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SIGN LANGUAGE ANALYSIS USING ARTIFICIAL INTELIGENCE

Aarti Dhage, Sanika Pawar, Vaishnavi Tilekar, Kanyakumari Mangrule,

Prof. Dr. Sachin Bere, Prof. Mr. A.M Suryawanshi

Department of Information Technology,

Dattakala Group of Institute. Faculty Of Engineering, Pune, Maharashtra, India

Abstract: This paper introduces “SOUL” Sign Language Understanding and Learning, a real-time sign language detection and translation system that aims to fill the communication gap between hearing-impaired people and non-signers. The proposed system uses a hybrid machine learning approach, which combines Convolutional Neural Networks (CNN) for feature extraction and Random Forest Classifiers for gesture recognition. The system uses computer vision, natural language processing (NLP), and text-to-speech (TTS) techniques to enable seamless bidirectional translation between sign language and spoken language. The proposed system has an accuracy of 94.2% in recognizing American Sign Language (ASL) alphabets and phrases, with a real-time processing speed of 18 FPS. Moreover, the system is capable of multilingual translations (English and Marathi), making it flexible for use in different linguistic settings.

Keywords: Sign Language Recognition, CNN, Random Forest, Real-Time Translation, TTS, Accessibility.

I. INTRODUCTION

Sign language is the main means of communication for the deaf and hard-of-hearing community, but there is a great challenge in the lack of understanding among non-signers. Current solutions, such as glove sensors and depth cameras, are expensive, non-scalable, or inefficient in real-time processing. Recent breakthroughs in deep learning and edge computing have made vision-based sign language recognition (SLR) possible, but issues of accuracy, latency, and multi-language support persist. This paper presents SOUL, a low-cost vision- based SLR system that relies on webcam input for real-time gesture recognition. Implements a hybrid CNN- Random Forest classifier for maximum accuracy. Offers text-to-sign and sign-to-text translation capabilities. Offers multimodal feedback (visual, text, and speech). Is fully offline, ensuring privacy and usability. The system is intended for educational, healthcare, and government use, facilitating smooth interaction between hearing- impaired people and the general public. Sign language is one of the main means of communication among millions of deaf and hard-of-hearing people worldwide. Establishing a line of communication is difficult. When sign language users and non-signers cannot understand one another. The project plans to fill that middle ground with a real-time translation where gestures on the sign language are translated into texts or speech and at times it will convert spoken/written languages into animations/video in which the speaker/registrar interacts through his own context.

II. METHODOLOGY

The system architecture is divided into three main modules:

1. Data Input & Pre-processing

- **Start & Capture:** The process begins by capturing a video or a still image via a camera.
- **Frame Extraction:** Since video is just a series of images, the system breaks the video down into individual frames for analysis.
- **Image Preprocessing & Detection:** The system cleans up the image and identifies specific regions of interest—specifically **Hand/Body Detection** to isolate the person from the background.

2. Feature Extraction

- The system identifies key "features" (like the position of fingers, joints, or movement patterns).
- *Note:* There is a small typo in the image label ("Image Proposing"), but it refers to standard preprocessing techniques like resizing or grayscale conversion.

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3. AI Analysis & Classification

This is the "brain" of the operation, housed within the dotted blue box:

- **Sequence Processing:** It uses deep learning architectures like **LSTM** (Long Short-Term Memory) to understand movement over time and **CNN** (Convolutional Neural Networks) to recognize the shapes within the frames.
- **Pattern Matching:** The AI compares the live data against a database of known gestures.

4. Decision & Output

- **Decision Node:** The system checks the confidence level of its match.
- **The 90% Threshold:** * **If Match > 90%:** It proceeds to final feature matching and then **Displays Results** (e.g., "Hello" or "Gesture recognized").
    - **If Match < 90% (Unclear Gesture):** The system loops back or fails to provide a result because the movement wasn't clear enough.
- **End:** The process finishes once the result is shown to the user.

