

AI BASED DYSLEXIA IDENTIFIER

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ABSTRACT

Dyslexia is a prevalent learning disorder that impairs a person's ability to read, write, and understand written language, making it difficult to effectively process textual information. In order to help people with dyslexia, this project suggests creating an AI-powered assistive system that makes use of text-to-speech and machine learning technology.

With the use of AI-powered spelling and grammatical correction, real-time voice aid, and dyslexia-friendly text layout for better readability, the system can recognize dyslexic writing patterns and provide adaptive solutions. Along with error correction, the tool incorporates color-coded reading aids, phonetic-based word prediction, and text simplification techniques to improve reading comprehension and readability.

The technology is made to provide a customized experience that dynamically adjusts to the particular learning requirements and difficulties of every user. To encourage the development of literacy skills and increase user confidence in both reading and writing assignments, it also offers real-time feedback. This solution helps people with dyslexia communicate more successfully and freely by providing personal accessibility tools, workplace applications, and educational applications. The method seeks to promote inclusivity and increase learning accessibility for everyone by closing the literacy gap.

KEYWORDS: *Dyslexia Detection, Machine Learning, NLP, Text-to-Speech, Adaptive Learning, AI Assistance, Accessibility.*

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INTRODUCTION

Background and Motivation

Dyslexia is one of the most prevalent and widely recognized learning difficulties, affecting a significant portion of the global population across different age groups and educational backgrounds. It is primarily characterized by persistent challenges in reading, writing, spelling, and language comprehension, despite individuals often possessing normal or even above-average intelligence.

These challenges do not arise from a lack of motivation, effort, or cognitive ability; rather, they stem from differences in how the brain processes written and spoken language. Neurological variations associated with dyslexia influence phonological processing, word recognition, and information decoding, making conventional literacy acquisition more demanding for affected individuals.

Beyond academic performance, dyslexia significantly impacts emotional well-being, self-confidence, professional productivity, and effective communication in everyday life. Individuals with dyslexia frequently encounter frustration, anxiety, and reduced self-esteem due to repeated academic struggles and misunderstanding of their learning needs.

Problem Statement

Traditional educational systems, which largely rely on standardized teaching methodologies, often fail to accommodate diverse cognitive learning styles. As a result, learners with dyslexia may become unintentionally marginalized, leading to underachievement and limited opportunities for personal and professional growth. These challenges highlight the urgent need for inclusive educational solutions that recognize individual differences and provide adaptive learning support.

Research Objectives

The primary objective of this project is to design and develop an AI-powered assistive system specifically aimed at supporting individuals with dyslexia. Specifically, the system aims to:

- Implement voice-assisted reading and writing capabilities through text-to-speech and speech-to-text technologies.
- Apply dyslexia-friendly text formatting techniques including specialized fonts, line spacing, and adjustable color themes.
- Integrate phonetic-based word prediction enabling users to generate accurate word suggestions based on pronunciation patterns.
- Implement color-coded reading assistance where words or syllables are highlighted to guide eye movement.
- Develop adaptive learning pathways that automatically adjust content complexity based on user performance.

Contributions

The primary contributions of this work include:

- **AI-Based Dyslexia Detection:** A complete system for identifying dyslexic writing patterns from user input.
- **Adaptive Learning Module:** A personalized system that evolves based on user performance history.
- **Multimodal Input Processing:** Support for text, speech, and image-based input via OCR.
- **Real-Time Feedback System:** Immediate correction and phonetic guidance to assist learners.

LITERATURE SURVEY

A comprehensive review of existing work in the domains of AI-based dyslexia detection, assistive technology, and adaptive learning systems was conducted to establish the theoretical and technical foundation of this project.

AI in Dyslexia Research (2025)

A scoping overview by Jia Rong Yap, Thirishankari Aruthanan, and Mellisa Chin examines 84 studies (2020–2024), identifying 4 key AI applications: early detection (handwriting, eye motion evaluation), customized learning (smart tutoring systems), speech and language processing (NLP), and neuroimaging (CNNs on EEG/fMRI). Machine learning (52%) and deep learning (22%) dominate, with major contributions from India (29%) and China (12%). The review emphasizes AI's role in correct diagnosis and inclusive learning but notes challenges including small imbalanced datasets, accessibility issues, and absence of transparency in DL models.

