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# A Multilingual Handwriting System for Visually Impaired People

Preethika.D, Sherly Persis Vinsta. S, Srinidhi. V,

Department of IT, Panimalar Institute of Technology, Chennai, Tamil Nadu, India

Dr. Suma Christal Mary. S, Swagatha.JP, Rajeshwari

Professor and Head, Department of IT, Panimalar Institute of Technology, Chennai, Tamil Nadu, India

Assistant Professor, Department of IT, Panimalar Institute of Technology, Chennai, Tamil Nadu, India

Assistant Professor, Department of IT, Panimalar Institute of Technology, Chennai, Tamil Nadu, India

**ABSTRACT:** The use of Artificial Intelligence (AI) in educational technology has recently gained prominence, especially for enhancing accessibility and inclusivity in education for visually impaired learners. This paper presents a Multilingual Handwriting System designed to improve accessibility, foster self-reliance, and support independent test-taking among visually impaired individuals. The system integrates speech recognition, haptic feedback, and Natural Language Processing (NLP) to convert voice input into text for educational and examination purposes. It enables users to listen to questions, respond verbally, and have their responses transcribed automatically. Multilingual support allows users to interact in their native language, enhancing usability and comfort. The system was tested with a group of visually impaired learners, showing improved engagement, comprehension, and confidence. By addressing limitations in traditional educational tools, this system offers a comprehensive, AI-driven solution tailored for real-world accessibility challenges in education.

**KEYWORDS:** Multilingual handwriting system, visually impaired learners, artificial intelligence (AI), natural language processing (NLP), haptic feedback, speech recognition, educational technology, voice-to-text conversion, user-centric design

## I. INTRODUCTION

The emergence of Artificial Intelligence (AI) has opened up a new realm of opportunities, transforming numerous fields, including education. Recently, AI-driven educational technologies have attracted considerable focus, especially in advancing accessibility and inclusivity for students with disabilities. The World Health Organization estimates that there are 285 million visually impaired persons worldwide, of whom 246 million have low vision and 39 million are blind [1]. Education for the blind and visually impaired is not only a fundamental right, but they also play an important role in society [2]. Also, a well-educated, visually impaired community dispels myths and misconceptions, fostering an inclusive, compassionate, and accessible society. Therefore, education is essential for children, empowering them with the knowledge and skills to contribute meaningfully to society [3]. As a result, education or literacy will give them the opportunity for employment, independence, and self-confidence, allowing them to actively participate in the workforce and society [4]. Visually impaired learners frequently face considerable obstacles within conventional educational systems.

Few studies have been conducted for visually impaired individuals, despite the fact that numerous researchers have been working to develop sign language recognition systems for the hearing-impaired [5]. However, assistive technologies such as digital screen magnifiers, screen readers, and refreshable Braille displays are employed to enable visually impaired people connect with information-grounded and communication systems [6]. This study explores the essential aspect of enhancing the learning and testing experience for visually impaired individuals through the creation of an innovative Multilingual Handwriting System. Visually impaired people have previously been included in learning and educational systems through various forms of assistive technology, such as haptic feedback systems. Haptic systems generally require expensive equipment and support from sighted instructors. Additionally, the learning process has traditionally involved letters composed of different elements mapped into tactile pattern. Writing is a big concern for the visually impaired as most formal tasks, such as signing, still rely on conventional handwriting styles [5][6][16].



People who are completely blind are unable to interact with the computer without assistive technologies. In order to overcome this barrier, they primarily use screen reader software and Braille displays. In simple terms, a screen reader system vocalizes all the information in a human-like voice which comes on the screen as well as the textbook which is compartmented on the keyboard.

A Braille display makes the same information appear on a Braille line which blind people can read with their fingers [7][17]. However, it's important to remember that although these technologies can interpret and provide feedback on the accuracy of handwritten letters, they do not ensure that users develop proper handwriting skills. People with visual impairments have largely advanced senses of hearing, touch, and sensory perception despite their visual limitations [8]. This implies that by providing them with detailed instructions while they write, voice-over technology can teach visually impaired individuals how to write by hand [8][9]. Unfortunately, the assessment module is not supported by the voice-over guidance system. The progress evaluation algorithm, which was employed in the assessment model, was occasionally found to be inconsistent [9]. This study incorporates cutting-edge technologies like speech recognition, haptic feedback, and Natural Language Processing (NLP) to improve learning and testing experiences in order to address the challenge of aiding the visually impaired in learning examinations and assessments on their own. Voice input in English, which is converted into text and saved in PDF or text formats, is how users communicate with the system. When the user responds orally to test questions that are read aloud by the platform, their responses are automatically converted into text. This creative approach promotes accessibility, inclusivity, and self-sufficiency by eliminating the need for physical assistance, supporting different languages, and enabling visually impaired individuals to independently practice handwriting and complete examinations.