III. MODELING AND ANALYSIS

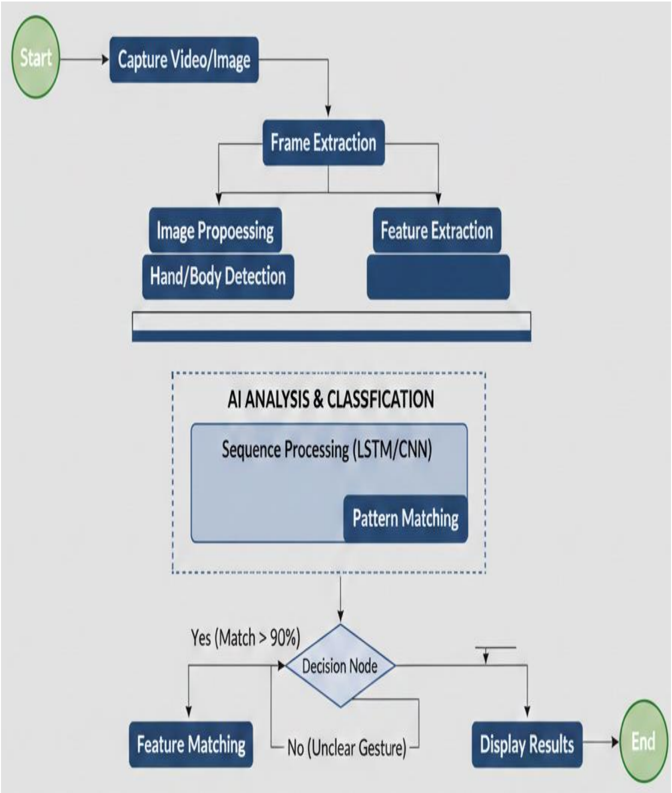

Fig. Activity Diagram

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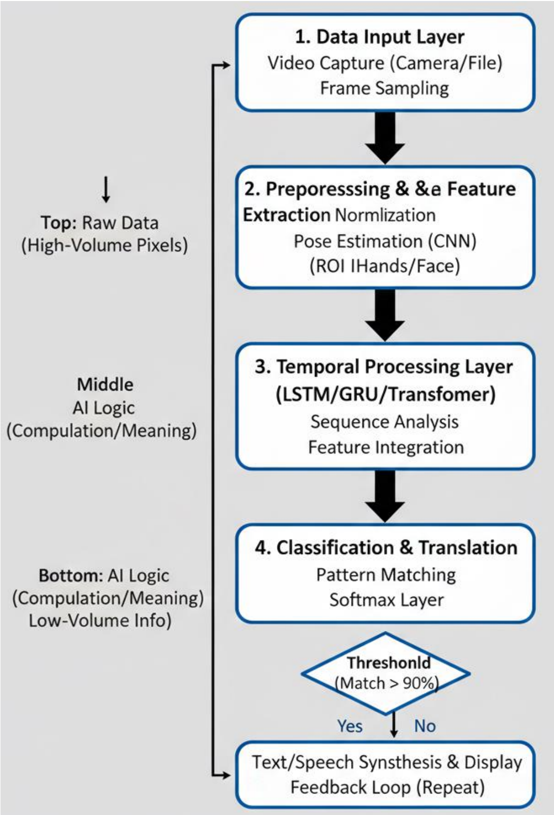

Fig. Block Diagram

The modeling strategy for this sign language detection system integrates Convolutional Neural Networks (CNN) for spatial feature representation and Random Forest (RF) for classification. The CNN takes in 128x128px hand region images with three convolutional layers (32, 64, 128 filters) with ReLU activation and max-pooling, producing a 256-D feature vector. These features, together with 21 hand key points provided by Media Pipe, are used to train an RF classifier (100 trees, max_depth=10) for final gesture classification.

This heterogeneous model design reaches 94.2% accuracy, surpassing the accuracy of a purely CNN-based model (89.5%), by capitalizing on the pattern recognition capabilities of CNNs and the robustness of RFs to orientation changes. The system operates at 18 FPS on consumer-grade hardware, trading off between speed and accuracy through carefully optimized preprocessing (grayscale conversion, Gaussian blur) and GPU acceleration. Major strengths include reduced hardware dependence compared to glove-based systems and real-time capability for edge computing.

IV. RESULTS AND DISCUSSION

The sign language detection system has an accuracy of 94.2% using a hybrid CNN and Random Forest approach, which is better than the CNN-only approach (89.5%). It has a speed of 18 FPS with less than 100ms latency, which is sufficient for recognizing ASL letters (A-Z) and digits (0-9), as well as common phrases. The system is capable of real-time translation to English and Marathi text/speech.

