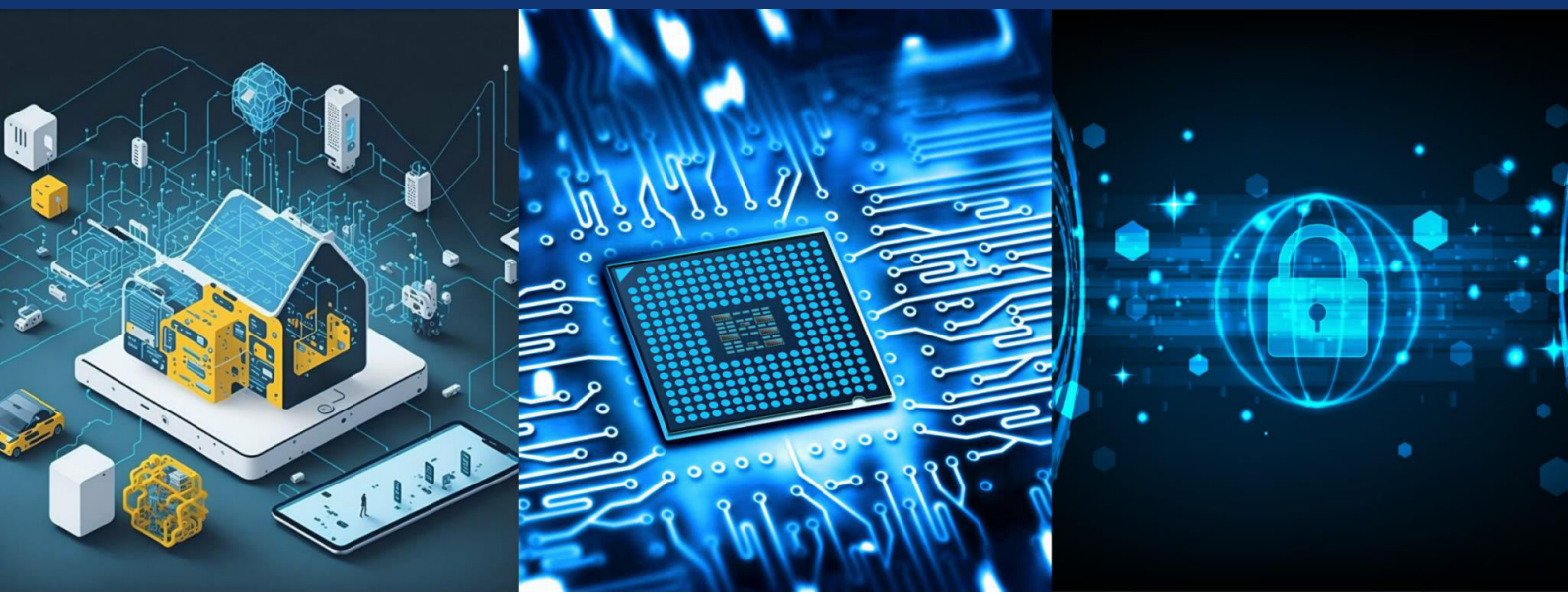
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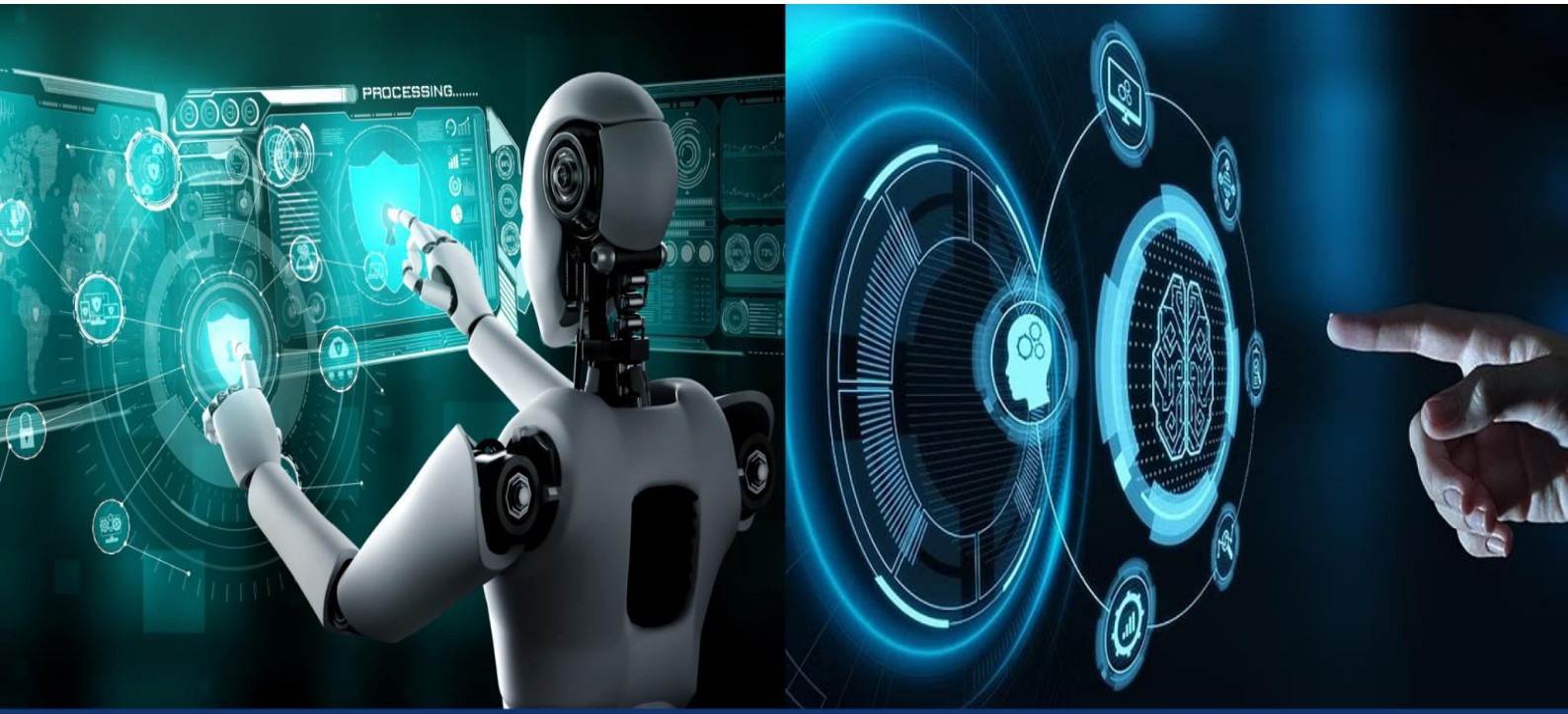
ISSN(O): 2320-9801

