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YOGA MUDRA GESTURES ON VIRTUAL SYSTEM

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ABSTRACT

The aim of this project is to develop a Virtual Yoga Mudra Hand Gesture AI Interaction System that measures the percentage of correction from the original Yoga Mudra position. The system uses non-contact input via a camera to capture hand gestures, leveraging computer vision (OpenCV), machine learning (CNN models), and real-time hand tracking to compare the user's hand movements with standard Yoga Mudra positions. The system detects and interprets hand gestures from the external environment, translating them into executable virtual Yoga Mudra interactions by matching them against predefined Yoga Mudra positions. The primary tools include Python for programming, OpenCV for image processing, and a CNN-based deep learning model for gesture recognition, all powered by a standard camera as the input device. This approach ensures high accuracy in recognizing Yoga Mudra gestures while accounting for variations in hand movements due to the external environment. By integrating AI-driven gesture recognition with traditional Yoga Mudras, the system provides real-time results on correctness, making it an accessible and intuitive interface for users. The system bridges traditional Yoga practices with modern assistive technology, ensuring precise hand gesture alignment between the physical (external) and virtual environments for accurate Yoga Mudra verification.

Key points: Artificial intelligence, Machine learning, Computer vision, Deep Learning, camera.

I. INTRODUCTION

Yoga, an ancient holistic discipline that originated in India over 5,000 years ago, is globally recognized for its profound physical, mental, and spiritual benefits. One of its essential yet often underappreciated elements is the use of Mudra symbolic hand

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gestures that are believed to influence energy flow, deepen meditation, and support overall well-being. Mastery of these Mudras typically requires the guidance of an experienced practitioner, as precision in finger positioning is critical; even subtle inaccuracies may diminish the intended benefits. With the rapid advancement of technology, particularly in the domains of Artificial Intelligence (AI) and Computer Vision, traditional practices like yoga are undergoing transformative modernization. The Virtual Yoga Mudra Hand Gesture AI Interaction System exemplifies this fusion by integrating AI-based analysis with classical yogic wisdom. This system employs non-contact camera input (such as webcams or smartphone cameras) to detect and interpret hand gestures in real time. Using deep learning algorithms and computer vision techniques, it compares the user's hand positions to a standardized Mudra database. It then provides immediate feedback, indicating the accuracy of the gesture as a percentage match to the ideal form. By offering real-time posture evaluation and corrective suggestions, the system democratizes access to high-quality Mudra practice. It transforms a traditionally instructor-led activity into an interactive and accessible digital experience ideal for both beginners and experienced practitioners seeking to refine their techniques. Ultimately, the system not only preserves the sanctity of traditional yoga but also reimagines it for a technology-enabled world, enhancing learning, engagement, and efficacy through intelligent feedback.

II. LITERATURE SURVEY

Authors of suggests virtual mouse control by use of hand gesture recognition with the experimental setup of the system makes use of web camera with high-definition recording capability that is installed in a fixed position. The work of illustrates the "concept of virtual mouse creating a mask from a red object and implemented it using Python software with various modules and functions. The research in introduced hand gesture recognition for Human Computer Interaction, enhancing interaction through background extraction and contours detection, exploring multiple sensor modes. Additionally, they have suggested a system using a blue-colored hand pad, a webcam, and Visual C++ with the OpenCV library.

III. METHODOLOGY

The methodology for detecting and evaluating yoga mudras using computer vision and AI involves a series of systematic stages. Each phase contributes to the accurate recognition, classification, and performance assessment of hand gestures, ensuring that the system functions effectively across different users and mudra types.

1. Selection of Target Mudras

The project begins by identifying commonly practiced and therapeutically relevant yoga mudras, such as Chin Mudra, Surya Mudra, Shunya Mudra, Prana Mudra, and others. These mudras are selected for their distinct finger configurations, cultural relevance, and ease of recognition using visual landmarks.

2. Dataset Preparation and Landmark Annotation

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Real-time hand gesture data is collected using a webcam. For each mudra, multiple samples are captured in different lighting conditions and hand orientations. Each sample is annotated based on 21 hand landmarks defined by the MediaPipe library, which include finger tips, joints, and the wrist point.