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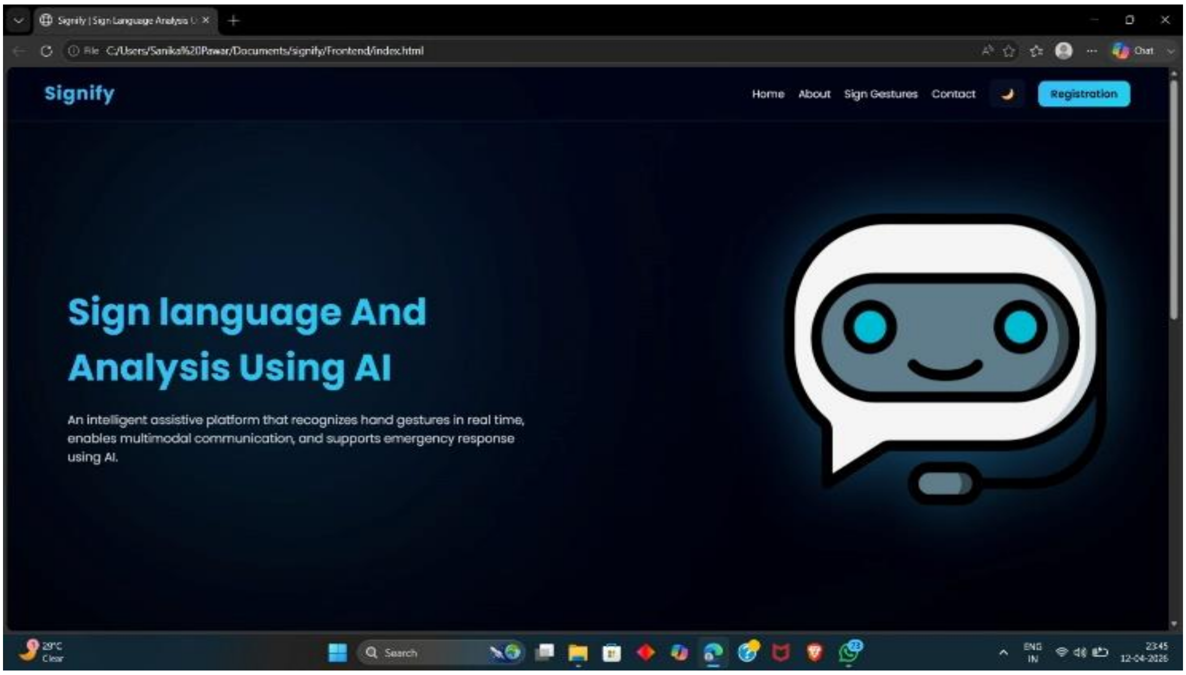
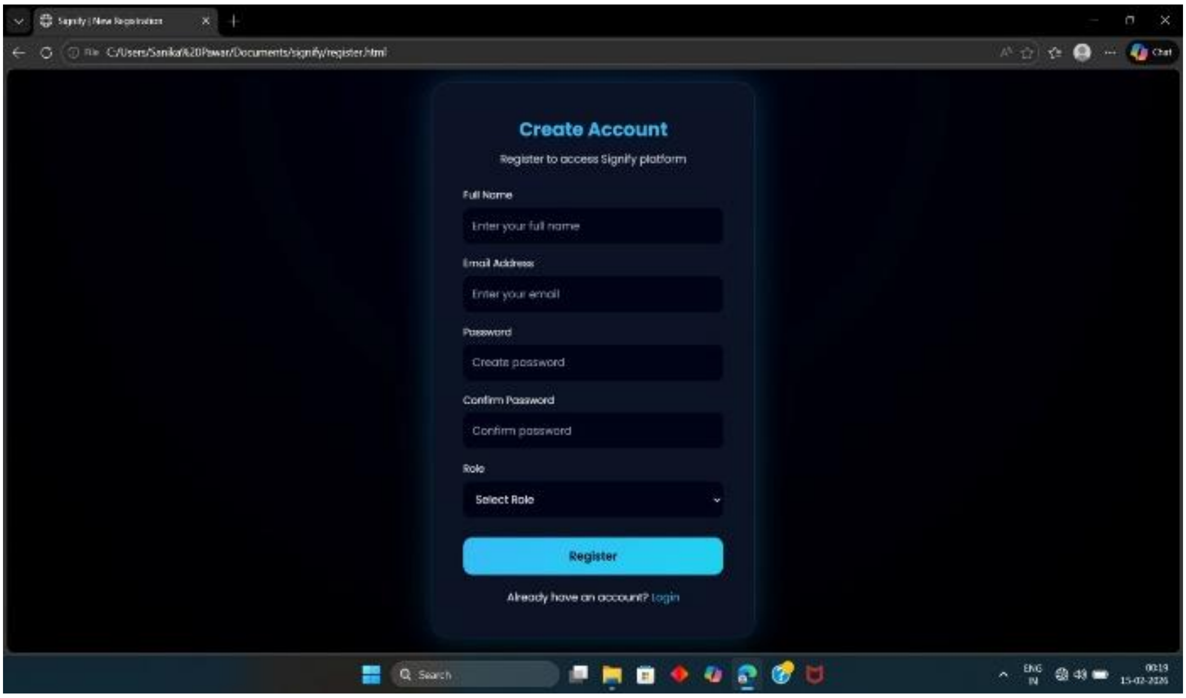


