



# Sign Language Interpreter

**Sakshi Thakre, Achal Gore, Dnyandip Jalamkar, Amit Mishra, Prof. A. A. Chinchamatpure**

U.G. Student, Department of Computer Science & Engineering, TIET, Darapur, Amravati, India

U.G. Student, Department of Computer Science & Engineering, TIET, Darapur, Amravati, India

U.G. Student, Department of Computer Science & Engineering, TIET, Darapur, Amravati, India

U.G. Student, Department of Computer Science & Engineering, TIET, Darapur, Amravati, India

Head of Department, Department of Computer Science & Engineering, TIET, Darapur, Amravati, India

**ABSTRACT:** The Sign Language Interpreter (Sign AI) project presents an advanced, web-based solution designed to bridge the communication gap between sign language users and digital systems. Traditional human-computer interaction methods rely heavily on physical input devices such as keyboards and mice, which are not accessible to individuals with motor impairments or those who primarily communicate using sign language. This creates a significant barrier in achieving inclusive digital communication. The proposed system utilizes modern computer vision and machine learning techniques to recognize and interpret hand gestures in real time using a standard RGB camera. By leveraging the MediaPipe Hands framework, the system detects and tracks 21 three-dimensional hand landmarks, enabling accurate gesture interpretation without requiring specialized hardware. This eliminates the need for costly sensors such as depth cameras or data gloves, thereby improving accessibility and affordability.

**KEYWORDS:** Sign language interpreter, hand gesture recognition, computer vision, MediaPipe Hands, real-time processing, web-based system, accessibility technology, human-computer interaction.

## I. INTRODUCTION

Human-computer interaction has evolved significantly over the years, yet it still primarily depends on conventional input devices such as keyboards, mice, and touchscreens. These methods are not always accessible or efficient for individuals with physical disabilities or those who communicate using sign language. This limitation creates a major barrier in achieving inclusive and seamless communication between humans and digital systems.

To address this challenge, the proposed Sign Language Interpreter (Sign AI) system introduces a modern, web-based approach that enables real-time hand gesture recognition using computer vision techniques. The system is designed to interpret sign language gestures and convert them into meaningful outputs without the need for specialized hardware. This makes the solution both cost-effective and easily accessible to a wider audience.

The core of the system is built upon the MediaPipe Hands framework, which is capable of detecting and tracking 21 three-dimensional landmarks of the human hand using a standard RGB camera. These landmarks provide detailed spatial information about finger positions and hand orientation, which are further processed using heuristic-based algorithms to recognize specific gestures. This approach ensures high accuracy while maintaining low computational complexity, making it suitable for real-time applications.

Unlike traditional systems that rely on external sensors or cloud-based processing, the proposed system operates entirely within a web browser. Technologies such as WebAssembly and WebGL are utilized to achieve hardware-accelerated performance, allowing all computations to be performed locally on the user's device. This not only reduces latency but also enhances data privacy and security.

Additionally, the system provides real-time visual feedback through hand skeletal overlays and gesture confidence indicators, improving user interaction and usability. The development of this system demonstrates that web-based artificial intelligence solutions can effectively support assistive technologies and promote inclusivity.

## II. LITERATURE SURVEY

The development of sign language recognition systems has gained significant attention in recent years due to the growing need for inclusive communication technologies. Various approaches have been proposed, ranging from hardware-based solutions to software-driven computer vision techniques. Early systems primarily relied on wearable devices such as data gloves and sensors to capture hand movements. Although these methods provided high accuracy, they were often expensive, intrusive, and inconvenient for daily use.

With advancements in computer vision and machine learning, researchers have shifted towards camera-based gesture recognition systems. These systems utilize image processing techniques to detect and interpret hand gestures without requiring physical contact or specialized equipment. However, many traditional vision-based approaches faced challenges such as sensitivity to lighting conditions, background noise, and high computational requirements, which limited their real-time applicability.

Recent developments have introduced frameworks like MediaPipe Hands, which enable efficient and accurate hand tracking using standard RGB cameras. This framework detects and tracks 21 three-dimensional hand landmarks, providing detailed information about finger positions and hand orientation. Such advancements have significantly improved the reliability and performance of gesture recognition systems while reducing hardware dependency.

## III. METHODOLOGY

The proposed Sign Language Interpreter (Sign AI) system is designed to perform real-time hand gesture recognition using a structured and efficient methodology based on computer vision techniques. The overall process involves hand detection, landmark extraction, gesture interpretation, and output generation, all executed within a web-based environment.

