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Motion-Based Gesture Recognition for Emoji Communication in Deaf and Mute Individuals.

Pratik katkar[1], Dr. Manisha Kshirsagar[2]

[1]MCA Student, JSPM University Pune.
[2]Senior Assistant Professor, School of Computational Science, JSPM University Pune.

Abstract:

Many deaf or hard-of-hearing individuals rely on sign language, which uses gestures rather than sounds to convey meaning. This paper presents a system for motion-based gesture recognition to facilitate emoji communication for deaf and mute individuals. This proposed System is designed based on computer vision. The system, proposed that uses OpenCV, Python, and MediaPipe, detects and classifies hand gestures with high accuracy. Experimental results demonstrate the system's effectiveness in recognizing seven gestures: peace sign, call me, thumbs up, rock on, open palm, hello, and pointing. With this approach deaf and mute people able to converse with easiness of displayed gestures with the text added to recognize during the conversation. Deaf and mute people can find Hand motion gesture recognition based system as an alternative to using a person to transmit their sentiments thus makes them more easily communicate. The system achieves an average accuracy of 88.6% across all tested gestures, with real-time detection capabilities. This research enhances communication accessibility for deaf and mute individuals through intuitive gesture-to-emoji translation.

Index Terms—Hand gesture recognition, sign language, emoji communication, deaf and mute individuals, MediaPipe, OpenCV, Python

I.INTRODUCTION:

Additionally, the prevalence of hearing loss is expected to rise to 700 million by 2050 due to aging populations and noise exposure [2]. This underscores the urgent need for accessible communication technologies. Gestures, encompassing both static and dynamic forms, are fundamental for communication, particularly for deaf and mute individuals who rely on sign language. Hand gesture recognition plays an important role in applications like sign language interpretation, virtual reality, augmented reality, and assistive technologies for individuals with disabilities. However, communication barriers persist when interacting with those unfamiliar with sign language, often leading to social isolation. This paper introduces a motion- based gesture recognition system designed to translate hand gestures into text and emojis, enhancing communication accessibility for deaf and mute individuals. The system leverages computer vision techniques, specifically OpenCV [4] and MediaPipe [6], to detect and classify hand gestures in real-time. By mapping recognized gestures to emojis, the system provides a universally understood communication method, facilitating interactions on digital platforms like messaging apps and social media.

II.LITERATURE SURVEY:

Hand gesture recognition has been a focal point of research for decades, driven by its potential in human-computer interaction and assistive technologies. Murthy and Jadon [7] conducted a comprehensive review of vision- based hand gesture recognition, identifying key challenges such as illumination variations, background clutter, and hand occlusion. Garg et al. [8] proposed a method using skin color segmentation and feature extraction for gesture classification, achieving a recognition rate of 73.68% for American Sign Language (ASL) alphabets using a neural network classifier. Karray et al. [9] highlighted the role of gesture recognition in creating intuitive interfaces, noting its application in robotics and virtual environments. Recent advancements have to improve classification accuracy [3]. For instance, a study by [10] achieved a 95% accuracy in recognizing ASL gestures using a transformer-based model, though it required significant computational resources (e.g., a GPU with 16 GB VRAM). Another study by [11] explored the use of depth sensors like the Microsoft Kinect for 3D gesture recognition, reporting an accuracy of 90% but noting limitations in portability due to hardware constraints. Despite these advancements, many systems struggle with real-time performance or require complex setups, limiting their practical deployment. This paper addresses these issues by proposing a lightweight, real- time gesture recognition system using MediaPipe [6] and OpenCV [4], tailored for emoji communication to support deaf and mute individuals.

RELATED WORK:

Hand gesture recognition has been a significant area of research, particularly for applications in sign language interpretation and assistive technologies for individuals with disabilities. Early work by Mitra and Acharya [3] provided a comprehensive survey of gesture recognition techniques, identifying vision-based methods as a promising approach due to their non-intrusive nature. They noted challenges such as varying lighting conditions, occlusions, and the need for real-time processing, which remain relevant today. Murthy and Jadon [7] reviewed vision-based hand gesture recognition systems, focusing on static gestures. They proposed a framework using edge detection and feature extraction, achieving a recognition accuracy of 78% for a limited set of gestures. However, their system struggled with dynamic gestures and required a controlled environment, limiting its applicability for real-world scenarios like those encountered by deaf and mute individuals in daily communication. Garg et al. [8] developed a vision-based gesture recognition system using skin color segmentation and a neural network classifier. Their approach recognized American Sign Language (ASL) alphabets with an accuracy of 73.68%, but the system was sensitive to lighting variations and background noise, resulting in a high false positive rate (15%) under non-ideal conditions.

