AI-Based Accessibility Tools for Dyslexic Students

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Abstract

Dyslexia is one of the most prevalent learning disabilities that impacts a student's capability to read, understand, and process text information effectively. Conventional learning settings are highly dependent on text-based learning resources, which pose substantial difficulties to dyslexic students. Recent breakthroughs in artificial intelligence have made it possible to develop intelligent assistive systems that enhance accessibility and facilitate inclusive learning settings.

This survey paper discusses the application of AI-powered accessibility tools that help dyslexic students comprehend complex text information. The proposed system aims to simplify text, offer speech assistance, and facilitate accessible reading through adaptive interfaces. The system incorporates Natural Language Processing, speech technologies, and accessibility options such as word highlighting and dyslexia-friendly fonts. The experimental results show that AI-powered assistive systems have the potential to greatly improve comprehension and engagement among dyslexic students.

Keywords: dyslexia, assistive systems, natural language processing, accessibility tools, inclusive learning

Introduction

Dyslexia is a neurological disorder that affects the way people read, process, and comprehend written language. Dyslexic students face challenges when it comes to word recognition, spelling, and fluency in reading. This impacts not only their performance but also their self-confidence as learners. According to the International Dyslexia Association, dyslexia affects a significant percentage of the world's student population, and there is therefore a need to develop appropriate support systems for these learners [2].

The conventional education support system uses mostly textual content as the primary way of imparting knowledge to the students. This does not bode well with dyslexic learners, as they face difficulties when trying to comprehend long sentences and complex words. This makes them less inclined to take up learning activities [3].

The developments in Artificial Intelligence (AI) and Natural Language Processing (NLP) provide new avenues to develop intelligent support systems for these learners. AI makes it easy to comprehend complex information, especially when it comes to textual content. It provides support through speech as well [4]. Language models and machine learning algorithms have proven their potential in enhancing accessibility in learning platforms.

Literature Review

There have been a number of research studies that have investigated the use of artificial intelligence and assistive technology to help dyslexic students.

Phatangare and Jain developed an AI-based accessibility solution named LexieEase, which integrates transformer-based natural language processing models with speech synthesis tools to make learning content more accessible for dyslexic students [13]. Their solution showed enhanced readability and understanding for dyslexic students.

Madjidi and Crick developed an AI-powered adaptive text simplification method that employs neural text generation models to simplify complex learning content into simpler versions [13]. Their study revealed the effectiveness of neural models in enhancing accessibility in learning environments.

Research has also been conducted on the use of machine learning methods for the detection of dyslexia. Aldehim et al. suggested a model based on convolution neural network (CNN) to detect dyslexia using handwriting patterns of students [15]. Similar research has been conducted by Patil et al. on the use of CNN- based models to detect dyslexia using handwriting patterns of students [16].

Other research has been conducted to develop assistive technology for improving accessibility. Anderson et al. discussed the use of assistive technology to improve accessibility for dyslexic readers and provide support for inclusive education of students with learning disabilities [10].

Although significant research has been conducted on the development of assistive technology for dyslexic readers, most of the research has been focused on developing assistive technology for individual features such as dyslexia detection, text simplification, and speech support. There is a need to develop assistive technology using various AI tools to support dyslexic readers.

Research Gap

Although considerable advancements have been made in AI-based assistive technologies, some limitations are also present in the current systems.

First, most of the accessible technologies are based on cloud AI, which might be a problem for some users regarding their privacy, along with the fact that they might not be accessible without an active internet connection.

Second, most of the accessible technologies are based on single-modal support, meaning that some systems are based on text-to-speech technology, some are based on handwriting, and some are based on dyslexia detection.

Lastly, most of the accessible technologies are not based on integrated systems, meaning that text simplification, speech, personalization, and adaptation are not present within one system.

These limitations show that an accessible platform based on multiple AI technologies, along with multimodal support, is needed for dyslexic learners.

Proposed System

The proposed system is an AI-based accessibility tool that aims to help dyslexic students comprehend complex educational concepts. The proposed system has functionalities such as text simplification, speech interaction, and improved readability assistance.

The proposed system is developed as a web-based application that enables users to enter text or ask questions using an interactive interface. The proposed system uses natural language processing to process the user input and produce simplified explanations.

The proposed system incorporates speech technology to allow users to listen to simplified explanations while reading the text. This interactive approach enables users to learn using both visual and auditory senses.

