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VR–BASED YOGA POSTURE DETECTION, CLASSIFICATION AND CORRECTION

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Abstract

Yoga promotes physical and mental health but practicing correct posture alignment without expert help isn't easy. To solve these problems, we propose a VR-based yoga posture detection, classification, and correction system in this research. Real-time images of yoga poses were captured using an ESP32-CAM interfaced with Arduino and processed with Python. Mediapipe and OpenCV frameworks are responsible for pose detection and classification. At the same time, angle-based calculations help to detect whether the user has achieved Bridge Pose, Mountain Pose, Downward Dog pose, and Warrior II pose. Real-time voice feedback helps users fine-tune their alignment. This system has combined Blynk software with Unity to build an immersive virtual reality experience where a headset shows off pose animations. Combining AI and VR ensures the solution connects practitioners to expert instruction and correct posture in real time, ultimately enhancing the benefits of yoga as a practice.

Keywords:

Mediapipe, OpenCV, Unity, Angle–Based Pose Recognition, Blynk Integration, Voice Feedback

1. INTRODUCTION

Asana has well-established benefits, such as physical flexibility, mental clarity, and emotional health. Many people practice it in a daily routine for better health and stress relief. Yoga itself is made up of several asanas (poses) that require the right alignment and focus. Nevertheless, proper alignment in asanas is difficult for many practitioners to achieve and maintain, particularly if you are a beginner or have begun practicing yoga independently using online tutorials and videos. Poor alignment may result in injuries and not being able to reap the full benefits of yoga. Thus, we must align properly while practicing yoga. Increasingly, the desire to elevate the practice of yoga's safety and accessibility, and to do so at scale, is a growing need as yoga culture grows.[1][4]

Real-time posture analysis and correction through AI and machine learning technologies can transform yoga practice. Powered by AI, the systems can identify and categorize a myriad of types of poses, provide individualized feedback, and monitor the gradual progress of yoga. Different styles of yoga will be recognized, and recommendations will be adjusted based on a person's skill level and health considerations. AI through yoga practice would give the user precise and real-time directions, acting as a personal instructor and making it more efficient and safer for everyone involved. AI-based systems will also provide analytical data to the user, empowering them to improve their performance and dodge common pitfalls, which would upgrade the level of experience on offer [4] [17].

Traditional yoga methods, such as following videos or attending in-person classes, often do not possess the real-time feedback necessary for a beginner or solo practitioner. Without immediate corrections, practitioners are often oblivious to their incorrect postures and thus may incur muscle strain or injury as a result. Such methods also have no provision for personalized feedback based on a user's body type, flexibility, or skill level, thereby limiting the effectiveness of the yoga practice itself. While instructors can correct students in a class, online platforms or videos cannot deliver this feedback because of a lack of interaction, thus making it impossible for a person to achieve optimal results. Hence, there is a strong need for an automatic mechanism that can provide timely and individualized feedback for maintaining proper posture and avoiding injury [10] [16].

The current paper thus presents a VR-based system for detecting, classifying, and correcting yoga postures. The system allows users to recognize immediate feedback about their alignment by combining VR technology with AI for real-time feedback and feedback correction on their posture while a yoga session is on. Advanced machine learning models detect and classify yoga poses, giving feedback in an interactive and immersive way. The combination of VR will enhance the experience, complementing the user's ability to visualize and correct the pose with the help of animations. The system provides a balance between becoming safer, cheaper, and more effective for practitioners while bringing the practices closer to the gap between traditional ideas and technological advancements [12].

The solution carries out its work in the following stages:

- **Data Capture**: The system collects real-time pictures of the candidate performing the yoga pose by an ESP32-CAM camera interfaced with Arduino.
- **Pose Detection and Classification**: The captured images are processed with Python using Mediapipe and OpenCV frameworks for pose detection and classification.
- **Real-Time Feedback**: The systems compare the angle calculations with certain thresholds and give the candidate auditory suggestions for correcting the pose.
- **VR Visualisation**: The VR Unity integrates this with a real-time immersive feel, where a candidate can see animated versions of the correct poses through a VR headset.
- **Iteration**: Continuous performance is logged to track progress and adapt real-time feedback based on the user's performance and ability, which helps the user continually improve.