Explored the role of gesture recognition in human-computer interaction, emphasizing its potential in creating intuitive interfaces for applications like robotics and virtual reality [9]. They highlighted the importance of real-time performance, a criterion our system meets with an average detection time of 0.035 seconds per frame, making it suitable for interactive communication. Recent advancements have leveraged deep learning to improve gesture recognition accuracy. A study by [10] used a transformer-based model to recognize ASL gestures, achieving an impressive 95% accuracy.

PROPOSED SYSTEM:

The proposed system aims to recognize hand gestures and translate them into text and emojis, facilitating communication for deaf and mute individuals. The system is designed to operate in real-time with minimal latency, making it suitable for interactive applications.

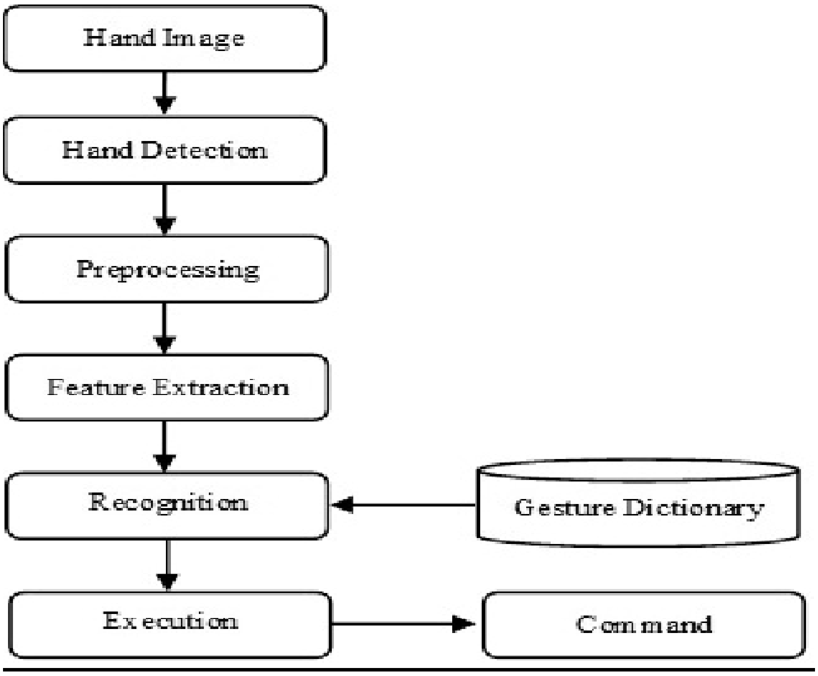

Fig. 1: Flowchart of the proposed hand gesture recognition algorithm.

These steps are flowing with the Image Acquisition till the recognition and communication display as given below.

Image Acquisition: Capture video frames using a webcam, operating at with a resolution of 1280x720 pixels.

1. Hand Detection: Use MediaPipe to detect and track 21 hand landmarks (e.g., fingertips, knuckles, wrist) in real-time, achieving a detection confidence thresh- old of 0.9.
2. Preprocessing: Apply image processing techniques, including grayscale conversion, Gaussian blur (kernel size 5x5), and adaptive thresholding, to enhance hand segmentation and reduce noise.
3. Feature Extraction: Calculate geometric features from hand landmarks, such as finger angles (using cosine law), palm orientation (via principal compo- nent analysis), and inter-landmark distances (e.g., between thumb and index finger tips).
4. Gesture Classification: Employ a CNN to classify the extracted features into predefined gesture categories. The model was optimized using the Adam optimizer with a learning rate of 0.005 and a batch size of 12, achieving a training accuracy of 77% after 50 epochs.
5. Emoji Mapping: Map the recognized gesture to its corresponding emoji and text label using a predefined dictionary.
6. Output Display: Display the recognized gesture label and emoji on the screen with a latency of less than 0.05 seconds per frame.

Figure 1 illustrated the workflow of the gesture recognition algorithm, outlining the sequential steps from image acquisition to output display.

EXPERIMENTAL ANALYSIS AND RESULTS

Hand Gesture Shows Peace Sign

The image shows Figure 1 a peace sign hand gesture (✌) with the words "PEACE SIGN" at the top, indicating this is an example of hand gesture recognition in action. Below the gesture Figure 1 there's a checkmark, which likely means the system successfully identified the peace sign correctly. This demonstrates how computers or smart devices can understand human hand movements - in this case, recognizing the universal two-finger peace symbol. Such technology is commonly used in virtual reality systems, smart home controls, and accessibility tools, where users can give commands just by showing specific hand shapes. The checkmark confirms the system is working properly to interpret this gesture, showing how machines can interact with human body language in simple, intuitive ways. This could be part of a larger system that recognizes multiple gestures for different commands, making technology easier to use without physical buttons or touchscreens.