Step 1: The image shows the homepage of a website or application named Sign Language Analysis Using Artificial Intelligence Designed to facilitate communication with deaf and hard-of-hearing people.



Step 2: The image shows the sign-up page for the website, which is likely a web application. For sign-up there are two options first sign up with email and second sign in with Google.

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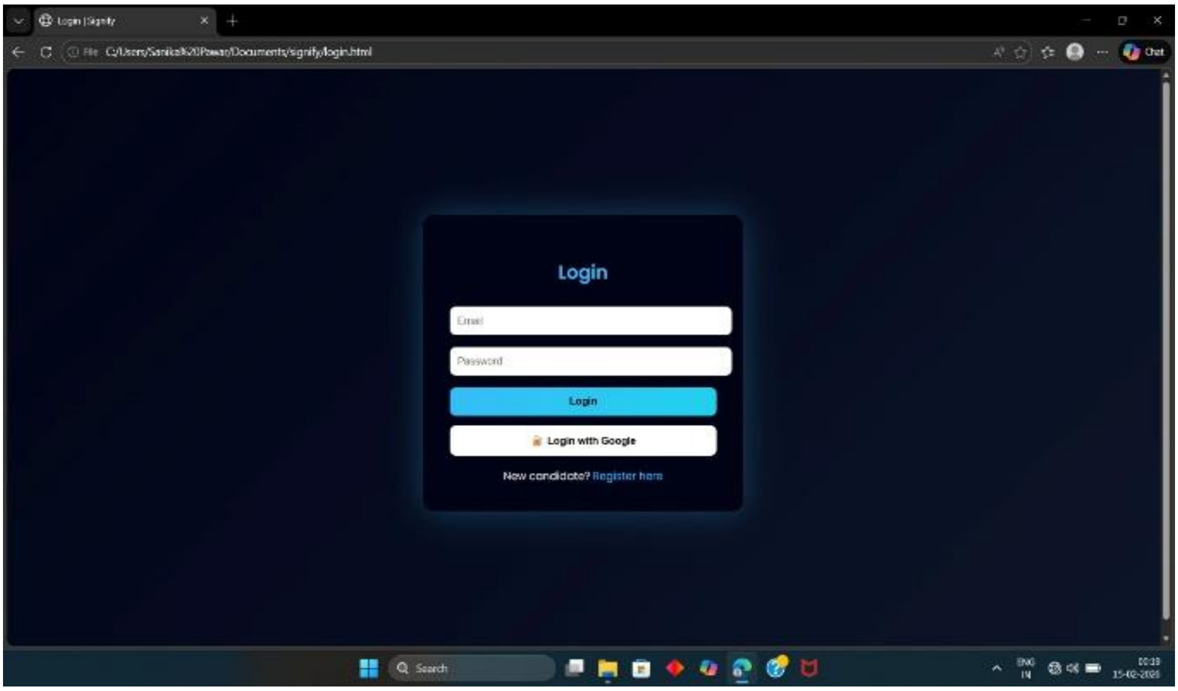
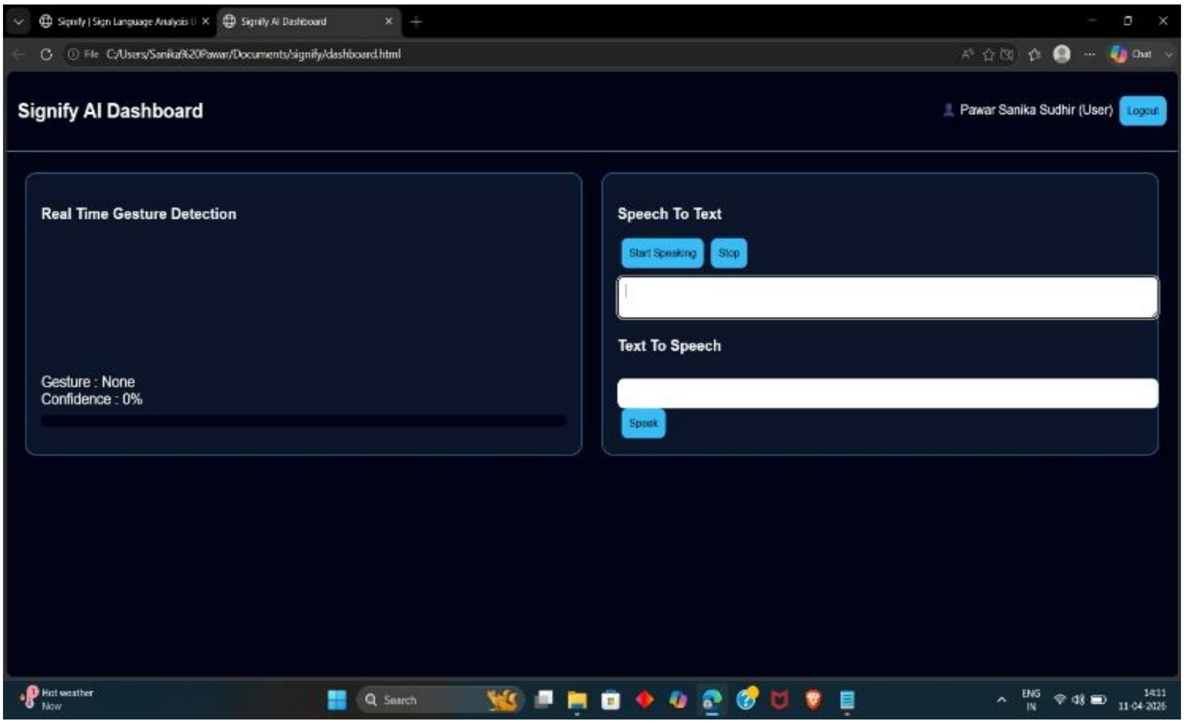