ISSN(P): 2320-9798



International Journal of Innovative Research in Computer and Communication Engineering

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Impact Factor: 9.927

Volume 14, Issue 10, October 2026

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International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

A Web-Based Text to Sign Language Animation System

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ABSTRACT: Communication between deaf or hard-of-hearing individuals and people who do not know sign language can be difficult in everyday situations. To address this issue, this work presents a web-based system that converts textual input into corresponding sign language animations. The system accepts text through a web interface and processes the input to identify words or phrases that have predefined sign representations. The selected signs are displayed sequentially using a 3D animated avatar, allowing the entered information to be presented visually. The system also supports voice input and multilingual text processing to improve accessibility. Flask is used for backend processing, while Three.js is used to render the 3D avatar and animations in the browser. Blender is used to create and prepare the avatar animations. The developed system provides a simple platform for communication support and sign-language learning. The current implementation uses a predefined sign vocabulary; future versions can include larger datasets, improved natural language processing, more realistic avatars, and real-time translation.

KEYWORDS: Sign Language, Text-to-Sign Conversion, 3D Animation, Web Application, Natural Language Processing, 3D Avatar, Accessibility, Voice Input, Text Processing

I. INTRODUCTION

Communication plays an important role in education, employment, healthcare, and everyday social interaction. Deaf and hard-of-hearing people may use sign language as their primary means of communication, but communication can become difficult when the other person does not understand sign language. Such situations can occur in classrooms, workplaces, healthcare facilities, and public services [1]. Recent developments in artificial intelligence and natural language processing have created opportunities for technology-assisted communication tools [2].

This work presents a Web-Based Text to Sign Language Animation System that converts written input into visual sign-language gestures. The user enters text through a browser interface, and the system processes the input to identify words or phrases that can be represented using predefined signs. The selected animations are then presented as a sequence through a 3D avatar [3], [4]. A web-based implementation makes the system easier to access without requiring specialized hardware.