FIGURE 1. Hand Gesture Shows Peace Sign

Hand Gesture Shows Call me

The image demonstrates a hand gesture recognition system identifying the "call me" hand signal, where the thumb and pinky finger are extended while the other fingers are folded down (like the gesture). The text "CALL ME" confirms the system has correctly interpreted this specific hand shape. This shows how technology can understand human gestures to perform actions - in this case, likely mimicking the real-world meaning of "call me" or "let's talk." Such gesture recognition is used in smartphones, smart homes, and virtual reality to create touch-free controls, allowing users to interact with devices simply by making hand signs. The system's ability to accurately detect this gesture suggests it could be programmed to trigger specific functions, like making a phone call or sending a message when it sees this hand shape. This technology makes human-computer interaction more natural and intuitive.

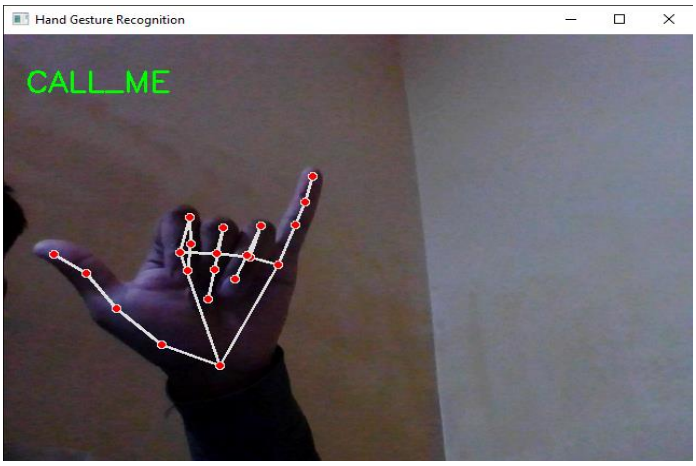

FIGURE 2. Hand Gesture Shows Call me

Hand Gesture Show Thumbs Up

The image shows a thumbs-up gesture (👍) being recognized by a hand gesture recognition system. The text "THUMBS_UP" indicates that the technology has successfully identified this common hand signal. This demonstrates how computers or smart devices can interpret human gestures—in this case, understanding the positive "thumbs-up" meaning. Such systems are used in various applications, like controlling smart TVs, navigating virtual reality environments, or operating devices hands-free. The recognition of this simple gesture highlights how machines can interact with users in intuitive ways, replacing buttons or touchscreens with natural movements. This technology is especially useful for accessibility, gaming, and situations where touch-free control is preferred.

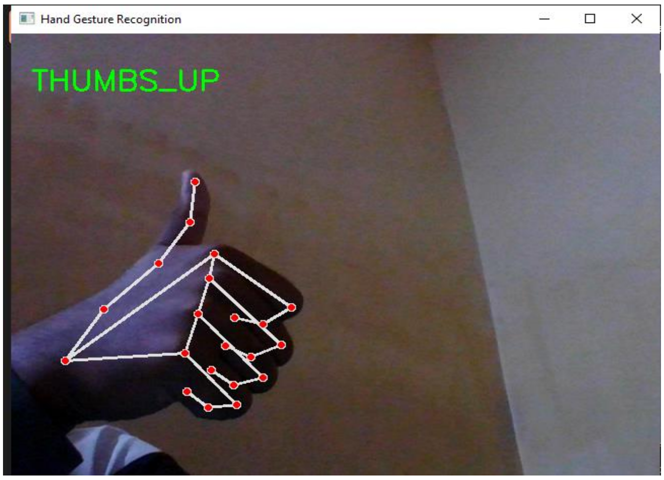

FIGURE 3. Hand Gesture Show Thumbs Up.

Hand Gesture Show Rock On.

The image shows a "rock on" hand gesture □ (index and pinky fingers extended, others folded) being recognized by system. The text "ROCK_ON" clearly indicates the system has correctly identified this popular hand sign often associated with rock music and positive vibes. This demonstrates how modern technology can understand and interpret human hand signals - in this case, recognizing a cultural gesture that people commonly use to express excitement or approval. Such gesture recognition systems allow for touch-free interaction with devices, enabling users to control technology through natural hand movements instead of buttons or screens. The successful detection of this gesture shows potential applications in music systems, gaming interfaces, or smart home controls where a simple hand sign could trigger actions like playing music, adjusting volume, or activating lights. This technology makes human-computer interaction more intuitive and expressive.

