCTION

Human pose estimation is a crucial field in computer vision with applications spanning sports, healthcare, workplace ergonomics, rehabilitation, and augmented reality. Correct posture is essential for preventing injuries, improving physical fitness, and aiding medical rehabilitation. Traditional motion capture methods, such as wearable sensors or marker-based systems, provide accurate pose tracking but are expensive, intrusive, and impractical for everyday users.

Advancements in deep learning and real-time computer vision have propelled markerless pose estimation to prominence. Techniques such as OpenPose, PoseNet, and MoveNet facilitate real-time tracking of human key points without the need for specialized equipment. Nevertheless, conventional models like OpenPose necessitate substantial computational resources, rendering them unsuitable for real-time applications on embedded systems or mobile devices.

This research aims to develop a lightweight, real-time pose detection and feedback system using MoveNet, an advanced deep learning model optimized for efficiency. The proposed system detects human poses, computes joint angles, and provides real-time corrective feedback via a graphical user interface (GUI) and text-to-speech engine. The system is evaluated based on accuracy, processing speed, and user experience, ensuring it meets the needs of fitness enthusiasts, physiotherapists, and general users.

II. PROBLEM STATEMENT

With the rise of at-home fitness training, yoga practices, and physiotherapy sessions, there is an increasing need for real-time, automated posture correction systems. Many individuals engage in physical activities without proper guidance, leading to incorrect postures, increased risk of injury, and inefficient workouts. Traditional solutions, such as hiring personal trainers or attending physical therapy sessions, are often costly, location-dependent, and not always accessible to everyone.

Current computer vision-based pose estimation models, such as OpenPose and HRNet, provide high accuracy but require significant computational resources, making them impractical for real-time applications on standard consumer devices. Additionally, these models often lack an integrated feedback mechanism, leaving users without actionable guidance on improving their posture.

There is a pressing need for a lightweight, real-time pose detection and feedback system that can operate efficiently on consumer-grade hardware while providing instant feedback on posture alignment. The system should integrate deep learning, computer vision, and audio-visual feedback to ensure that users receive real-time corrections, reducing injury risks and improving overall exercise effectiveness. This research aims to address these challenges by developing a MoveNet-powered pose detection and feedback system, optimized for real-time user interactions in fitness training, physiotherapy, and rehabilitation settings.

III. LITERATURE REVIEW

In order to achieve precise posture alignment and lowerthe risk of injury, effective feedback is vital in yogapractice. Real-time pose correction, which is crucial inyoga because of the accuracy of alignment needed, isfrequently absent from traditional fitness applications.Instantaneous corrective feedback has been shown toimprove learning and prevent injuries in users [1]. Thisneed is met by recent developments such as OpenPose,which provides real-time body key-point detection andis appropriate for correcting yoga posture, with studiesreporting accuracy rates of around 86.2% inapplications requiring ergonomic analysis and feedback[5]. OpenPose detects key points from live video feeds,providing users with immediate feedback and enablingthem to instantly correct their posture. Meanwhile, byidentifying minute details in body alignment andposture, neural network models like YoNet furthermaximize feedback accuracy [3].

Voice-guidedinstructions help users maintain their focus on the poseinstead of the screen, according to research on the roleof visual and auditory feedback. Like a virtual yoga instructor, this allows for minimal distraction andincreases engagement.Visual aids that help maintain proper alignment andimprove user understanding include color-codedskeletons that show correct and incorrect postures,which have been shown to improve user accuracy byup to 15% in some applications [4]. Deep learningmodels that combine CNN and OpenPose areparticularly useful for real-time pose correctionbecause they accurately identify body key points,reaching accuracies over 91% in postural correctiontasks. Research indicates that when it comes toassessing and giving precise feedback on posturaldeviations, deep learning performs better thanmoreconventional techniques like logistic regression [2].