The remaining sections of this paper elaborate deeply on the system designs and implementation. Section 2 reviews relevant literature and background work on AI and VR applications in yoga. Section 3 describes the methods involved in developing the hardware and software parts of the system. Section 4 is mostly concerned with the results and evaluation of the system's performance. Finally, Section 5 summarizes the conclusions of this technology and its possible applications in enhancing yoga practice.

This system is interfaced with an Arduino for control and coordination. Images of the user's live yoga poses are captured with the ESP32-CAM camera in real-time. The images processed with Python use Mediapipe and OpenCV as core pose detection and classification tools. Mediapipe is a Google-developed versatile framework that implements machine-learning models for real-time human body landmark detection and tracking, thereby identifying key points such as joints and extremities to map them to a skeletal structure for precise pose estimation. OpenCV (Open Source Computer Vision Library) sits atop this with necessary imaging capabilities such as noise reduction, edge detection, and angle calculation that help classify poses and enhance their recognition capability. Unity is used to act as animation for the poses in an interactive environment that allows the user to view correct postures in real-time and interactively. Real-time voice feedback is part of the system and will provide the user with auditory cues and corrections to effectively change his/her pose. Blynk software is used to provide very effective communication between hardware and software for data and feedback coordination. Together, these technologies provide an interactive, immersive, and personalized yoga experience for users.

2. LITERATURE SURVEY

Mane et al. [1] propose the SVM-based pose detection and correction system, grounded on the theory that yoga practice safety and correctness could be improved by providing real-time corrective feedback on a pose. Their work ties in with this paper, which discusses real-time feedback and correction for improving user experience. Waghmode et al. [2] discuss machine learning pose classification and correction for yoga poses. Similarly, this paper uses AI models for pose classification and correction and gives users guidance in real-time.

Ananth and Anuradha [3] used deep learning to accurately classify yoga postures. During the paper, some advanced models, like Mediapipe, are also used to classify poses precisely. Chittineni et al. [4] emphasized real-time machine learning for yoga pose identification and correction in their paper. This approach is reflected in the current paper, where pose detection and voice feedback would help users.

Kulkarni et al. [5] Yoga Pose Recognition Using Deep Learning uses deep learning algorithms to recognize yoga poses correctly. In such a case, the current work rife with OpenCV and Mediapipe fits the task of pose recognition. Borthakur et al. [6], in Yoga Pose Estimation Using Angle-Based Feature Extraction, identify angle-based features for pose estimation. In line with this paper, angle calculations are employed to guarantee the accuracy of pose detection and correction.

Yingdong [7] also outlines classification methods for yoga poses according to OpenPose, emphasizing more CNNs for pose classification. This paper is aligned with the integration of Mediapipe, in which machine learning is used for pose detection. Sharma et al. [8] undertook in Real-time recognition of yoga poses using computer vision for smart health care, a computer vision-based system for yoga pose recognition similar to what this paper does using OpenCV for pose detection and feedback.

The works performed by Gupta and Panwar [9] on AI techniques of yoga pose analysis have received attention. They deal with AI techniques for pose detection and error correction. Pala et al. [10] discuss real-time correction using deep learning in their paper. The other papers cited [11-19] approach AI and machine learning techniques from perspective views and the possibilities of using them in practical implementations for yoga training by seniors, facilitated by voice feedback, guidance through virtual reality, and so on. Finally, all works fall under one of the approaches related to computer vision, machine learning, and other sophisticated AI techniques that assist with yoga practice, which further helps these authors in ideas concerning yoga immersion and interactivity and systems.

