SignIQ- Sign Language Learning Platform

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ABSTRACT - With the rapid growth of digital learning and inclusive education, there is a strong need for an interactive and adaptive sign language learning platform. Existing Platform often depend on static videos or text-based lessons, lacking real-time corrective feedback for Deaf and mute learners. This project presents SignIQ, a hyper-personalized sign language learning Platform that integrates MediaPipe for hand landmark detection and YOLO-based deep learning for accurate gesture recognition.

The system analyzes user-performed signs, provides instant feedback, and adapts lessons based on performance. Built on a cross-platform architecture, SignIQ enhances accessibility, improves learning efficiency, and delivers reliable real-time recognition, making it an effective solution for inclusive digital sign language education.

Keywords - Sign Language Learning, Computer Vision, MediaPipe, YOLO, Adaptive Learning, Gesture Recognition, Inclusive Education, Flutter.

INTRODUCTION

The digital transformation of education has improved accessibility through online platforms and AI-based tools, but inclusive learning for Deaf and Hard-of-Hearing individuals still faces challenges. Many existing sign language learning apps rely on text-based instructions or static videos, lacking real-time feedback and interactive engagement. Since sign language is highly visual and requires accurate hand movements and positioning, learners often struggle to correct mistakes without immediate guidance.

To address these limitations, SignIQ is proposed as an AI-powered, hyper-personalized sign language learning platform. By integrating MediaPipe for hand landmark detection and YOLO-based models for gesture recognition, the system provides real-time feedback and adaptive learning pathways. This approach enhances learning effectiveness, promotes inclusivity, and supports ethical dataset development for future-ready digital sign language education.

In addition, SignIQ incorporates performance tracking and intelligent analytics to continuously monitor user progress. The system identifies weak areas, recommends targeted practice sessions, and adjusts lesson difficulty based on accuracy levels. Gamification features such as levels, quizzes, and progress indicators increase user engagement and motivation. With its visual-first design, scalable architecture, and mobile optimization, the platform ensures accessibility, efficiency, and long-term usability, empowering learners to confidently develop sign language communication skills.

Furthermore, the platform is designed with a modular and scalable architecture that supports continuous enhancement and expansion. The AI recognition engine is optimized for real-time mobile deployment, ensuring low latency and smooth performance across different devices. A secure backend system stores user profiles, learning history, and analytical data, enabling long-term progress tracking and personalized recommendations. The system architecture also allows easy integration of additional sign vocabularies, multiple sign language standards (such as regional variations), and advanced features like speech-to-sign conversion or interactive assessments. By combining intelligent recognition, adaptive learning, and scalable design, SignIQ establishes a strong foundation for sustainable and inclusive digital sign language education.

LITERATURE REVIEW

Recent advancements in artificial intelligence and computer vision have significantly contributed to the development of sign language recognition systems. Several existing applications such as ASL Bloom, Lingvano, and The ASL App provide structured lessons and video-based demonstrations. However, most of these platforms rely on static content and do not offer real-time gesture recognition or adaptive feedback, limiting interactive learning.

In the research domain, studies have explored deep learning models such as YOLO (You Only Look Once) for real-time gesture detection and classification. YOLOv5 and YOLOv8 models have shown high accuracy and fast performance in sign recognition tasks. MediaPipe has also been widely used for efficient hand landmark detection, enabling real-time tracking of finger and hand movements. Additionally, machine learning techniques such as LSTM and CNN have been applied for dynamic sign recognition with promising results.

Despite these advancements, many existing systems lack mobile optimization, adaptive learning pathways, and inclusive design principles. The proposed SignIQ system addresses these gaps by integrating MediaPipe and YOLO-based models to provide real-time feedback, personalized learning, and a visual-first interface, creating a more effective and scalable sign language learning platform.

Furthermore, existing research also highlights challenges related to dataset limitations, including small sample sizes, lack of diversity in sign representation, and restricted real-world testing conditions. Many recognition models perform well in controlled environments but struggle with variations in lighting, background, and user differences. These limitations emphasize the need for robust, optimized, and ethically sourced datasets along with mobile-friendly deployment strategies. By focusing on real-time mobile implementation and adaptive learning features, the proposed system aims to bridge the gap between theoretical research and practical, user-centered sign language education solutions.