The study progressed by systematically addressing key aspects, beginning with Section II, which delves into the literature review. Section III presents the problem statement and outlines the scope of the study. Section IV describes the proposed framework, providing a structured overview of the research methodology. Subsequently, Section V presents the results and facilitates discussion, offering a comprehensive analysis. Finally, Section VI concludes the study and outlines the future scope for potential research efforts.

## II. LITERATURE SURVEY

In the study by Islam et al. [9], a multilingual handwriting system was proposed using the Random Forest algorithm, achieving an F1-score of 99.8%. This system is particularly effective in supporting alphabet learning for visually impaired individuals. However, the system's reliance on expensive graphic pads limits its accessibility and scalability. The paper emphasizes the need for more cost-effective, inclusive solutions that support broader functionalities, such as preparing visually impaired learners for examinations. This contribution highlights the potential of machine learning algorithms to enhance handwriting learning tools for visually impaired individuals, while also identifying limitations in terms of accessibility.

Villalba et al. [13] introduced Eyeland, an English learning application tailored for visually impaired users at the A1 level. The system demonstrated a high accessibility rating of 91.67%, significantly improving the learners' English skills. Despite its success, the application primarily targets beginner English learners from a specific geographic region—namely, Colombian students.

In the study by Yu and Hu [10], a wavelet scattering network-based system was developed to assist visually impaired individuals with navigation on blind roads. While the focus of the paper is on mobility and not on education, the authors underscore the importance of advanced algorithms in creating accessible systems. This work contributes to the understanding of how algorithms can enhance the independence of visually impaired users, offering inspiration for educational tools that could incorporate similar techniques to improve interaction and accessibility. The study by Na et al. [11] proposed a biped constraint model to enhance walking path generation in indoor navigation systems for visually impaired individuals. Although the study addresses mobility challenges, it emphasizes the importance of precise, user-friendly interfaces that could also benefit educational systems.

Bamdad et al. [12] conducted a survey on Simultaneous Localization and Mapping (SLAM) applications for visually impaired individuals, focusing on navigation. Although the focus is on mobility, the authors highlight the potential cross-disciplinary applications of SLAM methodologies in educational systems. Their research suggests that spatial awareness and feedback systems, like haptic guidance, could be adapted for use in educational tools, improving the

tactile learning experience for visually impaired individuals. Kini et al.[15] explored the use of Extended Reality (XR) technologies in visual function testing and gamification for visually impaired individuals. The paper emphasizes the transformative potential of immersive technologies, which align with the goals of the proposed multilingual handwriting learning system. By incorporating XR or similar immersive technologies, the proposed system could offer more engaging and effective learning environments for visually impaired learners, fostering a more interactive educational experience. Singh et al. [14] investigated the usability of UPI-based smartphone applications for visually impaired users, revealing the challenges in designing accessible, user- friendly interfaces. This research is directly relevant to the design of interfaces for handwriting learning systems, as it underscores the importance of simplicity and usability in making such systems effective for visually impaired individuals. The study highlights the need for seamless interaction and independence, which are key goals of the proposed multilingual handwriting system.

In summary, while existing systems like those developed by Islam et al. [9] and Villalba et al. [13] address specific educational needs, they lack comprehensive, cost-effective solutions that support multilingual handwriting learning and examination. The integration of advanced technologies, such as speech recognition, haptic feedback, and natural language processing, remains underutilized in these systems. The proposed system aims to fill these gaps, offering a holistic approach that enhances accessibility and independence for visually impaired learners.

### III. METHODOLOGY

The methodology includes the application of advanced technologies, the proposed Multilingual Handwriting Learning and Examination System aims to provide visually impaired students with a holistic and innovative solution that is accessible, user-friendly, and self-sufficient. By integrating essential components that ensure accessibility, independence, and adaptability, this framework seeks to overcome current limitations. The framework comprises several interrelated modules, each designed to address specific user needs and enhance the educational and examination process for visually impaired individuals.