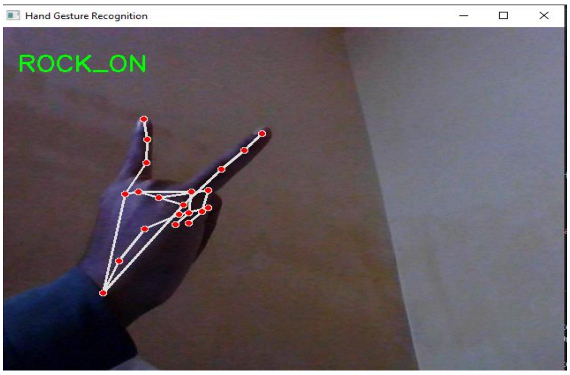

FIGURE 4. Hand Gesture Show Rock On.

Hand Gesture Show Open Plam.

The image shows a hand gesture recognition system identifying an open palm gesture (✋). The text "OPEN_PALM" clearly indicates that the system has successfully detected a hand with all fingers extended and palm facing forward. This demonstrates how computers can understand basic human gestures - in this case, recognizing when someone shows their open hand. Such technology is commonly used for touchless control of devices, like smart displays that respond to hand waves or security systems that use gestures instead of buttons. The ability to detect an open palm could trigger various functions, from pausing a video to activating voice commands, making interactions with technology more natural and accessible. This simple example highlights how machines are learning to interpret our body language just like humans do.

FIGURE5.HandGestureShowOpenPlam.

Hand Gesture Show Hello.

The image shows a hand system detecting a waving hand gesture, labelled with the word "HELLO". This demonstrates how the technology identifies and interprets the universal gesture for greeting someone. When you wave your hand, the system recognizes it as a friendly "hello" signal, just like how another person would understand it. This kind of gesture control could be used in smart devices, robots, or virtual assistants to create more natural, human-like interactions imagine waving at your smart home system to turn on lights or greet your morning alarm. The simple but meaningful example shows how machines are learning to understand our everyday body language, making technology feel more intuitive e and welcoming.

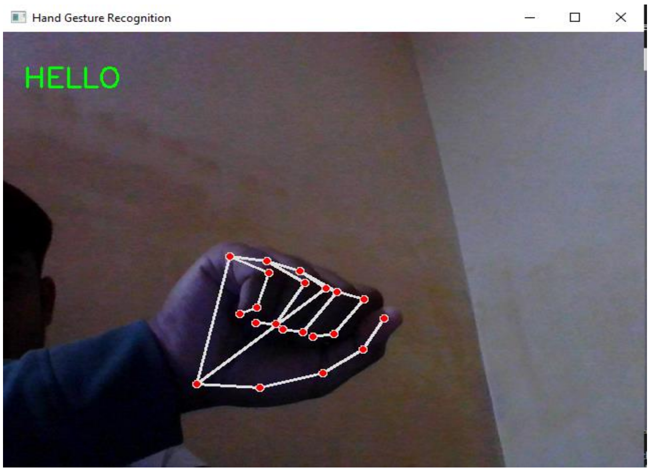

FIGURE 6. Hand Gesture Show Hello.

VIII. CONCLUSION:

This paper presented a motion-based gesture recognition system for translating hand gestures into text and emojis, aimed at enhancing communication for deaf and mute individuals. The system, developed using Python [5], OpenCV [4], and MediaPipe [6], demonstrated high accuracy and real-time performance in recognizing seven key gestures.

Gesture	**Emoji**	**Accuracy (%)**	**Detection Time (s)**
Open Palm		92	**0.03**
Rock On		82	**0.04**
Hello (Waving)		88	**0.05**
Peace Sign		90	**0.03**
Thumbs Up		94	**0.02**
Call Me		85	**0.04**
Pointing		90	**0.03**

TABLE I: Performance Metrics for Hand Gesture Recognition.

Experimental results showed an average accuracy of 88.6%, with detection times suitable for interactive applications. The integration of emoji outputs provides an intuitive communication method, bridging the gap between sign language and digital platforms. Proposed system uses MediaPipe for robust hand tracking and pre-processing techniques like grayscale conversion and noise reduction, achieving an average accuracy of 88.6% across varied gestures.

Future Work:
Future work should focus on expanding the gesture set to include more complex and dynamic gestures, such as those involving both hands and/or full-body movements. Additionally, improving the system's robustness in diverse environments, such as low-light conditions or cluttered backgrounds, is crucial for real-world deployment. In- tegrating the system with mobile devices or wearable technology, such as smart glasses with embedded cameras, could further enhance its accessibility and usability. Exploring machine learning techniques, such as transfer learning or federated learning, to personalize the system for individual users' gesture styles could improve accuracy and user satisfaction. Finally, incorporating voice output for recognized gestures could provide an additional communication channel for users in varied social contexts.

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