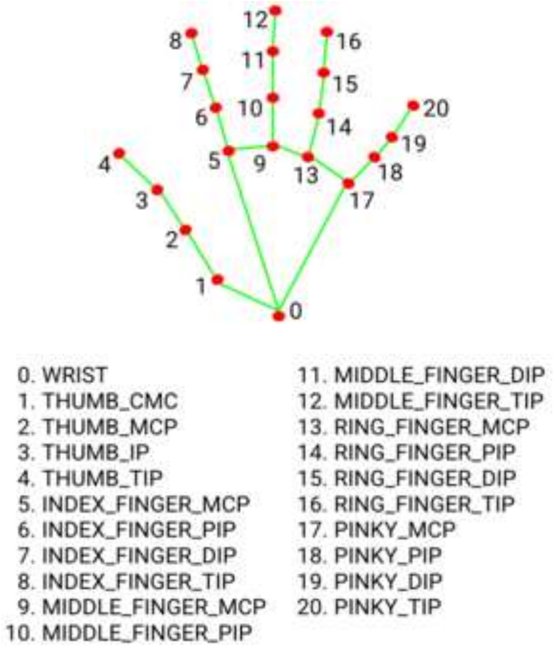

Figure 1: Hand Gesture

3. Hand Landmark Detection Using MediaPipe

MediaPipe Hands, a pre-trained deep learning-based model, is integrated to track and extract real-time hand landmarks. This model detects both single and dual-hand gestures and provides precise (x, y, z) coordinates for each landmark in every frame.

4. Gesture Definition and Rule-Based Conditions

For each mudra, a set of unique geometric and spatial rules are defined. For example, in Chin Mudra, the thumb and index finger tips must touch while the other fingers remain extended. These conditions are translated into mathematical rules based on landmark distances and angles.

5. Euclidean Distance and Angle Calculation

To verify mudra accuracy, Euclidean distances between relevant landmarks (such as fingertip-to-tip or tip-to-joint) are computed. In some mudras, internal finger angles are measured to confirm proper bending or extension (e.g., flexion of the ring finger in Surya Mudra).

6. Real-Time Gesture Capture and Preprocessing

Hand gesture frames are captured using a webcam at 30+ FPS. Each frame undergoes preprocessing including background filtering, normalization of hand size, and hand orientation correction to standardize recognition across users.

7. Threshold-Based Matching for Accuracy Evaluation

A percentage match score is calculated by comparing the detected gesture with the defined mudra configuration. A scoring threshold (e.g., 50-100%) is used to indicate a correctly performed mudra. Visual feedback is provided in real-time to guide user corrections.

8. Dual-Hand Mudra Detection

The system evaluates both hands separately. Each hand’s landmarks are analyzed for mudra-specific configurations, and individual scores are calculated. This is essential for symmetrical mudras like Chin Mudra or Prana Mudra which involve both hands.

9. Visual Output and Gesture Feedback

Using OpenCV, a visual interface displays the user's hand along with overlaid feedback such as recognized mudra name, accuracy percentage, and color-coded indicators. This enables real-time training and improvement.

10. Noise Filtering and Hand Orientation Management

To ensure consistent results, gesture recognition is adapted to work under varying lighting conditions and hand positions. A filtering algorithm is applied to ignore transient hand movements and false positives.

11. User Variation Handling

The model accounts for variability in hand sizes, skin tones, and finger lengths. This generalization improves accuracy across diverse user groups and minimizes the need for model retraining or individual calibration.

12. Error Logging and Continuous Learning

The system logs incorrectly classified gestures and edge cases. These logs help refine the rule base and, in future versions, may be used to train a machine learning model to improve performance using labeled data.

13. Statistical Analysis of Results

After multiple users perform the mudras, the collected accuracy percentages are statistically analyzed. Mean, standard deviation, and distribution curves help assess system consistency and identify mudras that require better rule optimization.

14. Validation Through Repetition and Multi-User Testing

Each mudra is tested multiple times by different users. Consistent accuracy scores across attempts indicate system stability. Mudras with poor repeatability undergo further rule tuning.