PROPOSED SYSTEM

The proposed system, SignIQ – AI-Based Sign Language Learning Platform, is designed to provide an interactive and intelligent solution for sign language education. The application enables users to practice signs in front of their device camera while the system analyzes their gestures in real time. Unlike traditional learning apps that rely only on pre-recorded videos, SignIQ offers instant feedback, allowing learners to identify and correct mistakes immediately.

The system integrates MediaPipe for hand landmark detection and YOLO-based deep learning models for gesture classification. MediaPipe accurately tracks finger positions, palm orientation, and joint movements, while the YOLO model classifies the detected gesture into the corresponding sign.

The platform follows a personalized learning approach by monitoring user performance and adapting lessons accordingly. It tracks accuracy levels, identifies weak areas, and provides additional practice when needed. With features such as progress tracking, quizzes, and gamification elements, the system enhances engagement while maintaining accessibility through a visual-first design. The application architecture also supports secure data storage and smooth mobile performance, ensuring scalability and long-term usability as an inclusive and efficient sign language learning solution.

The system is structured with a modular architecture consisting of a user interface, AI processing layer, and backend database. The frontend is developed using Flutter to ensure cross-platform compatibility, while the optimized AI model enables fast and accurate real-time recognition on mobile devices. User performance data is stored securely to generate analytics and progress reports, helping learners track their improvement over time. This organized design ensures reliability, scalability, and the ability to integrate future enhancements such as multi-language support, advanced gesture recognition, and expanded learning modules.

Figure 1: SignIQ System Architecture

METHODOLOGY

The methodology of the SignIQ project follows a structured approach starting with requirement analysis and system design. The needs of Deaf and Hard-of-Hearing learners are studied to develop a visual-first,

interactive, and user-friendly platform. Based on these requirements, the system architecture is planned, including the frontend application, AI recognition engine, and backend database integration. In the data preparation phase, a dataset of sign language gestures is collected and labeled accurately. The data is preprocessed using techniques such as resizing, normalization, and augmentation to improve model performance.

MediaPipe is integrated to extract hand landmarks, including finger positions and joint angles, which serve as input features for the deep learning model. A YOLO-based model is then trained to classify gestures with high accuracy and real-time capability.

After training, the model is optimized for mobile deployment using TensorFlow Lite to ensure fast processing and low latency. The frontend is developed using Flutter for cross-platform support, and backend services are implemented to store user progress and analytics. Finally, the system undergoes functional testing, accuracy evaluation, and user testing to validate performance, usability, and learning effectiveness before deployment.

Following system testing, performance evaluation metrics such as accuracy, precision, recall, and F1-score are analyzed to measure the effectiveness of gesture recognition. Usability testing is conducted with sample users to assess interface clarity, response time, and learning experience. Feedback collected during this phase is used to refine the model, improve UI elements, and enhance system responsiveness. This iterative improvement process ensures that the final deployed system is reliable, efficient, user-friendly, and capable of delivering accurate real-time feedback for effective sign language learning.

APPLICATIONS

The SignIQ platform can be widely applied in educational institutions to support inclusive learning for Deaf and Hard-of-Hearing students. Schools and colleges can integrate the application into classrooms to provide interactive sign language training. It can also help hearing students and teachers learn basic sign language, promoting better communication and fostering an inclusive academic environment.

The system is highly useful for self-learning and home-based education. Individuals who wish to learn sign language independently can use the application for structured lessons and real-time practice without needing a physical instructor. The instant feedback and personalized learning features help learners improve accuracy, build confidence, and progress at their own pace.

SignIQ can also be applied in professional sectors such as healthcare, customer service, and public services, where effective communication with Deaf individuals is essential.

Professionals can use the platform to learn commonly used signs, reducing communication barriers and improving service accessibility. Additionally, the system provides a foundation for future innovations such as real-time sign-to-text translation and integration with advanced assistive technologies, expanding its impact beyond education.

RESULT AND OUTPUT

The implementation of the SignIQ system demonstrated effective real-time gesture recognition with high accuracy under normal lighting and background conditions. The integration of MediaPipe for hand landmark detection and the YOLO-based model for gesture classification provided fast and reliable performance. The system was able to detect and classify sign gestures within milliseconds, ensuring smooth and responsive user interaction during live practice sessions.