#### A. Speech Recognition:

This module allows users to communicate with the system through the processing and conversion of spoken commands into text. The module accommodates users with different accents and speech patterns by ensuring high accuracy through the use of cutting-edge voice-to- text algorithms. This feature enables users to easily participate in handwriting practice and respond to questions during assessments.

#### B. Text-to-Speech (TTS) Engine:

By reading out test questions, user inputs, and educational materials, the TTS engine acts as the system's auditory interface and provides real-time feedback. This feature ensures that users are kept abreast of their actions and progress as they navigate the platform with ease. The auditory instructions reduce the learning curve for new users and enhance engagement.

#### C. Haptic Feedback:

To overcome the challenge of handwriting practice, the system has incorporated a haptic feedback mechanism. This module allows users to trace letters, words, or patterns with the help of tactile cues, thereby improving handwriting proficiency and motor skills. The system promises an engaging and successful learning experience by providing real-time tactile assistance.

#### D. Natural Language Processing:

The NLP module processes user responses and stores them in structured formats such as text files or PDFs, where they can be evaluated. The component also enables multilingual processing, which means that users can communicate in their preferred language. The NLP module ensures that learning and assessment remain accurate and accessible by organizing user inputs clearly.

#### E. Multilingual Support:

The strong multilingual features of the system recognize the diversity in the users' linguistic backgrounds. The feature ensures that language barriers are removed and guarantees inclusiveness for the users to communicate with the platform in their mother tongue. Improving user adoption and accessibility, the system is able to support a wide range of languages.

#### IV. IMPLEMENTATION

The system follows a streamlined workflow designed to improve productivity and user experience: The speech recognition module records and transforms the user's voice input into text. Real-time audio advice is given by the TTS engine that enhances the understanding and engagement of the user. The haptic feedback system gives users tactile guidance for tracing and learning letter formations accurately. The NLP module facilitates review and evaluation by structuring and storing processed responses in formats that are easy to use. For smooth communication and involvement, users can choose their desired language.

The system integrates various elements into a unified framework to provide a comprehensive and inclusive learning experience. The modular architecture of the system guarantees scalability and flexibility, allowing future improvements and incorporation of new technologies. In addition to overcoming the inadequacies of current resources, the proposed approach sets a new standard for the independence and accessibility of visually impaired students in the classroom. The workflow of the proposed multilingual handwriting system consists of a series of relations between the user and the system, designed to provide a seamless and inclusive learning and examination experience for visually impaired individuals. The process is outlined in the sequence illustration and developed below.

##### A.Furnishing Voice Input (test Question)

The user initiates the process by providing voice input, which includes the test question or command. These input initiates interaction with the system. The system leverages a Speech Recognition Module to convert the spoken input into text format.

##### B.Reading test Question Aloud

Once the test question is recognized and reused, the system uses a Text- to- Speech (TTS) Module to read the question aloud to the user. This ensures that the user fully comprehends the task, promoting inclusivity by appealing to their auditory senses.

##### C.User's Verbal Response

The user verbally responds to the question. This response is captured by the system and reused using the Speech Recognition Module, which converts the verbal input into text form. The system ensures the accuracy and integrity of the conversion to maintain the integrity of the user's response.

##### D.Converting Response to Text

The user's spoken answer is automatically transcribed into text format using advanced Natural Language Processing (NLP) ways. This transcription is vital for recording and storing the user's responses. It also allows users to review their answer before submission.

##### E.Saving test Answers

Once the user confirms their response, the system securely saves the answer in a chosen format, such as PDF or plain text. This step facilitates future reference, evaluation, and record- keeping, barring the need for manual documentation.

##### F.Furnishing Feedback

The system provides immediate feedback by reading the transcribed answer back to the user. This step helps ensure the accuracy of the response, eliminating the need for manual documentation.

##### G.Furnishing test Completion

After all questions are answered, the system confirms the completion of the test. This confirmation reassures the user that their responses have been successfully recorded.