3. METHODOLOGY

- **Data Capture**: The system starts to detect postures in yoga by obtaining the live image of the user performing yoga postures with an ESP32-CAM camera linked to an Arduino microcontroller. ESP32-CAM is a small, efficient camera module that an Arduino controls to help manage image-capture functionality. The IP address printed on the Arduino's serial monitor is copied and pasted into a web browser, which opens the CAM server's interface. From here, the CAM interface streams live images of the user. The images are captured automatically through the streaming video using Python scripts and stored in a pre-defined folder for later processing. The integration of hardware and software will permit the seamless collection of data and eventually make room for analyzing and classifying postures in yoga within a framework [5] [12].
- **Preparatory Poses and Warm-Ups for Yoga Posture**: To achieve proper execution of yoga poses and reduction of risk for injuries, preparatory poses and warm-up exercises must, therefore, be included before practicing the main set of asanas. Warm-ups will increase flexibility and also awaken key muscle groups, along with an enhanced sense of body awareness, which makes the transition into the final posture easier. The following warm-up exercises and preparatory poses are suggested for the four yoga postures that are the main subjects of this study: Bridge Pose, Mountain Pose, Downward Dog Pose, and Warrior II Pose.
- To ready the Bridge Pose for execution, laying on the back, pelvic tilts will instill activation of the core and lower back muscles while practicing pelvic tilts where one can gently tilt the pelvis upward and downward. Moreover, supine knee-to-chest stretch loosens up the hip joints. Meanwhile, the work done in Cat-Cow Pose promotes spinal mobility as one begins to perform the Reclined Bound Angle Pose in support of hip opening-the purpose of which is to create space for a backbending range in the Bridge Pose.
- Shoulder and ankle mobility will assure a balanced and stabilized stance in Mountain Pose (Tadasana). Simple drills of shoulder rolls and ankle circle motions improve proper joint flexibility and stabilization. The general workings of the Standing Forward Bend (Uttanasana) increase the length of the spine along with stretching the hamstrings. Finally, Seated Forward Fold (Paschimottanasana) opens up spaciousness and increases flexibility through the spine so that its arrangement remains good in Mountain Pose.
- Along with upper body-strengthening from Downward Dog Pose (Adho Mukha Svanasana), flexibility must also be incorporated in terms of shoulder and hamstring stretch. Engagement of the arms and shoulders during wrist rotations

and arm circles is necessary to avert any joint strain. Child's Pose stretches out the back and shoulders, promoting relaxation, while Plank Pose strengthens the core and the arms, working on the stability and endurance for the final pose.