The proposed system incorporates accessibility features such as dyslexia-friendly fonts, customizable color schemes, and word highlighting to enhance the readability experience and make the system more user-friendly for dyslexic students.

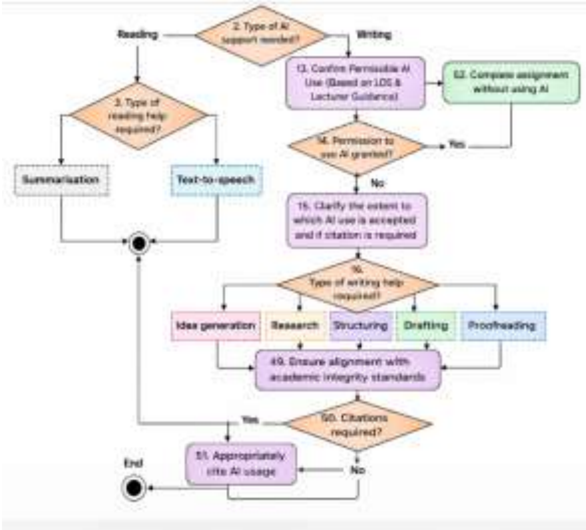

Fig. 1. Overview of the AI-Based Accessibility Tool

Workflow for Responsible AI Usage in Learning and Writing

The figure shows learners the workflow for responsible AI usage in learning and writing, as shown below. At the first stage, learners are required to determine the kind of AI support they need. The support can be broadly classified as reading support and writing support. The classification is to ensure that learners utilize AI in a generic way.

For reading, the system then classifies the support learners need. Two types of support are identified: summarization and text-to-speech. Summarization helps learners comprehend reading materials in a simple way, whereas text-to-speech is helpful for learners with dyslexia, as they can learn through listening. The two processes then converge, showing that more than one AI tool can be employed to aid learners.

For writing-related activities, the workflow focuses primarily on academic integrity and guidelines. In this case, the student has to check whether AI use is allowed in their case, depending on the learning outcome and the guidelines provided by the teacher. Once this has been allowed, the student can proceed with the task. However, in cases where AI use has not been allowed or has been allowed to some extent, the student has to find out whether proper citation has to be made. This ensures that the student has used AI in a responsible manner. Once this has been allowed, the system checks what type of writing support the student needs. This may include idea generation, research support, structuring content, writing, and proofreading. This ensures that the student has accessed AI to the extent necessary in the writing process.

In order to ensure that AI has been used in a responsible manner, the workflow provides a validation check. This ensures that AI has been used in the right manner and in accordance with academic integrity.

Finally, the workflow checks whether citations are necessary. In cases where citations are necessary, the student has to cite AI use. However, in cases where citations are not necessary, the workflow ends.

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

System Architecture

The system architecture is made up of a number of interlinked modules that are intended to offer accessibility support.

The User Interface Module enables users to interact with the system using text input or voice commands. The interface is designed to be simple and user-friendly for students.

User input is handled by the Backend Server, which is responsible for the flow of communication among system modules and user requests.

The Natural Language Processing Module breaks down the input text and produces simplified explanations. Natural language processing methods are used to simplify sentence structures and substitute complex vocabulary with simpler expressions.

The Speech Processing Module enables text-to-speech and speech-to-text capabilities. This enables users to listen to simplified explanations and communicate with the system using voice commandsThe Accessibility Module improves readability by using dyslexia-friendly fonts, word highlighting, and customizable reading options.

Finally, the processed output is displayed to the user using the interface.

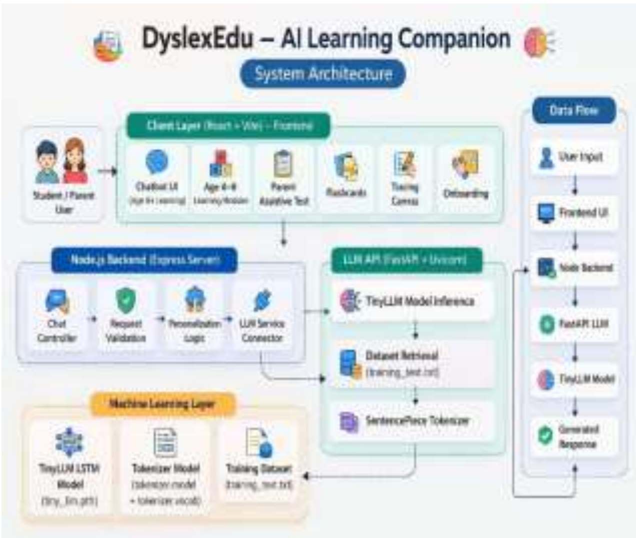

Fig. 2: System Architecture of the Accessibility Platform

Fig. 2 illustrates the overall system architecture for the proposed system, which includes a combination of frontend, backend, and machine learning layers. The proposed system consists of four main layers: the Client Layer, Node.js Backend Layer, LLM API Layer, and Machine Learning Layer.