IV. PROPOSED ALGORITHM

Input: Live webcam feed
Output: Detected mudra name, accuracy score (%), and visual feedback

Step 1: Initialization

- Import libraries (OpenCV, MediaPipe, NumPy)
- Initialize MediaPipe Hands and webcam

Step 2: Frame Capture & Preprocessing

- Capture frame, convert to RGB
- Detect hands and extract 21 landmarks per hand
- Normalize landmarks relative to wrist

Step 3: Feature Extraction

- Compute relative distances and angles
- Identify finger positions: bent, extended, touching

Step 4: Mudra Matching

- Compare extracted features with mudra reference vectors

- Use cosine similarity or Euclidean distance
- Select mudra with similarity > threshold (e.g., 85%)

Step 5: Accuracy Evaluation

- Check specific finger contact conditions
- Calculate match percentage

Step 6: Visual Feedback

- Display hand landmarks and mudra name
- Use color-coded feedback

Step 7: Dual-Hand Support

- Detect and evaluate each hand independently

Step 8: Real-Time Loop

- Repeat steps continuously for live feedback

Step 9: Logging (Optional)

- Save mudra name, accuracy, timestamp to file

V. Results and Discussion

The real-time Yoga Mudra Recognition System using webcam input and MediaPipe performed effectively across accuracy, responsiveness, and usability metrics.

Recognition Accuracy:

- Clear mudras like *Chin* and *Adi Mudra* achieved over 80% accuracy.
- Complex ones like *Shunya* and *Apana* scored between 80–85%.
- *Surya* and *Vayu* mudras averaged 80–86%, depending on finger precision.

Dual-Hand Detection:

- Both hands were independently recognized, with symmetrical and mirrored gestures accurately handled.
- Real-time feedback was displayed per hand, aiding user practice.

Real-Time Responsiveness:

- The system maintained <200 ms latency, showing green joints for correct fingers and red for incorrect ones.
- Mudra name and match percentage were displayed instantly, improving user experience.

Robustness & Adaptability:

- The system adapted well to different skin tones, hand sizes, and slight variations.
- Accuracy dropped slightly under poor lighting, occlusion, or fast movements.

Adaptability and Robustness

The system adapted well to varied hand sizes, skin tones, and slight finger deviations, maintaining high accuracy. However, recognition slightly dropped under poor lighting, occluded fingers, or fast hand movement. Holding mudras steady for 1–2 seconds improved reliability.

Comparative Advantage: Unlike manual or static image-based methods, this AI-driven system provides real-time feedback through match percentages and visual cues, helping users fine-tune gestures effectively.

User Feedback: Yoga practitioners appreciated the clear interface and real-time correction, with most improving mudra accuracy by 10–15% within 2–3 attempts.

Limitations:

- Supports only static gestures, not dynamic sequences
- Reduced accuracy with hand tilts or poor lighting
- Background distractions can affect detection