The main purpose of the proposed system is to provide a simple visual representation of textual information for communication support and learning. The current implementation has limitations related to vocabulary coverage, sentence structure, and the availability of suitable sign animations [5], [6]. These limitations also provide opportunities for future improvements such as larger sign-language datasets, stronger NLP methods, improved avatar animation, speech-to-sign conversion, and real-time translation.

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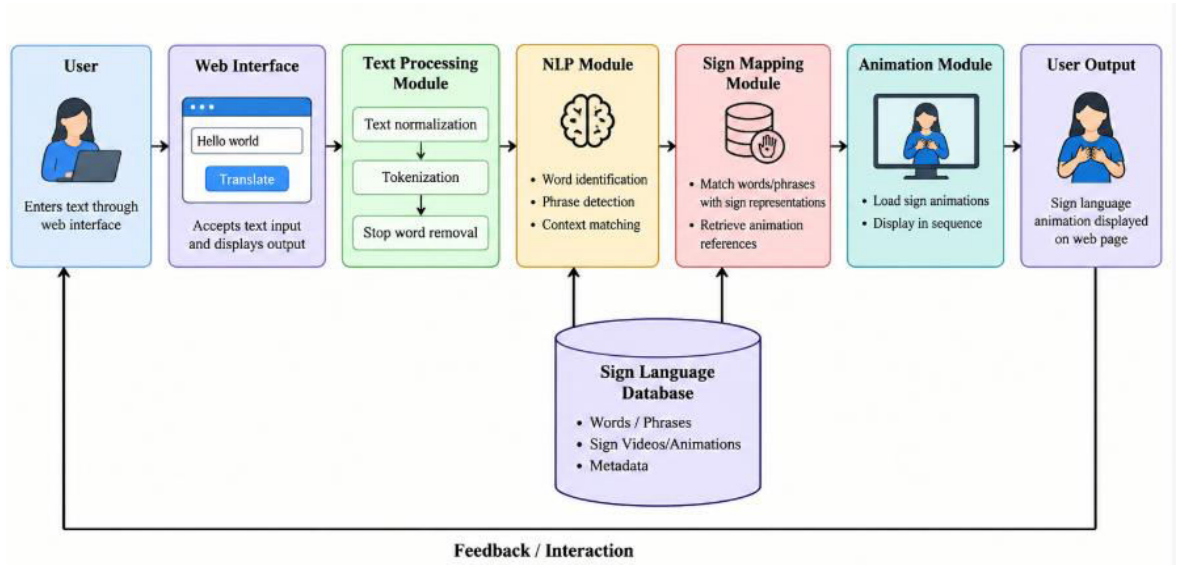


Fig.1.1 : System Architecture of Web-Based Text-to-Sign Language Animation System

II. PROBLEM STATEMENT

Communication between deaf or hard-of-hearing individuals and people who are unfamiliar with sign language can be difficult when an interpreter or suitable sign-language resource is not available. Existing approaches may depend on human interpreters, prerecorded videos, or manual searching for individual signs, which may not be convenient in every situation. Digital systems can also be limited by vocabulary size, sentence handling, animation quality, or platform requirements. Therefore, this project proposes a web-based system that accepts text or voice input, processes the input, maps supported words or phrases to predefined sign animations, and displays the result using a 3D avatar. The system is intended to provide an accessible communication-support tool while also creating a base for future improvements such as expanded vocabulary, better NLP, multilingual processing, and real-time sign generation

III. OBJECTIVES

1. To develop a web-based system for converting textual input into corresponding sign-language gestures.
2. To represent the converted signs using a 3D animated avatar for clear visual communication.
3. To implement a text-to-gesture mapping mechanism that connects supported words or phrases with predefined sign-language animations.
4. To provide voice and multilingual input support to make the system more accessible to different users.
5. To create a simple and user-friendly platform that can support communication and sign-language learning for deaf and hard-of-hearing users.