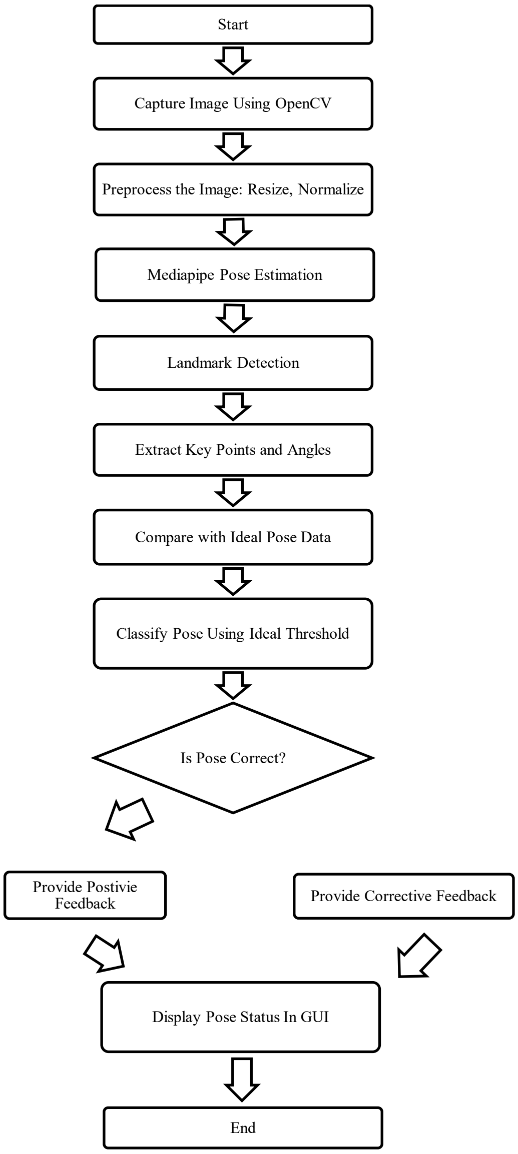

Fig.1. Process Flow of Mediapipe and OpenCV in Yoga Posture Detection

- In Warrior II Pose (Virabhadrasana II), wide hip and leg mobility are necessary to keep this wide stance and deep lunging. Hip circles and gentle lunges serve to mobilize the hip flexors and quadriceps in order to provide stability in that final posture. As preparatory poses, Low Lunge (Anjaneyasana) opens the hips and strengthens the legs; Triangle Pose (Trikonasana) improves equilibrium and adds to the flexibility in the spine and the sides of the body.
- **Pose Detection and Classification**: After receiving pictures from the ESP32-CAM, pose detection and identification are done using Python programming language incorporated in the Mediapipe and OpenCV library. Based on ML, Mediapipe detects human skeletal landmarks by locating certain key body points, such as joints and limb portions. The flexible computer vision library called OpenCV is employed in many pre-processing steps, such as resizing, filtering, and enhancement, to achieve maximum accuracy in detection. The code design integrates both frameworks to find angles of different selected knee, shoulder, elbow, and hip landmarks. Table I shows each pose's angle range set at different body parts. After this, these angles are compared against predefined ranges specific to each yoga pose. Based on this comparison, the identified pose is labeled. This incorporates the downward dog, mountain, warrior II, and bridge poses. The method ensures very accurate detection and classification of poses, allowing aided and real-time feedback and analysis for effective yoga practice [1] [14]. the Fig.1 depicts the process of Mediapipe and OpenCV models in yoga pose detection.

Table.1. Yoga Pose Angle Ranges (°)

Pose Name	Left Elbow	Right Elbow	Left Shoulder	Right Shoulder	Left Hip	Right Hip	Left Knee	Right Knee
Bridge Pose	160-200	160-200	30-350	30-350	Nil	Nil	Nil	Nil
Downward Dog Pose	Nil	Nil	160-245	160-245	Nil	Nil	Nil	Nil
Mountain Pose	154-198	168-200	Nil	Nil	169-196	169-196	Nil	Nil
Warrior II Pose	Nil	Nil	70-120	70-120	Nil	Nil	120-195	120-195

- **Real-Time Feedback:** The system provides real-time feedback on the accuracy of the user's pose by comparing the calculated angles with predefined thresholds and analyzer. When a pose is detected, the system triggers auditory feedback to instruct the user concerning correcting their posture. Python code was developed to give voice feedback whenever the model detects a pose. If no pose is detected, the system also gives a voice alert to inform the user to correct their position once again. The feedback system uses the pyttsx3 library, allowing feedback through voice alerts. This is a text-to-speech conversion library in Python. In this way, all the nuances of the yoga practice are implanted into the cause of interest as the experience remains its original focus to make it fun and engaging [1] [16]. The Table.2 shows the voice feedback given when the model detects each pose.

Table.2. Voice Feedback of the Detected Poses

Pose Name	Voice Feedback
Bridge Pose	Excellent! Keep your hips elevated and maintain balance.
Downward Dog Pose	Nice! Keep your back straight and stretch your legs.
Mountain Pose	Good job! Maintain your posture and keep breathing.
Warrior II Pose	Great! Focus on stretching your arms and balancing your feet.