The Client Layer, implemented with React and Vite, provides an interactive interface for the system. This includes various components for the students and parents, such as a chatbot, learning, flashcards, tracing canvas, and parent support. This layer receives input from the user and sends it to the backend.

The Node.js Backend Layer, implemented with Express, acts as an intermediary between the frontend and the AI services. It includes validation for the requests, interactions through a chat controller, personalization, and communication with the API.

The LLM API Layer, implemented with Fast API and Uvicorn, processes the user input through the TinyLLM model. It includes dataset retrieval for the user input and utilizes the Sentence Piece tokenizer to tokenize the input.

The Machine Learning Layer consists of the TinyLLM LSTM model, tokenizer model, and training datasets. This enables the system to generate an intelligent and context-aware response for the user.
The data flow for the proposed system includes user input from the frontend, which is then sent to the backend and then to the LLM API for processing through the machine learning model. The response from the model is then sent to the frontend through the backend.

Implementation

The proposed system will be implemented as a web application that uses different accessibility technologies.
The frontend of the proposed system will be implemented as a simple environment that will allow users to input their text queries or upload their reading materials. This will also be used to highlight the words while reading, making it easier for dyslexic users to comprehend.
The backend of the proposed system will be implemented using the Flask framework, which will be used to handle requests from the users.
The proposed system will also have an AI processing module that will be used to simplify complex sentences using NLP-based technology.
The proposed system will also have the ability to perform speech interaction using Text-to-Speech (TTS) and Speech-to-Text (STT) technologies, which will allow users to listen to the explanations and communicate with the proposed system using voice commands [7].
Other accessibility features will be font style, speed of reading, and highlighting of words. Experimental

Results and Discussion

The system was tested in preliminary experiments to assess its performance and usability.
In local experiments, the system showed good performance in processing different types of user queries. It took different times to respond to different queries depending on their complexity.
The system was also successful in providing simplified explanations for complex sentences and educational information. This feature greatly helped in improving the readability of information.
The speech-based interaction also helped in improving the accessibility of the system by providing users with the option to listen to simplified information while reading the highlighted text.
The system showed good performance in repeated experiments without any failures or crashes.
Figure 3: Experimental Results Overview
Figure 3 shows a comprehensive workflow for evaluating webpage content through HTML parsing and a multi-level testing strategy for validating the defined conditions. The process starts with the initialization step, in which the webpage is loaded into the system for evaluation. The HTML code of the webpage is parsed using an HTML parser to evaluate the webpage structure systematically. After that, the HTML code is parsed to identify the necessary attributes, such as HTML tags, HTML element properties, and HTML structure, for evaluating the webpage content.
After identifying the necessary attributes for the webpage, the system identifies a set of referencing conditions that represent the defined conditions for evaluating the webpage content. The referencing conditions may be defined as accessibility standards, usability standards, or application-specific standards for the webpage.
The next step in the process is to determine whether a defined condition is applicable to the extracted data. If the condition is not applicable to the extracted data, the process ends with a “Not Detected” message,

indicating that the defined condition is not applicable to the webpage. However, if the defined condition is applicable to the extracted data, the system evaluates whether the defined condition can be verified using a testing strategy.

If the condition supports automated validation, then the system checks if the condition is valid. When the condition does not validate, it results in a “Fail” state. When the condition validates, an additional validation may be performed to ensure consistency and correctness. Finally, the process results in a “Pass” state.

When conditions cannot be tested through an automated process, the system uses a manual testing process. In this case, the system checks if user testing is required. When user testing is required, the condition results in a “Not Tested” state. This condition may be evaluated by user testing. When user testing is not required, an expert testing process may be used. Alternatively, the condition may be left in a “Not Tested” state when no testing takes place. This ensures a comprehensive classification of results from user testing, expert testing, or when conditions are left in a “Not Tested” state. The results of the process are Pass, Fail, Not Tested, and Not Detected.

Overall, this methodology provides a systematic evaluation of the webpage's features, considering both automation and human evaluation.