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IV. LITERATURE SURVEY

Table 4.1: Literature Survey of Existing Sign Language Translation and Animation Systems

Author / Paper	Year	Focus Area	Methods / Technologies Used	Findings / Limitations
R. Hong and J. Kosecka – Toward Phonology-Guided Sign Language Motion Generation [1]	2026	Text-to-sign motion generation	Diffusion models, SMPL-X, CLIP/T5	Produces 3D sign motion, but the approach relies on advanced models and suitable datasets.
R. Zuo et al. – Signs as Tokens: A Retrieval-Enhanced Multilingual Sign Language Generator [2]	2025	Multilingual text-to-sign generation	Pretrained language models, retrieval, 3D sign avatars	Supports multilingual sign generation, but requires substantial models and sign-language resources.
N. S. L. Pokanati et al. – Bridging Communication Gaps [3]	2025	Real-time sign-language translation	AI, CNN, LSTM, 3D camera	Demonstrates real-time translation but depends on AI processing and suitable hardware.
Z. Jiang et al. – Meaningful Pose-Based Sign Language Evaluation [4]	2025	Sign-language evaluation	Pose-based metrics, embeddings, back-translation	Improves evaluation of generated sign poses, but the work mainly addresses evaluation.
J. Ma et al. – MS2SL: Multimodal Spoken Data-Driven Continuous Sign Language Production [5]	2024	Continuous sign production	Sequence diffusion, text/audio/sign embeddings	Generates continuous signs but requires multimodal training data.

The literature survey covers different approaches developed for sign-language translation, motion generation, avatar-based representation, and evaluation. Earlier work concentrated on rule-based English-to-Indian Sign Language translation, while later research introduced neural machine translation, generative models, continuous sign production, and 3D motion generation. Recent studies also investigate multilingual sign generation, avatar quality, and pose-based evaluation. These developments demonstrate progress in producing more realistic and flexible sign-language representations. At the same time, many approaches require large datasets, complex models, or substantial computational resources. The proposed project therefore focuses on a simpler web-based implementation that combines text processing, predefined sign mapping, and 3D animation.

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V. RESEARCH GAP

Table 5.1: Research Gap Analysis of Existing Sign Language Systems

Sl. No.	Author(s)	Year	Research / Approach	Research Gap / Limitation
1	Hong and Kosecka	2026	Phonology-guided sign-language motion generation using diffusion models.	The advanced generation pipeline may require considerable computation and may not be suitable for a lightweight web application.
2	Zuo, Potamias, Ververas, Deng and Zafeiriou	2025	Retrieval-enhanced multilingual sign-language generation using 3D sign avatars.	The approach depends on advanced models and large sign-language resources, making lightweight deployment difficult.
3	Jiang et al.	2025	Meaningful pose-based sign-language evaluation.	The main contribution is pose evaluation rather than an end-to-end text-to-sign animation application.
4	Ma, Wang, Yang and Zheng	2024	Multimodal spoken-data-driven continuous sign-language production.	The method requires multimodal data and advanced processing, which increases the complexity of simple web deployment.
5	Dong, Wang and Nwogu	2024	Word-conditioned 3D American Sign Language motion generation.	The work concentrates on 3D ASL motion generation rather than a complete lightweight web-based text-to-sign system.

Previous research has addressed sign-language conversion through rule-based systems, machine learning, neural networks, video resources, and animated avatars. The reviewed studies demonstrate useful progress, but several practical challenges remain, including limited vocabulary, difficulty with complete sentences, differences between spoken-language structure and sign-language grammar, dependence on large datasets, and high computational requirements. Some systems concentrate on isolated words, motion generation, or evaluation rather than providing a complete lightweight web application.

The proposed project addresses this practical gap by combining text processing, predefined text-to-gesture mapping, and 3D avatar animation in a browser-based application. This design is intended to provide a simple starting point that can be expanded later with a larger vocabulary, improved language processing, additional sign animations, and more advanced translation methods.

VI. PROPOSED SYSTEM

1. The application is developed as a web-based system so that users can access it through a standard browser. Supported words and phrases are connected to their corresponding sign animations.
2. A 3D avatar is used to present the selected sign gestures, with Three.js providing browser-based animation rendering.
3. The system processes the input and presents the available sign animations as a sequence for the user.
4. The system supports multilingual text and voice input; non-English text can be translated into English before the sign-mapping stage.