The first stage of the system focuses on hand detection and tracking. This is achieved using the MediaPipe Hands framework, which processes input from a standard RGB camera to identify and track hand movements. The framework detects 21 three-dimensional landmarks on the hand, representing key points such as fingertips, joints, and the wrist. These landmarks provide precise spatial information that forms the foundation for gesture recognition.

In the second stage, the extracted landmark data is analyzed using a heuristic-based approach to interpret gestures. Instead of relying on complex machine learning models, the system uses geometric relationships between landmarks, such as distances, angles, and relative positions of fingers, to determine whether a finger is open or closed. By combining the states of multiple fingers, specific gestures are identified. This method reduces computational overhead and ensures faster processing, making it suitable for real-time applications.

The third stage involves real-time processing and system optimization. The entire system is implemented as a browser-based application, utilizing technologies such as WebAssembly and WebGL to achieve high performance and hardware acceleration. These technologies enable efficient execution of complex computations directly on the user's device without requiring external servers. As a result, the system maintains low latency and ensures smooth user interaction. Finally, the system provides output through a user-friendly interface. Visual feedback is displayed using a skeletal hand overlay that represents detected landmarks, along with confidence indicators for recognized gestures. This helps users understand system responses and adjust their gestures accordingly in real time.

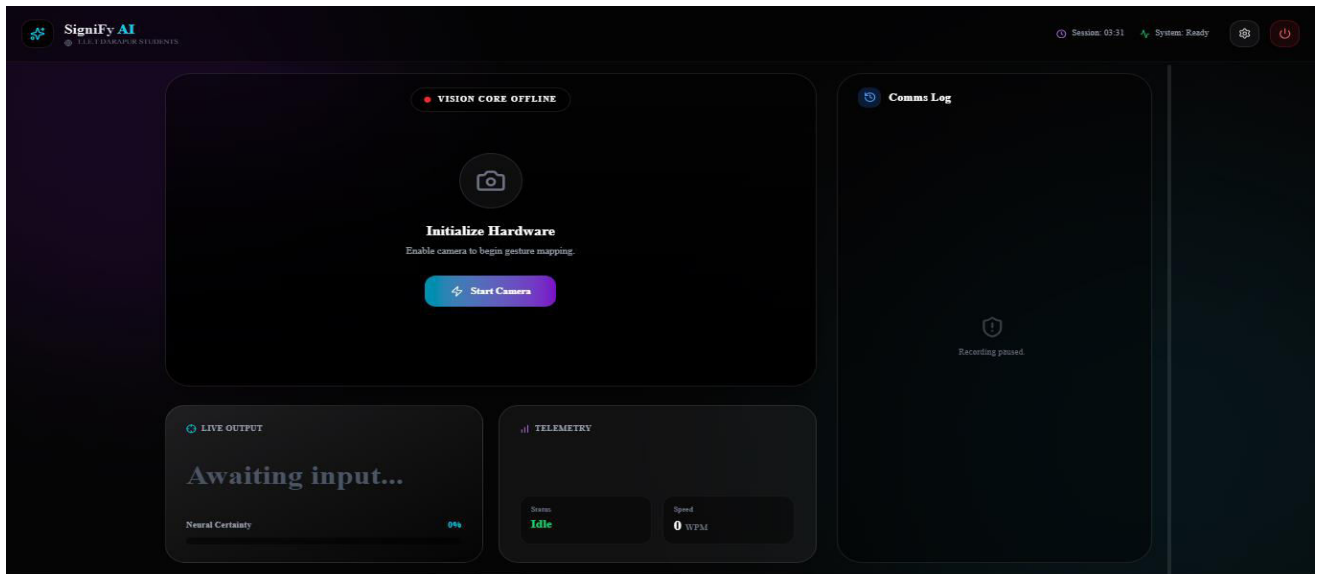
## IV. EXPERIMENTAL RESULTS

The performance of the proposed Sign Language Interpreter (Sign AI) system was evaluated through a series of real-time experiments to assess its accuracy, responsiveness, and usability. The system was tested using a standard RGB camera under different environmental conditions, including variations in lighting, background complexity, and hand orientations. The results demonstrate that the system is capable of accurately detecting and interpreting hand gestures in real time.