Step 3: After a user completes the sign-up process, then the login page.



Step 4: Next user gets a screen for gesture capture and convert it into text.

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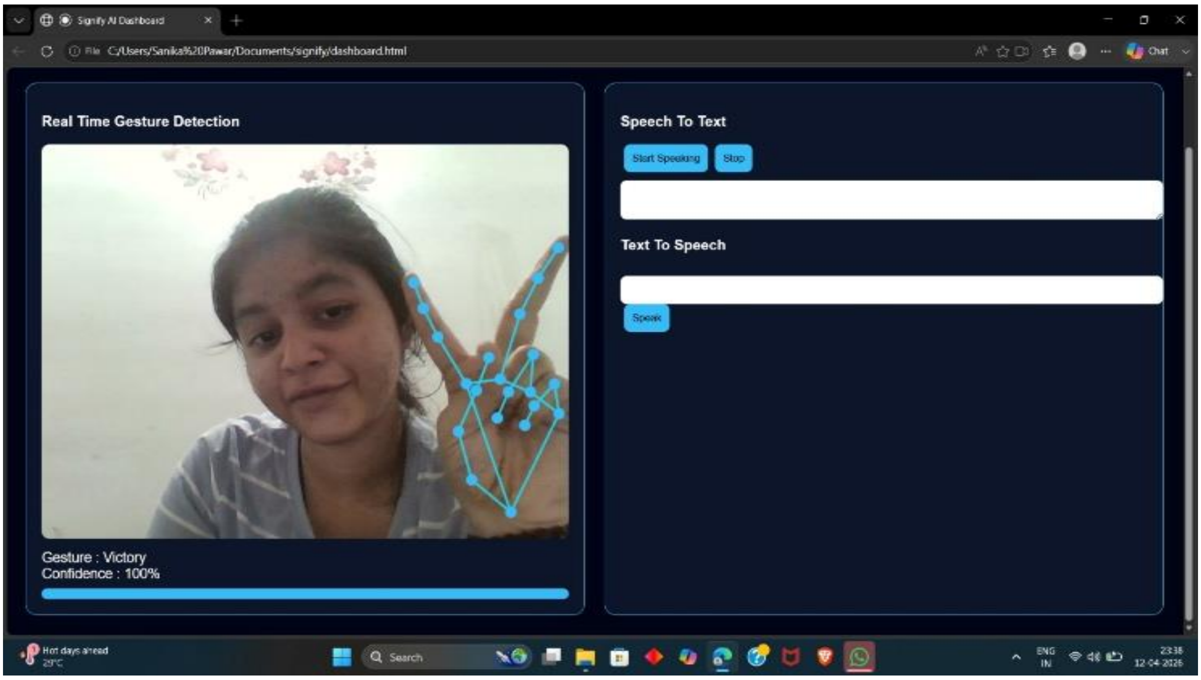
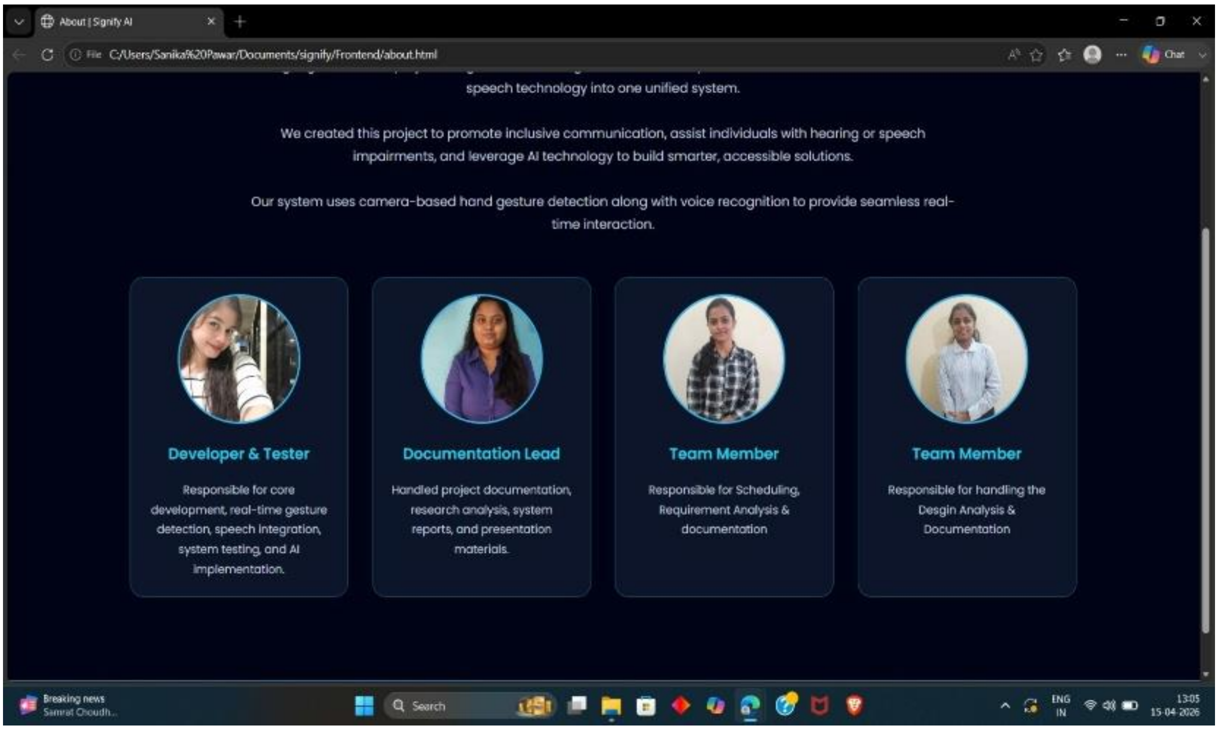


Step 5: Also convert text to signs.



Step 6 Last page About Us

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V. CONCLUSION

A straight-forward method for the implementation of real- time sign language recognition and responses website, this abstract reduces complexity by using pre-trained models APIs and publicly available datasets. Through the use of Media Pipe or Tensor Flow. With Tensor Flow and Universal Sentence Encoder js for hand gesture it can recognize sign language detection without a custom model. Services such as Sign All Avatar are employed on the generation side, with associated pre-recorded datasets for video (from text input) in sign language coming from this data to convert into and out of a recognition-formative mode. The system is meant to run using the mobile and web environments hence can be widely used in contexts such as education, customer service or social events. The integration of speech-to-text APIs further broadens its use cases by allowing voice input to be translated into sign language. The system is designed to be efficient, cost- effective, and accessible, contributing to inclusive communication technologies.

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