- **VR Visualisation**: The VR Unity system provides real-time immersion wherein the candidates can see the animated versions of correct yoga poses through a VR headset. The pose name detected by the model is forwarded to Blynk software, which is there to create the widgets and has integrated the Python code of the model with its URL. This helps to connect the pose detection system and the VR setup smoothly. The pose name is then sent to Unity by integrating the Blynk software within Unity. This code then sends the name to Unity, triggering the corresponding animation for the pose detected. The animations are played automatically and seen through the VR headset to provide a user-experience-oriented way of learning and practicing yoga poses [10] [17]. The Fig.2 shows the labels of detected poses in the Blynk software.

Fig.2. Labels of Detected Poses in Blynk Software

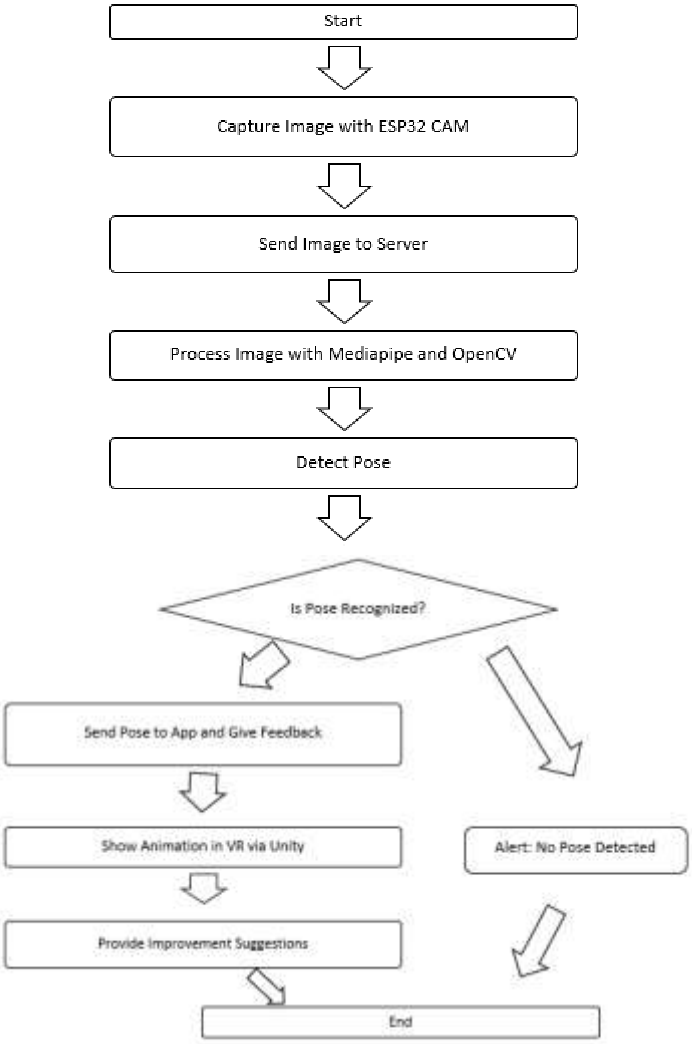

Fig.3. Process Flow Diagram of VR Based Yoga Posture Detection, Classification and Correction

- **Iteration**: Continuous performance tracking is integrated into the system for the monitoring of user progress and real-time feedback. Every detected pose, its angles, and corrections necessary are systematically recorded. This data will help determine the rate of consistency and improvement of an individual over time. The system dynamically adjusts its feedback according to the user's ability level with the help of the analyzed log of performance. This iterative mechanism gives the user personalized heed while growing gradually and steadily in their yoga practice [9] [12]. The Fig.3 illustrates the complete process flow of the VR-based yoga posture detection, classification, and correction system.

4. RESULTS

After successfully incorporating different technologies into one interactive, immersive, personalized yoga training system, four yoga poses: Bridge Pose, Downward Dog Pose, Mountain Pose, and Warrior II Pose were detected and classified through Mediapipe and OpenCV. Real-time voice feedback, given through the pyttsx3 library, provided auditory corrections and alerts to the user experience. The VR aspect created an in-depth visualization of the correct poses, enabling users to understand and follow the desired posture more easily [1] [14].