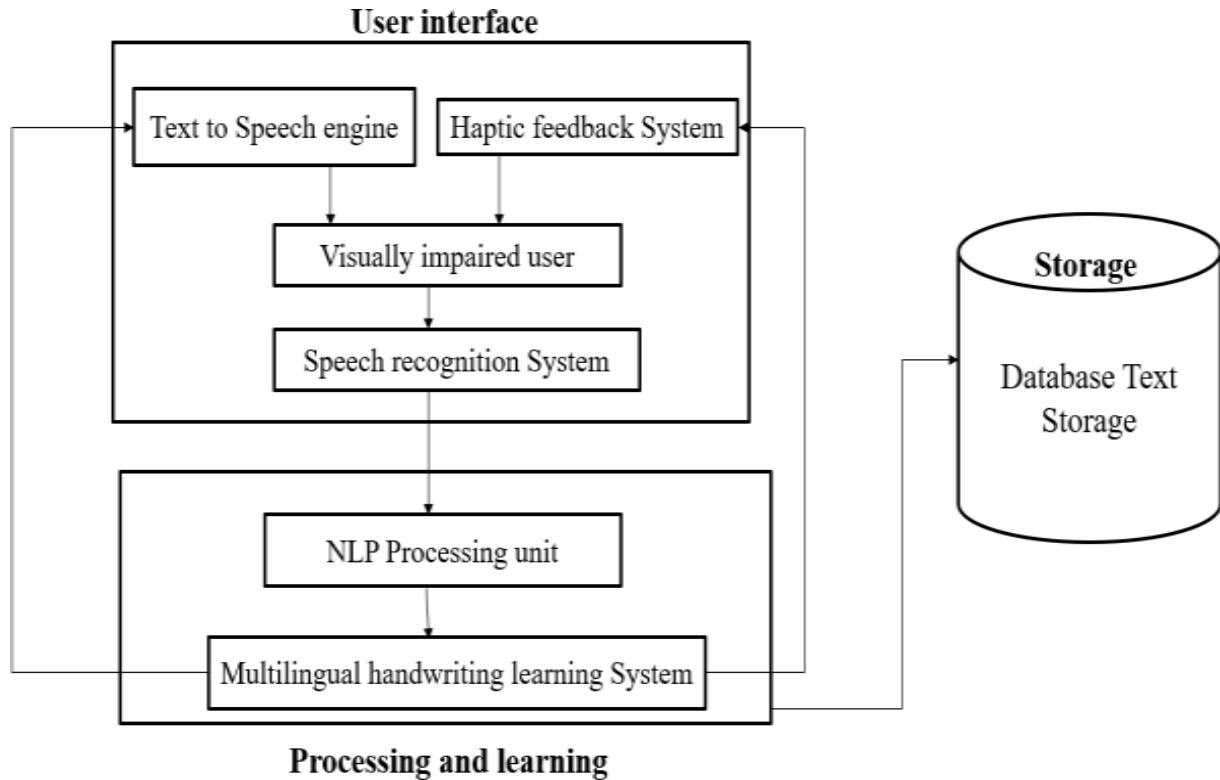


Fig 1. System Architecture

## V. RESULTS AND DISCUSSION

### System Performance and Evaluation:

The multilingual handwriting system for visually impaired individuals was evaluated based on user interaction, handwriting recognition accuracy, ease of use, and multilingual support. A group of visually impaired learners tested the system, and the results showed significant improvements in handwriting practice and examination completion. Users demonstrated improved understanding, increased confidence, and greater engagement during their interactions with the system.

Table I. System Performance Metrics

Performance Metrics	Score (out of 10)
Handwriting Recognition Accuracy	9.0
Speech Recognition Accuracy	8.7
Multilingual Processing	9.2
Overall System Efficiency	9.0

### User Interaction Metrics:

The system interface was evaluated for user-friendliness and accessibility. Feedback indicated that the integration of speech recognition, text-to-speech (TTS), and haptic feedback significantly enhanced the user experience. Users were able to interact with the system using voice commands, which were accurately transcribed into text, enabling hands-free operation. The TTS engine clearly read out test questions, enabling users to respond verbally. These responses were then transcribed automatically, ensuring continuity in the interaction.