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VII. SYSTEM ARCHITECTURE

The proposed architecture connects the user interface, input-processing functions, translation service, backend, sign-mapping module, and 3D rendering component. A user can provide text or voice input through a web browser. Voice input is converted to text using the Web Speech API. When the entered text is not in English, the Google Translate API is used to obtain an English version before sign mapping. The Flask backend manages the application logic and prepares the required sign animations. Each supported word or phrase is associated with a predefined animation. The selected GLB avatar and animation are rendered in the browser using Three.js. Blender is used during development to prepare the avatar and animation assets.

Main components of the architecture are:
1. User Interface: Provides the browser-based controls for entering text or using voice input.
2. Input Processing: Receives the entered content and prepares it for the next processing stage.
3. Language Translation: Uses the Google Translate API to convert supported non-English input into English.
4. Flask Backend: Controls application logic and coordinates the input, mapping, and animation functions.
5. Text-to-Gesture Mapping: Associates supported words or phrases with their corresponding predefined sign animations.
6. 3D Avatar Module: Provides the GLB-format avatar together with the required sign animations.
7. Three.js Renderer: Loads and displays the avatar and its animations in the web browser.
8. Output: Presents the resulting sign sequence to the user through the animated 3D avatar.

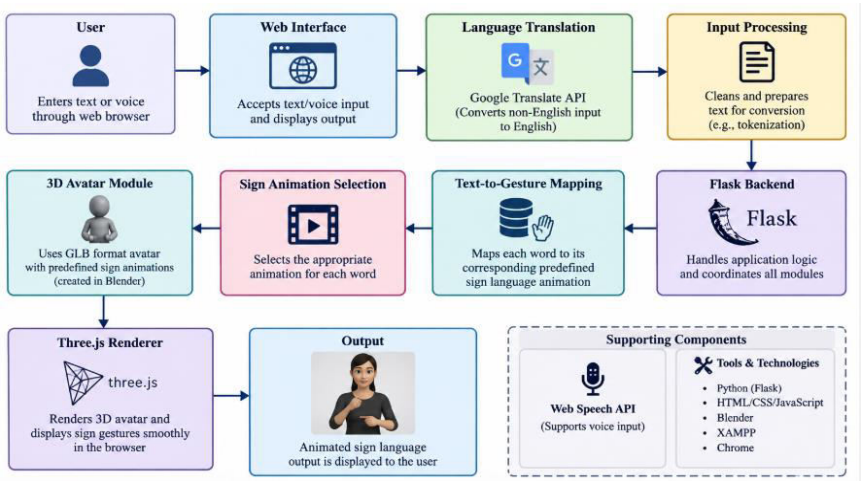


Fig.7.1 : System Architecture of the Web-Based Text-to-Sign Language Animation System

VIII. METHODOLOGY

1. Input (Text / Voice): The user enters text or provides voice input through the web interface.
2. Speech-to-Text: When voice input is selected, the speech is converted into text so that it can follow the same processing path as typed input.
3. Language Detection: The system identifies the language of the supplied text to determine whether translation is required.
4. Translation: Non-English input is translated into English before the sign-mapping process.
5. Text Preprocessing: The input is cleaned and separated into words or tokens that can be compared with the supported sign vocabulary.
6. Word/Phrase Mapping: Each supported word or phrase is matched with its predefined sign-language animation.
7. GLB File Retrieval: The required GLB asset containing the avatar and corresponding animation is loaded.
8. 3D Avatar Rendering: Three.js renders the avatar and selected animation in the browser.
9. Display Sign Gesture: The final gesture sequence is presented as an animated 3D sign representation.

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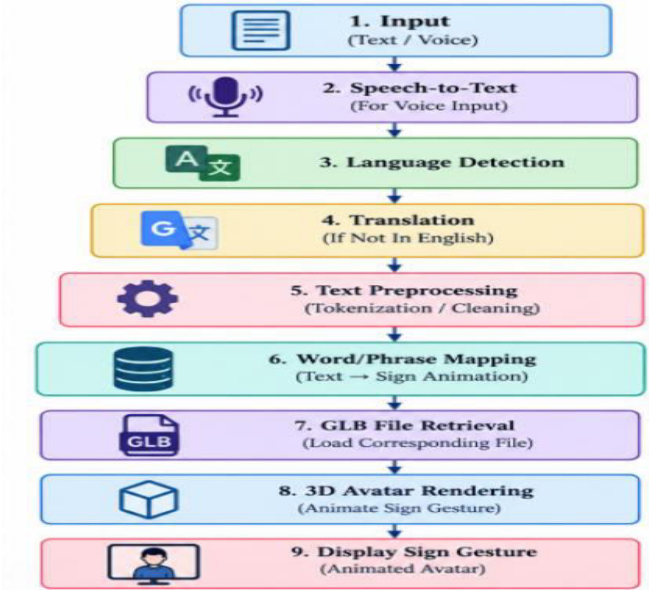