OpenPose's effectiveness in identifying and resolving
postural misalignments has been demonstrated by
ergonomic research, which has important ramificationsfor yoga practice as well as more general fitnessapplications [5]. Real-time correction systems withfeedback loops compare user postures to the
recommended yoga poses and recommend adjustmentsas necessary. It has been demonstrated that theseongoing feedback systems greatly enhance yogapractitioners' learning outcomes [6],[8]. Research onhuman pose estimation demonstrates the value ofseveral sophisticated models, such as CNN and LSTM,which improve classification and correction accuracyfor yoga poses, reaching upwards of 90% in certainimplementations [7],[10].Furthermore, various deeplearning-based techniques have demonstratedencouraging outcomes in correctly classifying andgiving users constructive criticism on their poses, withaccuracy rates around 88% or higher, providing crucialassistance for self-learning andenhancing postureaccuracy during live yoga practice [1],[9].

IV. METHODOLOGY

A. System Architecture:

The Yoga Pose Detection and Feedback System is designed to assist users in performing yoga poses correctly by providing real-time feedback based on body posture analysis. The architecture consists of multiple interconnected modules that work together to ensure seamless functionality. The system follows a structured workflow, beginning with user authentication and leading to pose execution and feedback generation.

The system starts with a User Authentication and Account Management Module, where users enter their credentials to access the application. If they do not have an existing account, they can register by providing personal details, including information about any past injuries. All credentials and medical history are securely stored in a MySQL User Databaseto personalize the user experience and minimize injury risks. Once authenticated, users are directed to the main interface of the application.

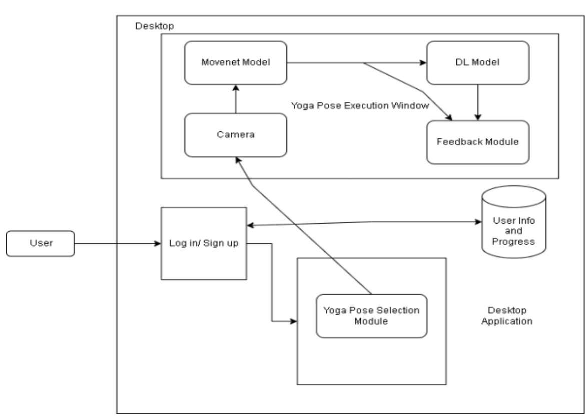

Fig 1. High Level System Architecture

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Following authentication, users enter the Pose Selection Module, where they can choose from a predefined list of yoga poses. Before they proceed, a Disclaimer Screen is displayed, informing them about potential physical risks and advising them to take necessary precautions. This ensures that users acknowledge and accept responsibility for their movements during the session.

Once a pose is selected, the Pose Execution and Key point Detection Module activates the user's camera, providing a live video feed alongside a reference image of the selected pose. The MoveNet Model is used to detect key points on the user's body in real time. The system then calculates the angles formed by key joints to assess the accuracy of the user's pose. This information is critical in determining whether the user’s form aligns with the correct posture.

The extracted key points and calculated angles are then processed by the Deep Learning-Based Pose Evaluation Module. If the detected posture is accurate, a success message is displayed, confirming that the pose has been performed correctly. However, if deviations are detected, the system generates feedback to guide the user in correcting their form.

To facilitate pose correction, the Corrective Feedback Module analyzes the user's detected posture against the ideal pose and generates up to three corrective feedback suggestions based on the extent of deviation. These suggestions are displayed on-screen in text format and can also be provided via voice output using a Text-to-Speech Module. This interactive approach enhances user engagement and ensures accessibility for individuals with visual impairments.

The system operates in a Continuous Monitoring and Iterative Improvement Mode, where it reassesses the user’s pose at regular intervals. This ensures that users can track their progress and make necessary adjustments throughout their session. Once the user successfully corrects their posture, they can proceed to another pose or exit the application.

B. Process Flow:

1) Application Launch:

The user initiates the application, triggering the display of a splash screen that showcases the app name and thematic visuals related to yoga.

2) User Authentication:

After the splash screen, users are directed to the login interface. Existing users can sign in, while new users are prompted to register by providing personal details such as name, age, any prior injuries, or health conditions. This data helps personalize the yoga session experience.

3) Pose Selection Interface:

Once authenticated, users proceed to the Yoga Pose Selection Module, where they choose a specific yoga asana. This selection signals the system to begin preparation for real-time posture tracking and analysis.

4) Camera Activation and Live Feed:

The system activates the computer’s webcam to capture the user's movements. The real-time video feed is continuously sent to the pose detection engine for processing.