Performance evaluation showed that the trained model achieved strong accuracy, precision, and recall metrics during testing. The model performed consistently across different users, demonstrating good generalization capability. Mobile optimization using TensorFlow Lite ensured low latency and efficient processing without requiring continuous internet connectivity, making the system suitable for everyday smartphone usage.

The output of the system includes real-time sign detection results displayed on the screen, along with immediate corrective feedback indicating whether the gesture is correct or incorrect. The application also generates progress reports, accuracy percentages, and performance analytics for each learner. These outputs not only validate the technical effectiveness of the system but also confirm its ability to enhance learning efficiency, user engagement, and accessibility in sign language education.

Fig 2

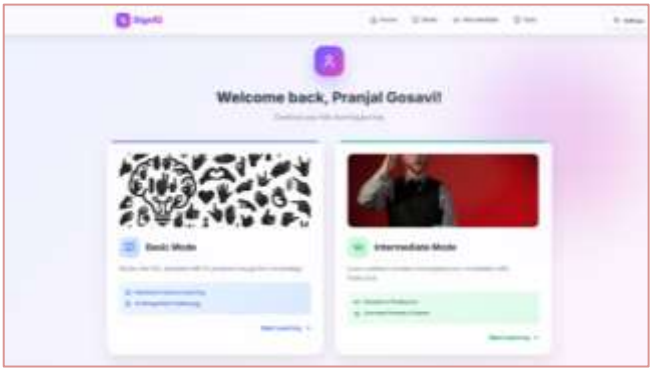


Fig 3

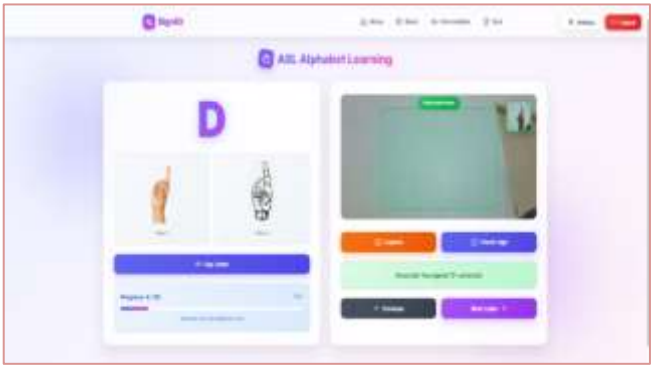
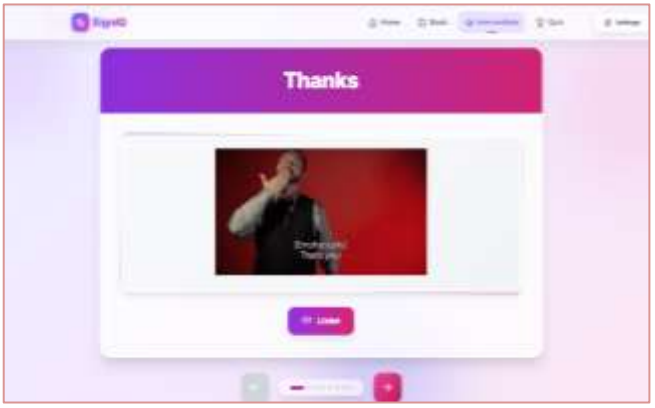


Fig 4



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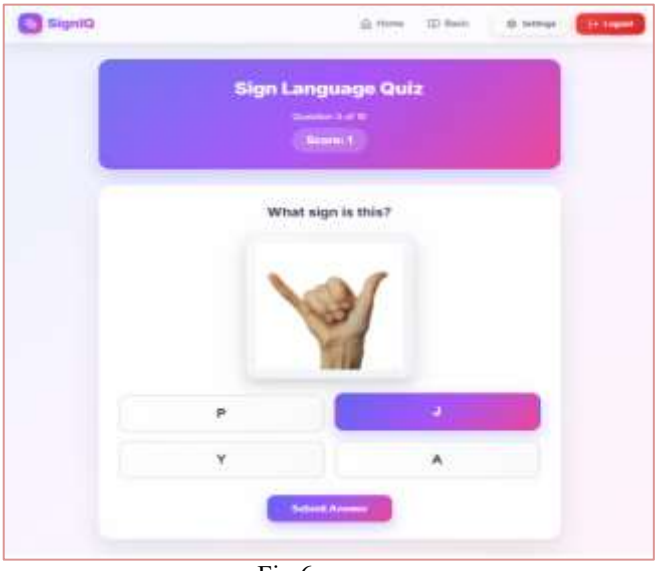