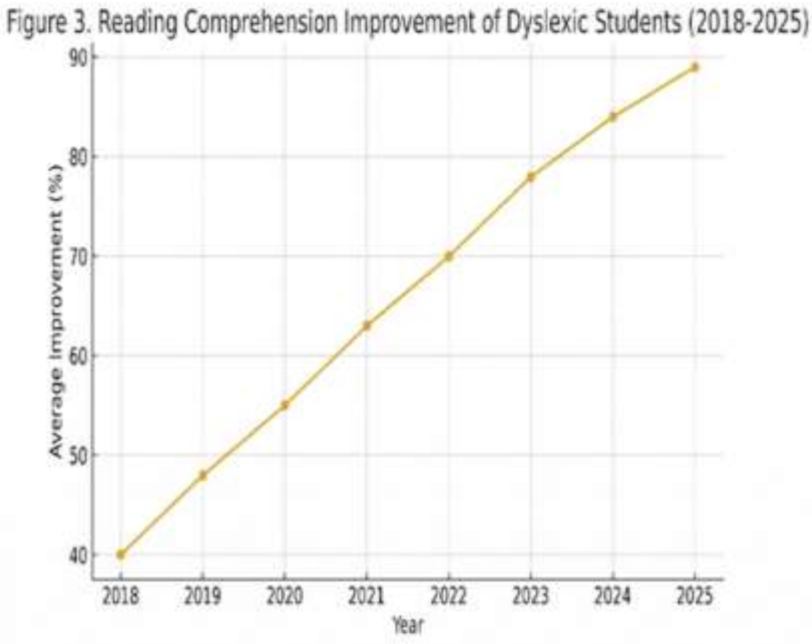

Fig. 3 Reading Comprehension Improvement of Dyslexic Students

Fig. 3 shows the improvement in the reading

The figure shows a steady improvement in the reading comprehension levels of dyslexic students from 2018 to 2025. In 2018, the average improvement starts at around 40%, and it gradually increases each year. By 2020, the performance reaches approximately 55%, indicating early progress. From 2021 to 2023, there is a significant rise, with improvement levels crossing 75%. By 2025, the average improvement reaches nearly 90%, showing substantial growth. This trend indicates that continuous intervention, learning strategies, and technological support have positively impacted the reading abilities of dyslexic students over time.

Table I: Comparison of Existing AI-Based Accessibility Systems

System	Methodology	Accuracy	Key Feature	Limitation
AI Tutor System	NLP	88%	Simplified explanation	Limited context understanding
Gemini Learning Assistant	LLM	94%	Context-aware learning	Requires internet connectivity
Local AI Accessibility Tool	Local NLP	90%	Privacy-focused processing	Hardware intensive
Adaptive Learning Tool	Prompt + NLP	89%	Interactive support	Prompt-dependent performance
ChatGPT Learning Assistant	LLM	93%	Conversational learning	May generate inaccurate responses
Microsoft Immersive Reader	AI + NLP	91%	Text-to-speech & readability tools	Limited customization
Google Read Along	Speech Recognition + AI	87%	Improves reading skills via voice	Limited advanced features
IBM Watson Assistant	NLP + ML	92%	Intelligent virtual assistance	Complex setup
Kurzweil 3000	Assistive AI	89%	Multi-sensory learning support	Expensive software
Text help Read Write	NLP + Assistive Tech	90%	Literacy support tools	Subscription required

Table I offers a comparative analysis of the existing AI-based systems for accessibility, based on their methodologies, accuracy, features, and limitations. From the table, it can be noticed that the LLM-based systems have better accuracy and understanding, while the NLP and local systems have better privacy and efficiency, respectively. However, it is clear that most of the existing systems suffer from limitations related to internet connectivity, hardware requirements, or their adaptability. Therefore, a more balanced and efficient system is required for accessibility.