AI-Based Dyslexia Detection Techniques (2024)

Yazeed Alkhurayyif and Abdul Rahaman Wahab Sait analysed 39 studies, highlighting PCA and CNNs for feature extraction with accuracies as much as 99.8%. Data sources included MRI, EEG, eye-tracking, and handwriting, revealing key dyslexia markers. Multimodal models advanced detection by integrating neuroimaging, behavioural, and linguistic data. Challenges included small datasets, excessive computational costs, low interpretability, and ethical concerns.

Deep Learning for Dyslexia Detection via Handwriting Analysis

Ghadah Aldehim et al. proposed a CNN model using handwriting images from the NIST 19 dataset, attaining 99.5% training and 96.4% testing accuracy. The Keras-based model consists of convolutional, pooling, dropout, and dense layers, with 4.7M trainable parameters and an F1-score of 96. It relies completely on handwriting, lacks generalizability across populations, and does not combine other indicators like eye movements.

Machine Learning for Checklist and Game-Based Datasets (2023)

S. Santhiya and C. S. Kanimozhiselvi explored ML/DL models like SVM, KNN, Decision Trees, and CNNs across checklist, questionnaire, and gamified test datasets. Checklist strategies achieved up to 100% accuracy (ANFIS), while gamified tests using models like XGBoost reached 90%, offering scalable, language-unbiased screening. Small and varied datasets (125–1124 samples) restricted generalizability.

Eye Movement-Based Dyslexia Prediction (2021)

Alae Eddine El Hmimdi et al. used eye movement data from the Alouette reading and Remobi saccade tests to predict dyslexia with 81.25% accuracy. Non-reading eye data showed promise for reading speed prediction, with the Remobi vergence test outperforming conventional methods. The study's small sample (87 participants) and shortage of hyperparameter tuning restricted model optimization.

Real-Time Assistance for Dyslexic People (2019)

Shahna E. et al. developed Dyslexic Reader, an Android app that aids dyslexic users by converting text from images, PDFs, and videos into the Open Dyslexic font. Leveraging Google's Mobile Vision API and OCR, it extracts real-time text accurately from small areas like signboards and supports text-to-speech for added accessibility. The app offers a low-cost, portable solution for dyslexic individuals.

SYSTEM REQUIREMENTS

Software Requirements

The Dyslexia Assistance Web Application is developed using a robust and scalable software ecosystem designed to support advanced text processing, machine learning capabilities, and an accessible user interface. The system leverages Python as its core programming language along with multiple specialized libraries and development tools.

Python and Its Libraries

Python serves as the foundational programming language due to its simplicity, flexibility, and extensive ecosystem of libraries. Its readable syntax facilitates efficient development and collaboration, while its strong community support enables rapid implementation of advanced computational and linguistic functionalities.

Key Libraries

- **Whisper:** Employed for accurate speech-to-text transcription, enabling the application to process and analyse user voice inputs effectively.
- **Pytesseract & Easy OCR:** Integrated to enable Optical Character Recognition (OCR), allowing text extraction from images and scanned documents.
- **Language Tool:** Provides advanced grammar checking and spelling correction capabilities with a customized dyslexia-oriented lexicon.
- **Pytsx3:** Implements text-to-speech functionality, enabling voice-assisted reading support. Operates offline ensuring reliability and faster response times.
- **Google Generative AI (Gemini):** Leverages Google's Gemini AI models for intelligent content generation and adaptive learning paragraph creation based on user performance.
- **Flask:** Serves as the primary backend web framework, providing URL routing, request handling, templating, and session management.
- **PyMongo:** Provides Python-based interface for seamless interaction with MongoDB, enabling efficient storage and retrieval of user data and learning records.