5) Keypoint Detection via OpenPose:

The OpenPose Module analyses the live feed, detecting key body landmarks such as joints and limb positions. These keypoints are crucial for evaluating the accuracy and alignment of the performed pose.

6) *Pose Assessment by Deep Learning Model:*

The extracted skeletal keypoints are forwarded to a pre-trained deep learning model. This model compares the user's posture against an ideal version and identifies any misalignments or errors.

7) Real-Time Corrective Feedback:

Based on the analysis, the Feedback Module generates actionable guidance like "raise your left arm" or "straighten your spine." These corrections are shown on-screen and optionally delivered through voice prompts to enhance clarity.

8) User Adjustment and Iteration:

Users adjust their posture in response to the guidance. The system continues to capture new frames, reassessing and providing updated feedback in a continuous loop throughout the session.

9) Session Completion and Data Logging:

When the yoga session ends or the application is closed, the system stores session data locally. This includes performance metrics such as pose accuracy, correction history, and improvement trends. Users can review this data to track progress and improve future performance.

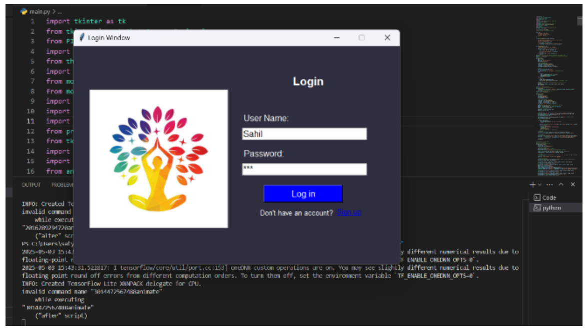

Fig 2. User Login Window

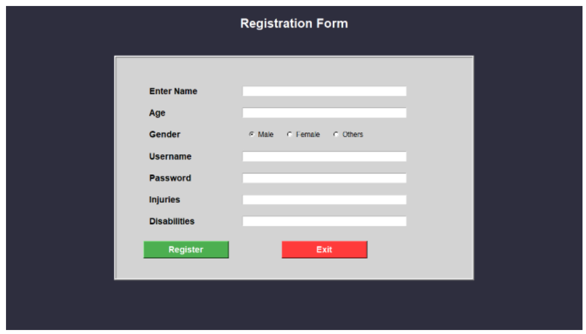

Fig 3. User Registration Window

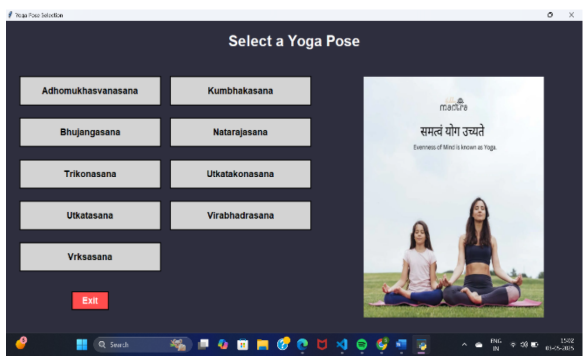

Fig 4. Pose Selection Window

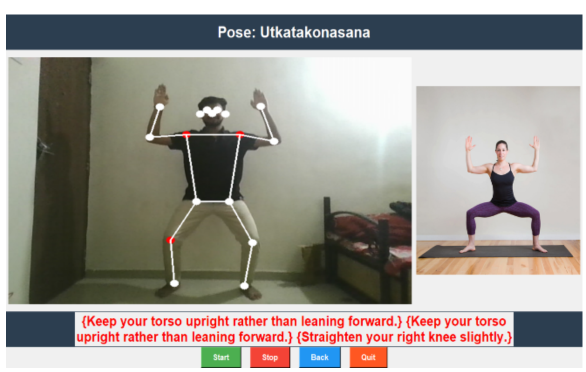

Fig 5. Pose Execution Window

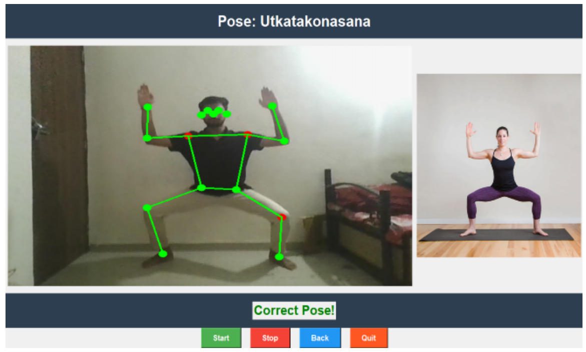

Fig6. Pose ExecutionWindow with correction feedback

C. Dataset

The dataset used for training and evaluation of the yoga pose detection system is a custom dataset that combines multiple publicly available datasets, primarily Yoga-82 and other similar pose datasets. Yoga-82 is a well-established dataset that contains a diverse collection of 82 different yoga poses, with images labeled accordingly for supervised learning. This dataset provides a solid foundation for model training by covering a wide range of common and complex yoga postures.

To enhance the dataset's diversity and improve generalization, additional pose images from various open-source datasets and manually annotated images were incorporated. These supplementary data sources include images from real-world yoga sessions, ensuring that the system can effectively recognize and analyze poses across different body types, lighting conditions, and camera angles. The dataset was preprocessed to extract key-point annotations, which were aligned with the MoveNet framework for seamless model integration.