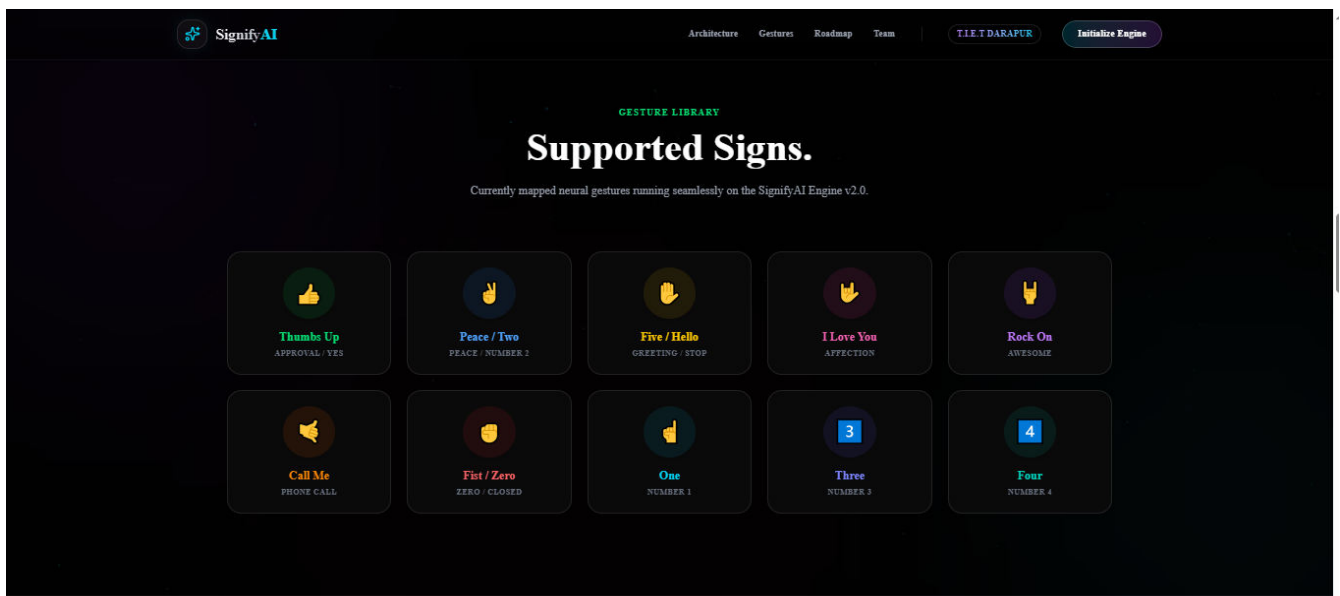
The MediaPipe Hands framework successfully detected and tracked 21 hand landmarks with high precision, enabling reliable extraction of spatial features required for gesture recognition. The landmark-based approach proved to be

effective in capturing finger positions and hand movements, even during continuous motion. This ensured that gestures were recognized consistently without significant delays.

The heuristic-based gesture recognition algorithm showed efficient performance in identifying gestures based on geometric relationships between landmarks. Since the method does not rely on heavy machine learning models, it significantly reduced computational complexity and improved processing speed. The system achieved low latency, making it suitable for real-time applications where immediate feedback is essential.