Fig.8.1: Methodology of the Proposed Text-to-Sign Language Animation System

IX. SYSTEM DESIGN AND IMPLEMENTATION

System Design: The system design is divided into input, processing, translation, mapping, and presentation functions. The web interface accepts typed text and voice input. Voice capture is handled through the Web Speech API, while the Google Translate API can be used to translate supported non-English input into English. The resulting text is passed to the backend for further processing.

System Implementation: The system is implemented with Python and Flask for backend processing and HTML, CSS, and JavaScript for the user interface. Three.js is used to render the 3D avatar in the browser, while Blender is used to prepare the avatar and sign animations.

X. RESULTS AND DISCUSSION

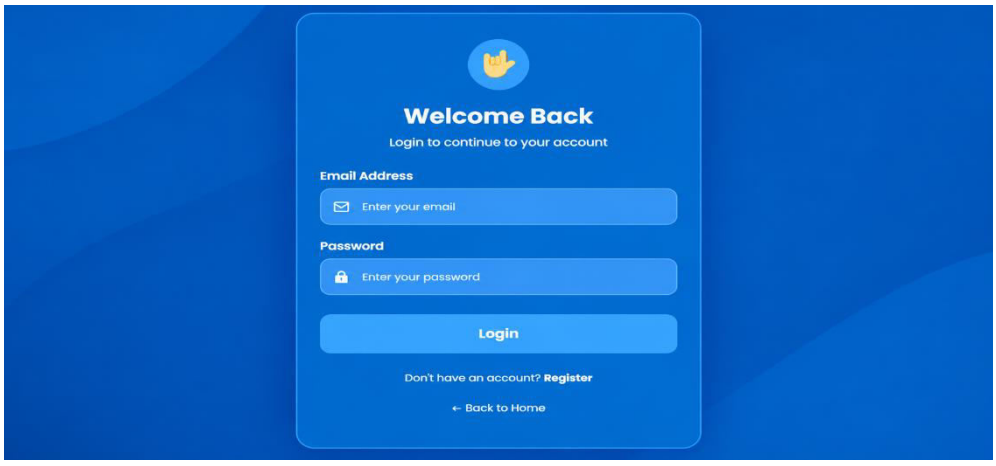


Fig.10.1 : User Login Interface of the Proposed System

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The login screen provides the entry point for registered users. It contains fields for the user's email address and password, together with a Login button. A Register option is available for new users, and a Back to Home option provides navigation to the previous page. The interface organizes the authentication functions before the user enters the main application.

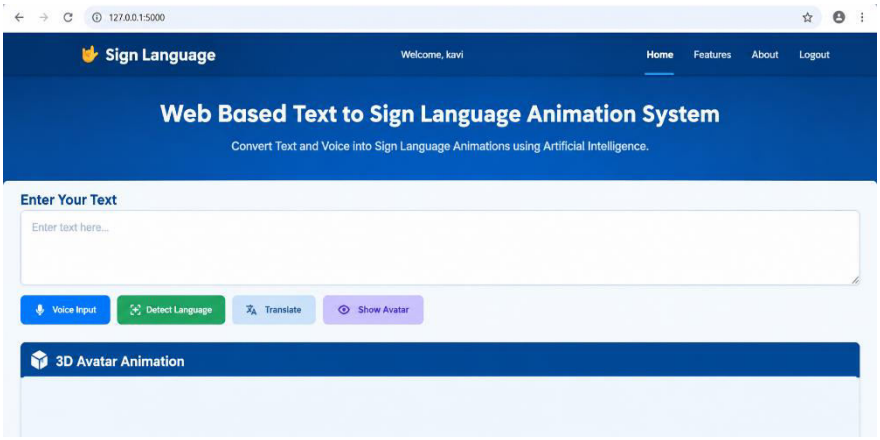


Fig.10.2 : Main User Interface of the Web-Based Text-to-Sign Language Animation System

After login, the main interface provides a text area for entering a sentence and controls for Voice Input, Detect Language, Translate, and Show Avatar. The page also contains the 3D Avatar Animation area in which the selected sign representation is displayed.