Each image in the dataset is labeled with pose names, key-point coordinates, and angle measurements. These annotations facilitate training the deep learning model to accurately assess posture correctness and deviations. The dataset was further augmented using image transformations, such as rotation, flipping, and brightness adjustments, to improve model robustness against variations in user positioning and environmental factors.

By leveraging this extensive dataset, the system ensures high accuracy in yoga pose detection and feedback generation, making it adaptable to real-world applications and user needs.

D. Performance Evaluation

The performance of the yoga pose detection system was evaluated using multiple metrics, including test accuracy, confusion matrix analysis, and classification reports. The system achieved a binary model test accuracy of 0.9933, demonstrating high reliability in distinguishing correct and incorrect poses. The evaluation was conducted on a variety of yoga postures, ensuring robustness across different movements and user postures.

Table 1 . Overall Model Performance

Metric	Value
Binary Model Test Accuracy	0.9933
Precision	0.99
Recall	0.99
F1-Score	0.99

The detailed analysis of each pose indicates that the model consistently achieves high precision and recall values, effectively identifying correct and incorrect yoga poses.

The system's robust classification capability ensures accurate posture evaluation, making it a highly effective tool for yoga practitioners of all levels. Real-time feedback based on pose classification and deviation analysis enhances user engagement, helping users refine their movements and posture efficiently.

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By incorporating deep learning-based assessment with real-time feedback, the yoga pose detection system delivers a comprehensive solution for automated posture correction and training guidance.

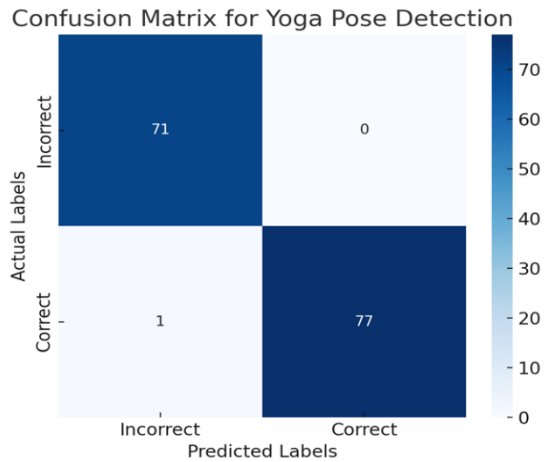

Fig 7. Confusion Matrix for Yoga Pose Detection

Table 2.Performance Breakdown by Pose Type

Pose Name	Samples	Accuracy
Adhomukhasvanasana	78	98.72%
Ardhamatsyendrasan	54	100.00%
Kumbhakasana	40	100.00%
Natarajasana	31	96.77%
Trikonasana	23	100.00%
UtkataKonasana	32	100.00%
Utkatasana	68	100.00%
Vrksasana	58	96.55%
Bhujangasana	38	100.00%
Natarajasana	25	100.00%

The model performs exceptionally well, with 99.33% accuracy.
False classifications are minimal (only one incorrect prediction out of 149 samples).
Precision and recall values indicate reliable classification performance, making the system highly effective for real-time yoga pose detection.