Fig.4. Mountain Pose Image

Fig.5. Detected Image

Fig.6. Pose Played in Unity

Fig.7. Bridge Pose Image

Fig.9. Pose Played in Unity

Fig.10. Warrior-II Pose Image

Fig.11. Detected Image

The system experienced a few challenges in pose detection and classification. In most cases, poses were raised as Unknown Pose, which was attributed to errors in the angle adjustments when the RL image was captured this also led to the misclassification of poses that were part of the four recognized postures. Another direct error was that classification mismatched sometimes; thus, the Downward Dog Pose was taken for the Bridge Pose, while the opposite used to happen as well.

Fig.12. Pose Played in Unity

Fig.13. Downward Dog Pose Image

Fig.14. Detected Image

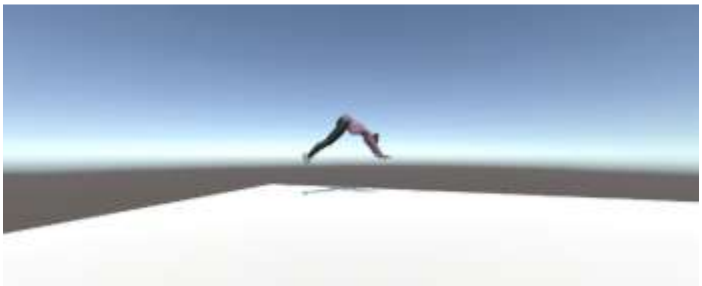

Fig.15. Pose Played in Unity

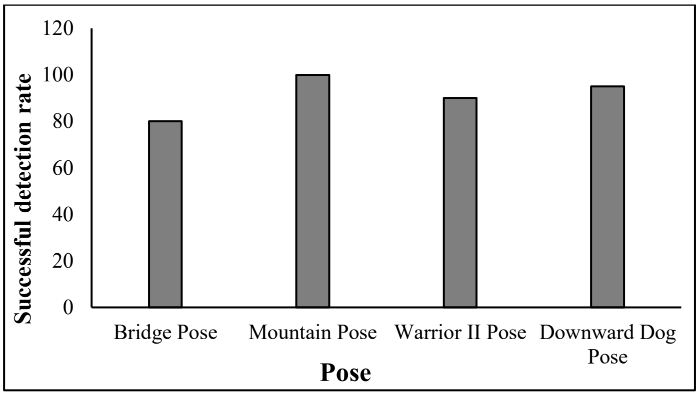

Fig.16. Detection Rates of Yoga Poses by the Trained Model

These errors were largely caused by the overlapping angle ranges and subtle discrepancies in pose alignment [6] [10]. The model's accuracy in detecting the pose is depicted in Fig.16. Given this, the system provides excellent feedback about user performance and records data for continuous development. Adaptive feedback paired with performance tracking allowed the user to improve postures over time, making the system literally a promising tool to support and refine yoga practice and training.

5. CONCLUSION

The purpose of yoga in ancient times, combined with the latest technological innovations such as Virtual Reality (VR) and Artificial Intelligence (AI), aims to improve human wellness by providing real-time feedback, accurate body alignment, and a more personalized approach to yoga. By providing personalized coaching and feedback, the system assists users to learn and correct their postures, regardless of their experience level. The platform relies on AI for the execution of functions, such as precise pose detection and the creation of a virtual reality setting so that users can be enwrapped and gain the benefits of the simulation as the most engaging of the entire experience. Not being available to professional tutors and facilities is not an obstacle; they can do it anyway. We're facing challenges now. For instance, we have to hit the precision threshold for the sensors and utilize high-power instruments. Nevertheless, the system still has the potential to be extended for bio and medical reasons, such as aiding the recovery process. As more technologies are introduced, like the use of computer-generated images and the option of multiplayer gaming, this venture might be the pivot of the wellness revolution, where the option of a technological-savvy and reliable way of practicing sports leads to recovery and thus the immune system is through the treatment [4] [9] [17].

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