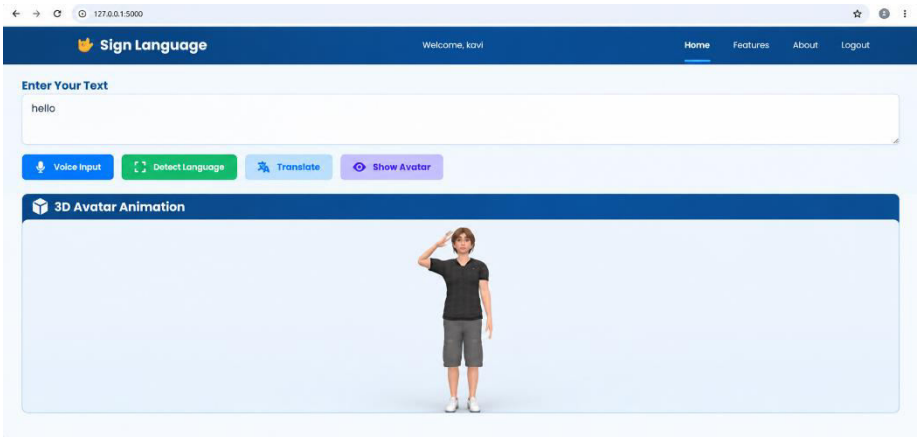


Fig.10.3 : 3D Avatar-Based Sign Language Animation Output

Figure 10.3 presents the output generated for the input word “hello.” The system receives the text, identifies the corresponding supported sign, and displays the gesture through the 3D avatar.

The interface includes controls for voice input, language detection, translation, and avatar display. For the tested input, the avatar performs the corresponding hand movement, demonstrating the connection between the entered text and the predefined visual sign representation.The system was evaluated using 50 test inputs. The evaluation considered successful conversion, conversion accuracy, response time, and animation output. Based on the recorded test results, 45 inputs were successfully converted, giving a reported conversion accuracy of 90%, with an average response time of 1.2 seconds. The animation output was recorded as successful.

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Table 10.1: System Performance Evaluation Results

Evaluation Parameter	Result
Total Test Inputs	50
Successfully Converted	45
Conversion Accuracy	90%
Average Response Time	1.2 seconds
Animation Output	Successful

XI. FUTURE SCOPE

The current system demonstrates how text can be converted into visual sign-language animations through a browser-based interface. Several extensions can improve the system's vocabulary, language understanding, animation quality, and accessibility.

1. Larger Sign Vocabulary: Add more words, phrases, and commonly used expressions so that a wider range of inputs can be represented.
2. Advanced Natural Language Processing: Introduce NLP methods for sentence structure, context, synonyms, and differences between spoken-language syntax and sign-language grammar.
3. Multilingual Support: Extend the input and translation pipeline to cover additional languages and language-specific sign resources.
4. Speech-to-Sign Conversion: Improve speech recognition so that spoken sentences can be processed directly and converted into sign animations.
5. Real-Time Translation: Support continuous text or speech input and generate sign output with minimal delay.
6. Improved 3D Avatar: Develop more detailed hand, facial, and body movements to make the visual output more natural and expressive.
7. Machine Learning-Based Translation: Use machine-learning or deep-learning approaches to learn relationships between natural-language sentences and sign sequences, reducing reliance on fixed word-to-gesture mappings.
8. Mobile Application: Adapt the system for smartphones and tablets to make the sign-language support tool more convenient to access.

XII. CONCLUSION

The developed Text-to-Sign Language Animation System provides a web-based method for presenting textual information as visual sign-language gestures. The application accepts user input, processes supported words or phrases, maps them to predefined sign representations, and displays the selected gestures through a 3D animated avatar.

The implementation demonstrates the practical integration of text processing, text-to-gesture mapping, and browser-based 3D animation. The interface also provides voice and multilingual input functions, making the application useful as a communication-support and learning tool in suitable environments.

The current implementation is limited by its predefined vocabulary and available sign animations. These limitations can be addressed through larger sign-language datasets, improved NLP, broader multilingual support, real-time processing, and more realistic avatar animation. Overall, the project provides a practical foundation for developing more capable and accessible sign-language communication systems.

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