V. RESULT

The evaluation results confirm that the Yoga Pose Detection and Feedback System effectively identifies and classifies yoga poses with high accuracy and precision. The real-time feedback mechanism ensures that users can adjust their postures promptly, improving their alignment over time.
Overall Model Performance: The system achieved a 99.33% accuracy rate, as evidenced by the confusion matrix and classification report. This highlights the robustness of the deep learning model in distinguishing correct and incorrect yoga poses.
Pose-Specific Performance: The analysis for individual poses shows that most poses, such as Ardhamatsyendrasan, Kumbhakasana, Bhujangasana, and Trikonasana, were classified with 100% accuracy. The model performed slightly lower on poses such as Natarajasana and Vrksasana, but still achieved an impressive accuracy of over 96%.

Real-Time Feedback Efficiency: The integration of MoveNet and the deep learning model allowed the system to process live camera feeds with minimal latency. Users were able to receive immediate feedback based on angular deviations, ensuring a seamless and interactive experience.

Classification Performance Metrics: The precision, recall, and F1-score values consistently remained above 0.99, confirming the system's ability to minimize false classifications and maximize pose recognition accuracy.

User Experience and Adaptability: The text-to-speech module and visual feedback provided clear and actionable guidance, making the system user-friendly for beginners and advanced practitioners alike. The model's adaptability to different user environments and body types further enhances its practical usability.

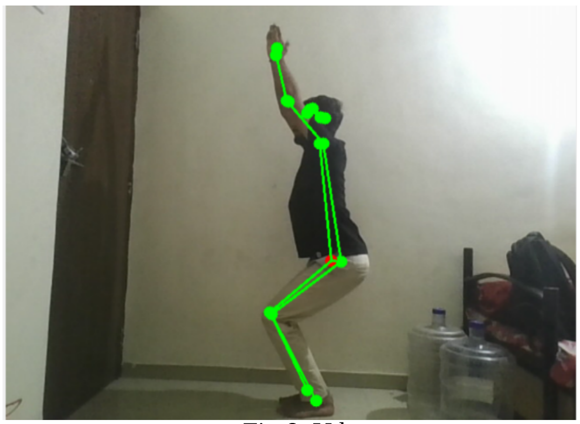

Fig 8. Utkatasana

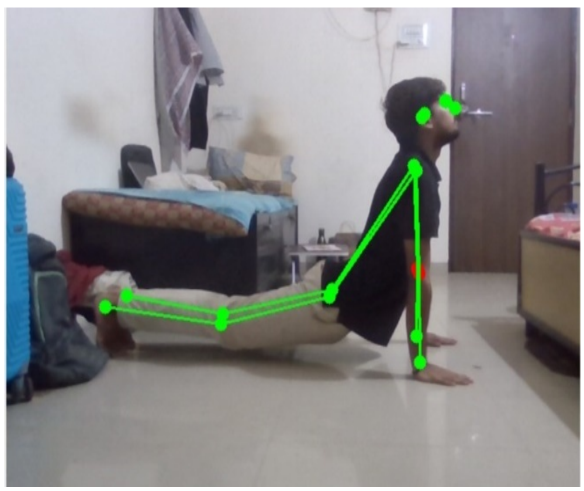

Fig 9. Virabhadrasana

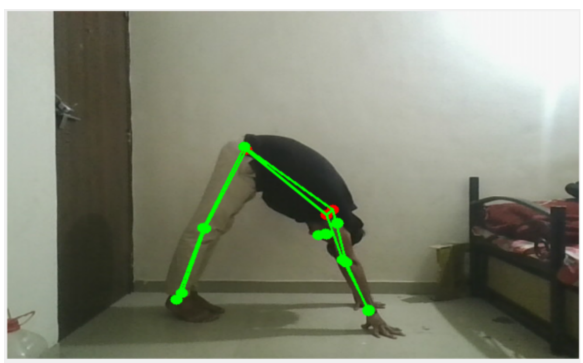

Fig 10. Adhomukhasvanasana

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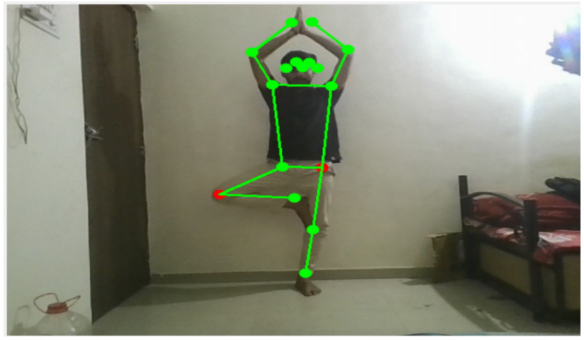