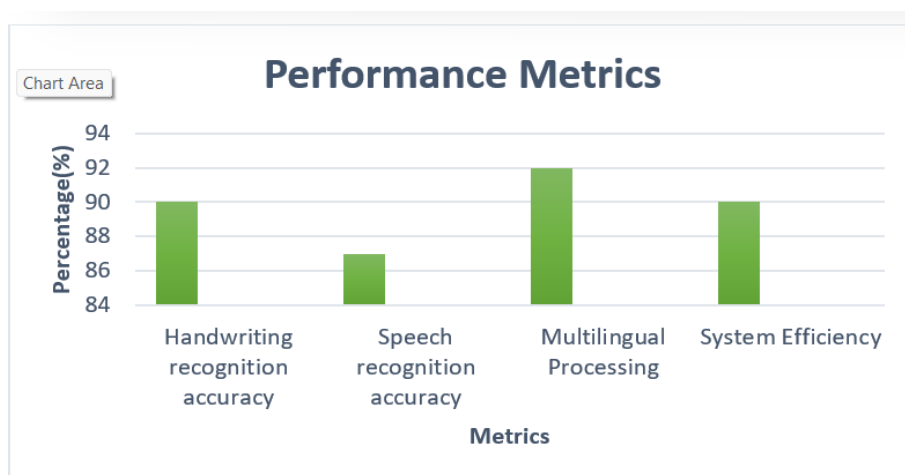
$$\text{Accuracy} = \frac{\text{Number of Correctly Written Characters} \times 100}{\text{Total Number of Characters Written}}$$

**Table II. User Interaction Feedback**

Metrics	Evaluation Score (out of 10)
Voice input Accuracy	9.2
Text-to-Speech Effectiveness	9.5
Haptic Feedback Usefulness	9.0
Ease of System interaction	9.2

### Multilingual Support:

One of the key features of the system is its multilingual support, which enables users to interact in various languages. During the evaluation, participants were able to switch between languages seamlessly, enhancing their comfort and confidence. The NLP module successfully processed and stored responses in multiple languages, supporting non-native speakers .



**Fig. 2. Performance Metrics Graph**



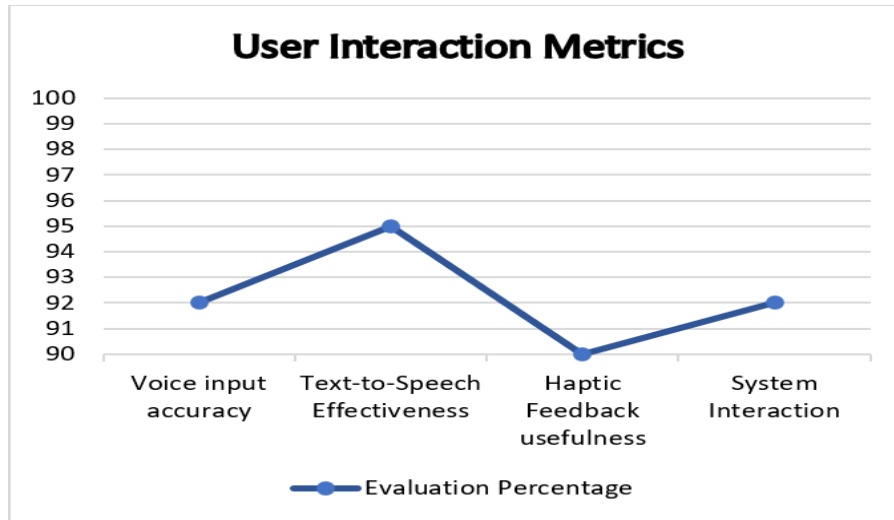


Fig. 3. User Interaction Metrics Graph

## VI. CONCLUSION AND FUTURE SCOPE

The integration of advanced technology into the Multilingual Handwriting System represents a significant step toward greater inclusiveness and independence among visually impaired students by addressing critical gaps in accessibility and autonomy. The seamless incorporation of natural language processing, haptic feedback, speech recognition, and multilingual support creates new possibilities for self-directed learning and examination. This system enables users to practice handwriting and complete exams independently, while allowing instructional resources to be tailored to individual needs—promoting a sense of achievement and self-confidence. By exploring the synergy between cutting-edge technologies and user-centric design principles, the framework provides a comprehensive, adaptable, and intuitive platform capable of transforming the educational landscape for visually impaired learners.

Future work will focus on dynamic handwriting adaptation through machine learning, enabling the system to recognize and respond to diverse writing styles for personalized feedback. Additionally, expanding multilingual capabilities to include regional and less widely spoken languages will further enhance global accessibility. Real-time AI-driven feedback systems will also be developed to offer users immediate, context-aware guidance during practice sessions, ensuring continuous skill development. Further enhancements may include the integration of cloud-based storage for seamless synchronization of user data across devices, allowing learners to track progress over time.

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