Hardware Requirements

Table 1

Component	Specification
Processor	Intel Core i5 or higher (or equivalent)
Memory (RAM)	Minimum 8 GB RAM
Operating System	Windows, macOS, or Linux
Input Devices	Standard keyboard and mouse
Output Devices	Monitor or display screen
Internet Connectivity	Stable broadband, minimum 10 Mbps

Methodology and Dataset

The methodology of the Dyslexia Assistance Web Application is designed to provide an intelligent, accessible, and adaptive learning environment following a structured processing pipeline: input acquisition, linguistic analysis, real-time correction, phonetic assistance, and personalized learning adaptation.

Input Acquisition and Preprocessing

The system begins by acquiring user input through either manual text entry or voice-based interaction. Once input is received, preprocessing operations are applied to standardize data — converting text to lowercase, removing unnecessary symbols, and tokenizing sentences into individual words for accurate NLP processing.

Identification of Dyslexia Patterns

After preprocessing, the system performs linguistic analysis using the Language Tool-based NLP module to detect spelling and grammatical inconsistencies. Examples of identified patterns include:

- Letter reversals (e.g., "scool" instead of "school")
- Phonetic substitutions (e.g., "bcos" instead of "because")
- Visually confusing word usage (e.g., "thier" instead of "their")

Dataset Architecture

The detection and correction mechanisms rely on a specialized dataset containing dyslexia-specific spelling patterns: phonetic spelling errors (e.g., "frend" → "friend"), visually similar word confusions (e.g., "recieve" → "receive"), and letter transposition/omission errors. The system employs a hybrid detection approach combining rule-based linguistic analysis with machine learning techniques.

PROPOSED APPROACH, MODULES & UML DIAGRAM

Proposed Approach

The Dyslexia Assistance System is designed to process user inputs provided in multiple formats, including speech, images containing textual content, and direct text input. Speech-based input is first converted into textual form using speech-to-text processing, enabling uniform handling of user data. Similarly, image inputs are processed using Optical Character Recognition (OCR) techniques to extract readable text.

Once the input is standardized, a pre-processing stage is performed to clean and normalize the text. After preprocessing, feature extraction techniques are applied to identify essential linguistic and contextual characteristics such as phonetic patterns, spelling structures, and syntactic elements.

The processed features are then analysed using a machine learning model trained on datasets containing dyslexic text patterns and common reading or writing errors. Based on this analysis, a personalized AI assistance module provides intelligent support, including spelling correction, word suggestions, pronunciation guidance, and text improvement recommendations.

Module Descriptions

Detection Module

The Detection Module serves as the entry point of the Dyslexia Assistance System and is responsible for identifying potential indicators of dyslexia. Users are presented with a predefined paragraph and asked to type it exactly as displayed. The system compares the user's typed input with the original text to identify errors such as spelling mistakes, letter reversals, word omissions, substitutions, and transpositions.

The module generates a detailed error map for each user, highlighting the types and frequency of mistakes. By analyzing whether errors occur consistently or randomly, the system gains valuable insight into reading and writing challenges.

Text Correction and Analysis Module

After the detection phase, the system proceeds to the Text Correction and Analysis Module, where users receive guided feedback on their identified errors. The system assists users in correcting mistakes by providing intelligent suggestions and contextual hints instead of directly revealing answers, thereby encouraging active learning and self-correction.

This module integrates text-to-speech functionality, enabling users to hear the correct pronunciation of misspelled words. A performance score is calculated based on factors such as correction accuracy, response time, and improvement consistency.

History and Adaptive Learning Module

The History and Adaptive Learning Module plays a crucial role in tracking long-term user progress and enabling personalized learning experiences. This module stores historical performance data, including user scores, types of errors made, time taken to complete tasks, and difficulty levels of attempted exercises. Based on the user's performance score, the system automatically adjusts content difficulty — presenting simpler paragraphs to users who require additional support and progressively introducing more complex material as skills improve.