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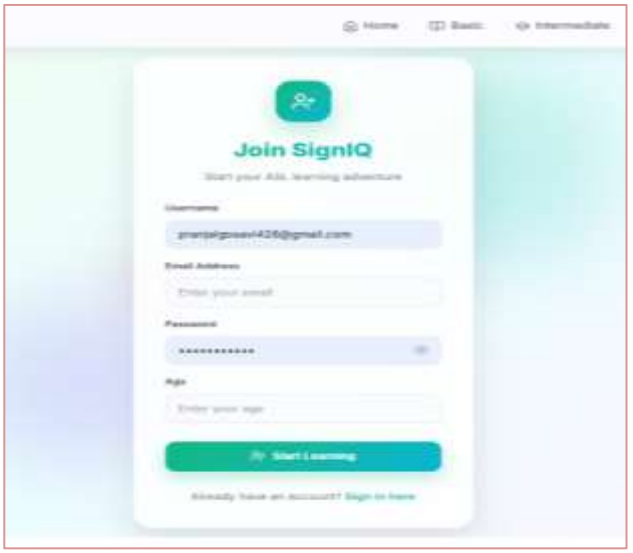

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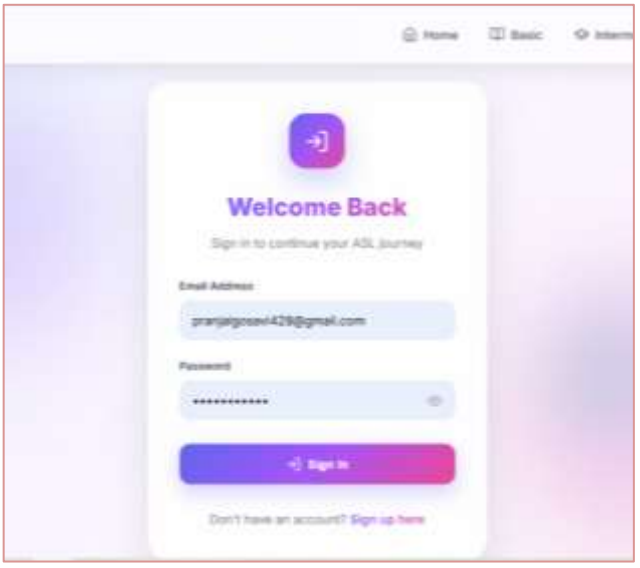

Fig 8

CONCLUSION

The SignIQ project successfully demonstrates the integration of artificial intelligence and computer vision technologies to create an interactive and adaptive sign language learning platform. By combining MediaPipe for hand landmark detection and YOLO-based deep learning models for gesture classification, the system provides real-time recognition and instant corrective feedback. This approach overcomes the limitations of traditional static learning methods and enhances user engagement through personalized learning pathways and gamification features.

Overall, the project contributes to inclusive digital education by offering a visual-first, accessible, and scalable solution for Deaf and Hard-of-Hearing learners. The results confirm that the system is accurate, efficient, and suitable for mobile deployment. SignIQ lays a strong foundation for future enhancements such as multi-language support,

advanced gesture recognition, and integration with emerging technologies, making it a promising step toward accessible and intelligent sign language education.

The project also highlights the practical feasibility of deploying AI-driven educational tools on mobile platforms without compromising performance or accessibility. Through optimized model integration and efficient system architecture, SignIQ ensures smooth real-time operation while maintaining user-friendly interaction. The continuous performance tracking and adaptive learning capabilities further strengthen its effectiveness as a self-paced educational solution. Overall, SignIQ not only addresses existing gaps in sign language learning applications but also establishes a sustainable framework for future research and development in inclusive and intelligent digital education systems.

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