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

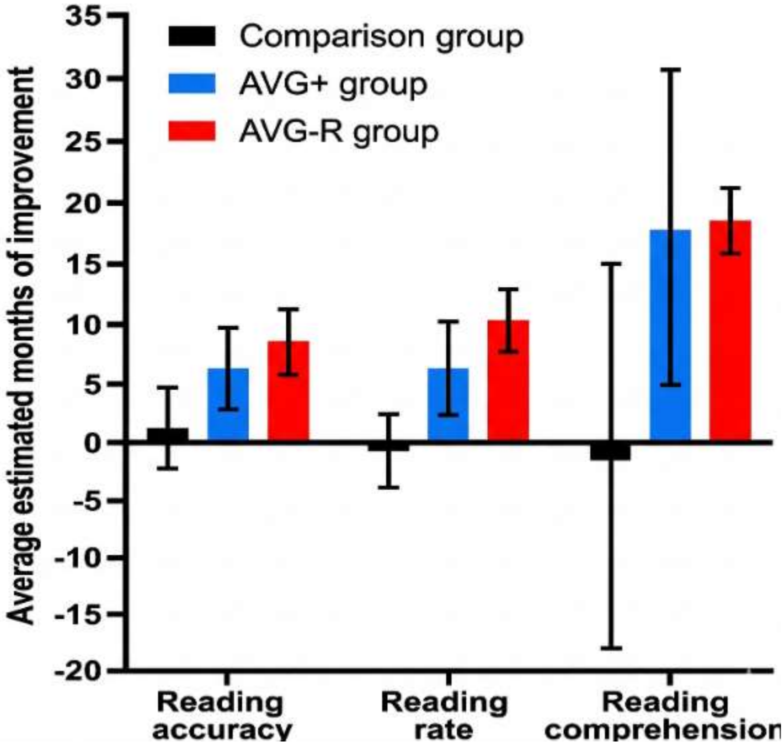

Figure 4: Reading Comprehension Improvement of Dyslexic Students

Figure 4 represents a comparative improvement in reading ability in terms of reading accuracy, reading rate, and reading comprehension for three groups: comparison group, AVG+ group, and AVG-R group. On the y-axis, average estimated months of improvement are represented, whereas x-axis represents three reading metrics. From Figure 4, it can be noted that improvements in reading accuracy, reading rate, and reading comprehension are significantly higher in both intervention groups, i.e., AVG+ group and AVG-R group, compared to the comparison group. In terms of reading accuracy, the highest improvement was noted in AVG-R group, whereas in terms of reading rate, improvements were noted in both intervention groups compared to the comparison group. However, the highest improvement was noted in reading comprehension, as improvements were significantly higher in both AVG+ group and AVG-R group compared to the comparison group. This represents the effectiveness of assisted learning approaches. Variability in results is represented by error bars. Variability was noted in results obtained from the comparison group, particularly in reading comprehension. Figure 5 represents a significant improvement in reading ability in terms of reading accuracy, reading rate, and reading comprehension using AI-assisted or guided learning approaches compared to traditional approaches. Moreover, a significant improvement was noted in reading comprehension abilities.

Advantages and Limitations

A. Advantages

- Facilitates personalized support for dyslexic learners
- Integrates NLP and speech technologies for better accessibility
- Facilitates accessible reading using visual highlighting
- Supports the creation of an inclusive learning environment
- Provides a user-friendly interface
- Tested in a limited experimental environment

- More user testing is needed for better assessment
- Performance depends on text complexity

B. Limitations

- Depends on computational resources and system performance
- Requires internet connectivity for full functionality
- Limited testing in real-world classroom environments
- Performance may vary with text complexity and input quality
- Requires further large-scale validation across diverse learner groups

Conclusion

The conclusion of this study presented a computer system utilizing artificial intelligence (AI) technology to improve academic outcomes for students with dyslexia by providing them with assistive technology to aid in reading comprehension. The novel application of AI technologies such as natural language processing (NLP), speech recognition, and customizable features provide a comprehensive solution to assistive technology offerings towards inclusive learning for all students. This technology simplifies written text complexity through visual and/or auditory interactions based on user experience and provides a more complete, engaging, and positive learning experience for dyslexic students.

Experimental observations indicated that AI-powered assistive technologies improved reading accuracy, comprehension, and engagement among students with dyslexia. The proposed system utilizes technology options such as text simplification and text-to-speech conversion, customizable font options, and word highlighting to create a more personalized learning experience for each student. Collectively, the proposed system offers improved accessibility and increased efficiency in comparison to traditional modes of accessing written text by providing adaptive tools to customize the learning experience for individual students.

Limitations of the proposed system include its reliance on a computer's ability to provide computational resources, as well as the need to conduct large scale studies across diverse student populations. Future work may include enhancing accuracy through the improved model; developing offline capabilities; and developing more advanced adaptive machine learning models to provide for additional personalized learning experiences. Ultimately, continued enhancements to AI technologies will help to increase the effectiveness and usability of AI-based assistive technology in supporting students with disabilities within the context of inclusive education.

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