Fig 11. Bhujangasana

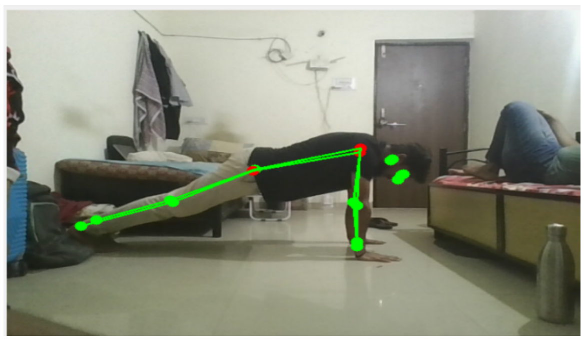

Fig 12.Vrksasana

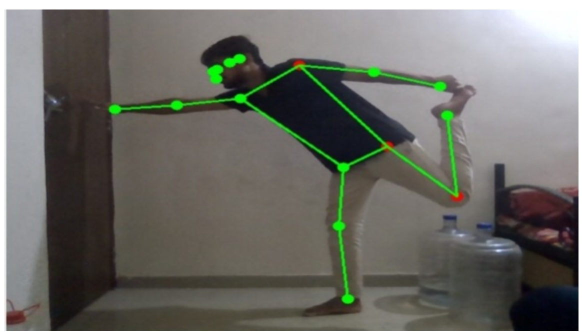

Fig 13.Kumbhakasana

Fig 14.Natarajasana

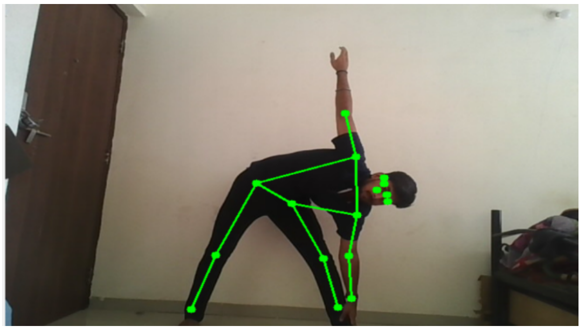

Fig 15.Utkatakonasana

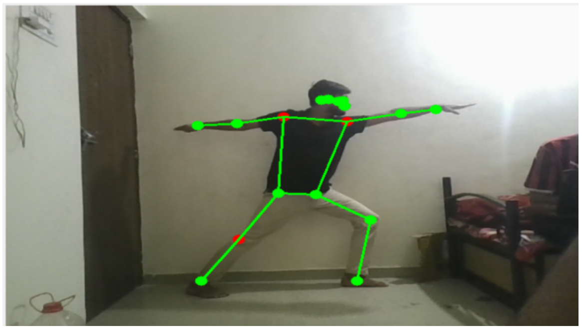

Fig 16.Trikonasana

VI. CONCLUSION

The Yoga Pose Detection and Feedback System successfully achieves its goal of providing real-time posture analysis and corrective feedback to users practicing yoga. By leveraging MoveNet for key-point detection and a deep learning-based evaluation model, the system effectively classifies yoga poses with high accuracy and efficiency. The results demonstrate that the system achieves an overall 99.33% accuracy, with several poses classified with 100% accuracy, ensuring a reliable and precise evaluation mechanism.

The integration of text-to-speech guidance and visual feedback enhances user engagement, making it easier for individuals to adjust their poses in real time. The system is designed to be adaptable for yoga practitioners of all skill levels, providing a user-friendly experience that promotes safe and effective yoga practice.

Future enhancements could include expanding the dataset to incorporate more diverse body types and postures, integrating edge computing solutions for deployment on mobile devices, and improving the feedback mechanism with AI-driven adaptive learning. These improvements would further enhance accessibility, usability, and real-time performance, making the system a valuable tool for fitness training, physiotherapy, and wellness applications.