User Interface of the Proposed Sign AI System Showing Real-Time Gesture Output

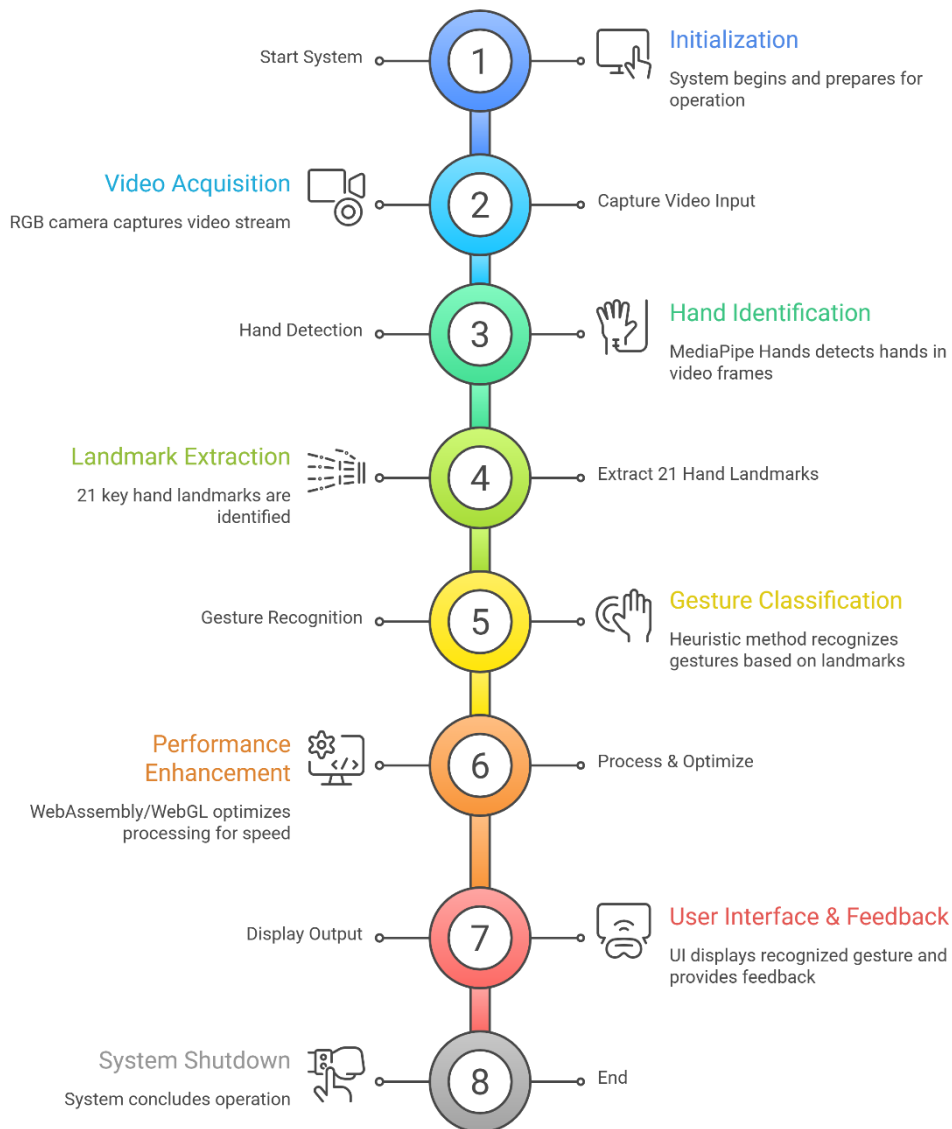


Detected Hand Gestures in the Sign AI System Interface

**V. SYSTEM ARCHITECTURE**

The architecture of the proposed Sign Language Interpreter (Sign AI) system is designed to enable efficient real-time hand gesture recognition using a web-based framework. The system follows a modular architecture consisting of input acquisition, hand detection, landmark processing, gesture recognition, and output display. Each module works in coordination to ensure accurate and low-latency performance.

**Real-Time Hand Gesture Recognition System Workflow**



Flowchart of the Proposed Sign AI System for Real-Time Gesture Recognition

**SYSTEM ARCHITECTURE**

- **PROGRAMMING PLATFORM:** WEB-BASED APPLICATION (BROWSER ENVIRONMENT)
- **Core Framework:** MediaPipe Hands
- **Technologies & Tools:** WebAssembly, WebGL
- **Libraries / Modules:**
  1. **Hand Detection & Tracking** – MediaPipe Hands (21 landmark detection).
  2. **Computer Vision Processing** – Real-time video frame processing using RGB camera input.
  3. **Gesture Recognition** – Heuristic-based algorithms (geometric analysis of hand landmarks).
  4. **Performance Optimization** – WebAssembly (high-speed execution), WebGL (hardware acceleration).
  5. **User Interface & Visualization** – Real-time skeletal hand overlay and gesture feedback system.

**VI. CONCLUSION**

The proposed Sign Language Interpreter (Sign AI) system successfully demonstrates an efficient and accessible approach to real-time hand gesture recognition using modern web-based technologies. The system addresses the limitations of traditional human-computer interaction methods by providing an intuitive, gesture-based interface that does not rely on physical input devices such as keyboards or mice. This makes it particularly beneficial for individuals who communicate using sign language or have physical limitations.

The integration of the MediaPipe Hands framework enables accurate detection and tracking of 21 hand landmarks using a standard RGB camera. This eliminates the need for specialized hardware, reducing system cost and improving accessibility. The use of a heuristic-based gesture recognition approach further enhances system efficiency by minimizing computational complexity while maintaining reliable performance. As a result, the system achieves fast response times suitable for real-time applications.

Additionally, the implementation of the system within a web browser using technologies such as WebAssembly and WebGL ensures high performance through hardware acceleration. All processing is performed locally on the user's device, which reduces latency and enhances data privacy by avoiding reliance on external servers.

The experimental results confirm that the system is capable of delivering accurate gesture recognition with low latency under various conditions. The user-friendly interface, combined with real-time visual feedback, further improves usability and interaction experience.

In conclusion, the Sign AI system provides a scalable, cost-effective, and privacy-preserving solution for sign language interpretation. It contributes significantly to the development of assistive technologies and promotes inclusive human-computer interaction. The system lays a strong foundation for future enhancements in gesture recognition and AI-driven communication systems.

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