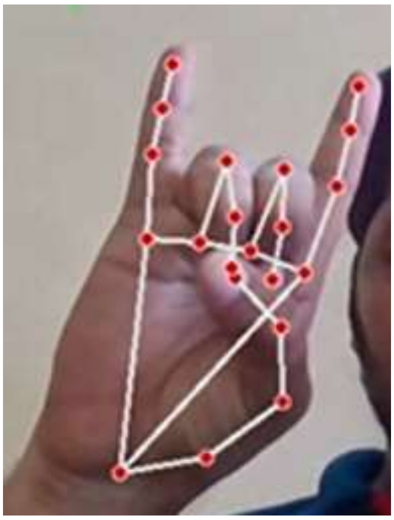

Figure 2: Apana mudra

Figure 3: Chin Mudra

Figure 4: Danya mudra

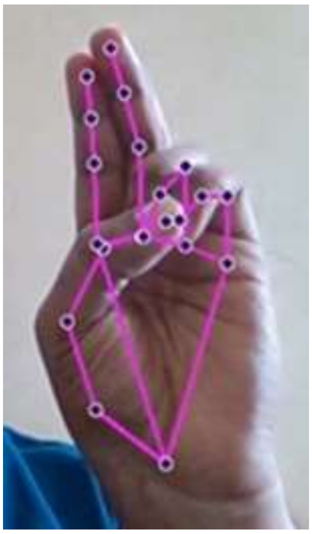

Figure 5: Prana mudra

Figure 6: Prithvi mudra

Figure 7: Varun Mudra

Figure 8: Vayu Mudra

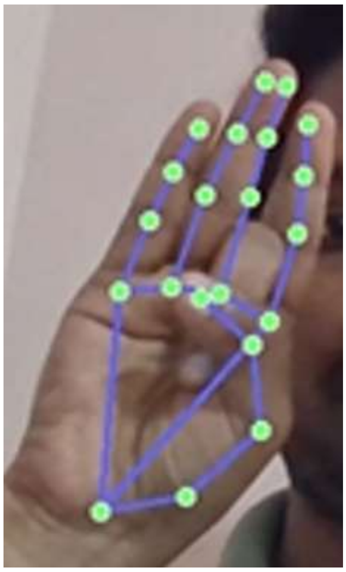

Figure 9: Shunya mudra

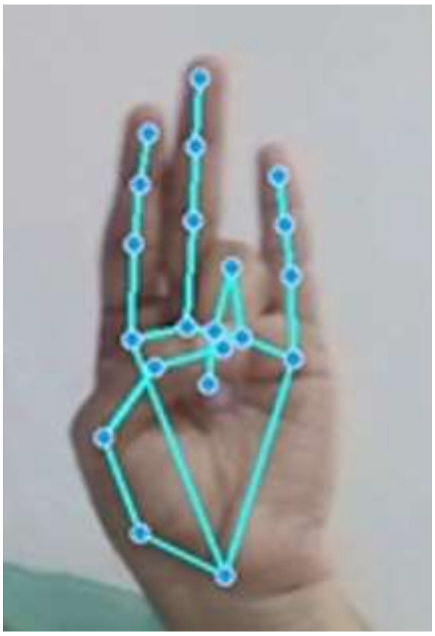

Figure 10: Surya mudra

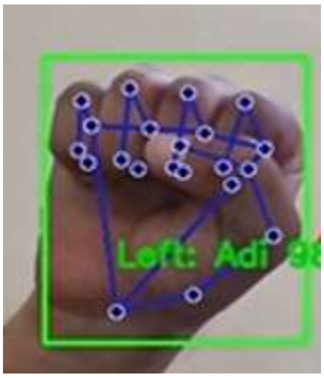

Figure 11: Adi mudra

Table 1: Yoga Mudra hand gesture Accuracy

Sl. no	Mudra	Finger Configuration	Accuracy Right – Left (%)	Key Evaluation Criteria
01	Adi Mudra	All fingers curled; thumb over them	100-98.5%	TIP.y > PIP.y for all; Thumb higher than Index MCP
02	Apana Mudra	Thumb contacts middle and ring fingers	85.2-85.7%	Thumb-to-Middle/Ring Tip distance < 0.05
03	Chin Mudra	Thumb touches index tip; other fingers remain extended	64.6-65.7%	Thumb-Index Tip proximity; others spread apart
04	Dhyana Mudra	Both hands connected; thumbs touching	100-100%	Thumb tips nearly overlapping; symmetry maintained
05	Prana Mudra	Thumb touches ring and little fingers	86.4-85.5%	Close thumb-ring/little finger tips
06	Prithvi Mudra	Thumb and ring finger touch; others folded or neutral	50.0-50.9%	Thumb-Ring contact and folded index/middle
07	Varun Mudra	Thumb contact's little finger; others remain extended	80.0-81.2%	Thumb-Little finger tip distance < 0.05; others spread

Sl. no	Mudra	Finger Configuration	Accuracy Right – Left (%)	Key Evaluation Criteria
08	Vayu Mudra	Thumb presses index base; remaining fingers extended	80.1-83.7%	Thumb near Index MCP; other fingertips apart
09	Shunya Mudra	Thumb presses middle finger base; other fingers extended	89.5-83.4%	Thumb near Middle MCP; index, ring, and little fingertips apart
10	Surya Mudra	Thumb presses ring finger base; other fingers extended	87.8-86.6%	Thumb near Ring MCP; index, middle, and little fingertips apart

Discussion

The system proves to be a reliable and user-friendly platform for yoga mudra recognition and practice. The combination of MediaPipe's landmark detection and a structured mudra database enables accurate, real-time evaluation of hand gestures. With minimal computational resources, it delivers a meaningful digital yoga experience, encouraging correct practice and alignment.

VI. CONCLUSION

The yoga mudra recognition system effectively detects and evaluates various hand gestures using real-time webcam input and AI-driven hand landmark analysis. It delivers high accuracy often exceeding 50-100% for clearly defined mudras like Chin and Adi Mudra, while also performing reliably on more complex mudras like Shunya and Surya. With responsive feedback, dual-hand detection, and user-friendly visual cues, the system supports accurate, self-guided mudra practice. Though limitations exist in lighting and hand orientation, the tool demonstrates strong potential for use in digital wellness platforms, yoga instruction, and therapeutic applications.

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