In conclusion, the proposed system provides a technologically advanced, accessible, and practical solution for individuals looking to refine their yoga practice with automated, real-time posture correction. The combination of deep learning, real-time video processing, and interactive feedback makes it a significant contribution to the field of computer vision-based fitness applications.

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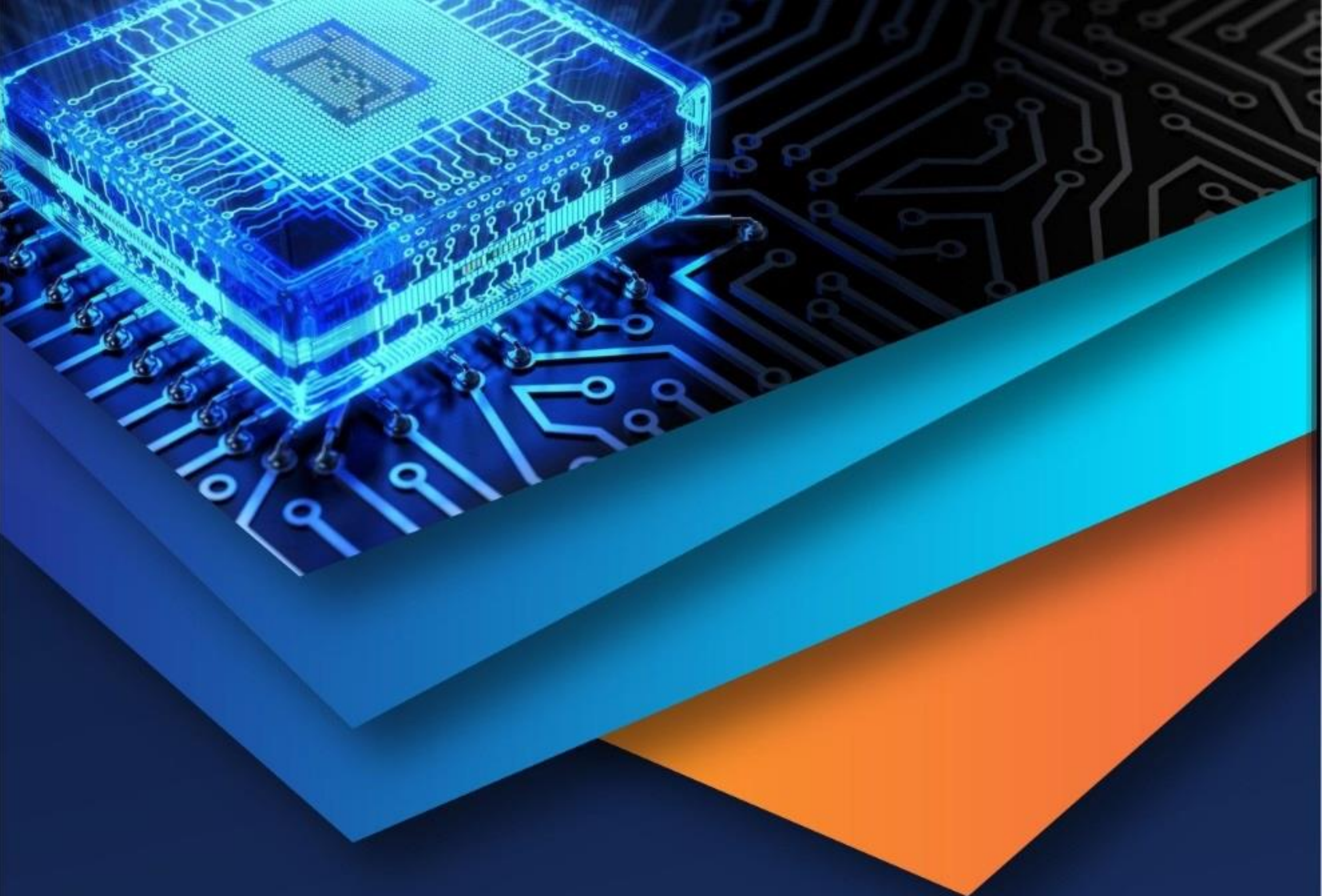

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