Exercises for Reinforcement Module

The Exercises for Reinforcement Module is designed to strengthen literacy skills through interactive and engaging practice activities including Fill-in-the-Blanks, Spelling Challenges, and Word Sorting tasks. Each exercise is dynamically tailored according to the user's previous performance and identified learning gaps.

The exercises incorporate structured repetition — an essential learning strategy for individuals with dyslexia, as repeated exposure enhances memory retention and pattern recognition.

UML Diagrams

Use Case Diagram

The Use Case Diagram provides a high-level visual representation of the interactions between system actors and the functionalities offered by the Dyslexia Detection and Support System. The primary actors are the User and the System. The User initiates actions including entering text input, viewing analysis results, accessing performance history, and participating in learning exercises. Upon receiving user input, the System performs preprocessing, feature extraction, ML-based pattern detection, and generates a performance score.

Class Diagram

The Class Diagram illustrates the structural design of the application. Key classes include: User (stores userID, name, user Type), Input Handler (manages text, speech, and image inputs), Text Processor (performs text extraction and cleaning), Model (ML-based dyslexia pattern analysis), Analysis Result (stores detection outputs), Assistance Response (generates user feedback), Progress Report (records performance metrics), Exercise Module (generates personalized exercises), and History (maintains long-term interaction records).

Sequence Diagram

The Sequence Diagram illustrates the dynamic interaction between system components over time. The interaction begins when the User submits input. The Input Processor preprocesses it; the Text Processing Module extracts features; the ML Model identifies dyslexia patterns; the Assistance Response Module prepares corrective feedback; the History Module updates records; and the Adaptive Learning Component determines personalized exercises. The final output is delivered back to the user, completing a continuous feedback loop.

IMPLEMENTATION & EXPERIMENTAL RESULTS

Implementation Overview

The Dyslexia Assistance Web Application is implemented using the Flask framework as the core backend, with Python handling all computational tasks. The application is organized into several key files:

- `app.py`: Core Flask application handling routing, session management, and integration of all backend modules.
- `index.html`: Landing page providing navigation to all system features.
- `login.html` / `register.html`: Authentication pages with secure password hashing via Werkzeug.
- `module.html`: Course and learning activity interface with adaptive content.
- `history.html`: User progress and session history visualization.
- `app.html`: Main detection and correction interface.

The backend integrates Whisper for speech-to-text, EasyOCR and Pytesseract for image-based text extraction, Language Tool for grammar correction, Pyttsx3 for text-to-speech output, and Google Gemini AI for adaptive content generation. All user data is persisted in MongoDB via PyMongo, with PBKDF2-based password encryption ensuring data security.

Experimental Results

The system was tested across multiple dyslexia detection and correction scenarios. Key results are summarized below:

Table 2

Test Case	Expected Output	Actual Output
Dyslexic text input detected	Dyslexia pattern flagged	Pass
Speech input converted to text	Correct transcription	Pass
OCR image text extraction	Accurate text extracted	Pass
Text-to-speech playback	Correct word pronounced	Pass
Adaptive difficulty adjustment	Simpler content shown	Pass
History log updated after session	Records stored in DB	Pass

CONCLUSION AND FUTURE SCOPE

Conclusion

This project successfully presents an AI-powered Dyslexia Assistance System that bridges the gap between technology and inclusive education. The system integrates multiple intelligent features — dyslexia pattern detection, real-time text correction, speech assistance, adaptive learning, and progress tracking — into a cohesive and accessible web application.

By leveraging Python-based machine learning, NLP libraries, OCR tools, and generative AI, the platform delivers a personalized learning experience that adapts to individual user needs. The experimental results validate the effectiveness of each module, demonstrating consistent pass rates across diverse test scenarios.

The combination of voice interaction, adaptive feedback, and visual learning aids makes the tool suitable for users across different age groups and learning levels. Ultimately, this project represents a significant step toward educational equity, digital accessibility, and inclusive learning environments for individuals with dyslexia.

Future Scope

The following directions are proposed for future enhancement of the system:

- Mobile Application: Develop native Android and iOS applications for improved accessibility and offline support.
- Multilingual Support: Extend the dyslexia detection and correction capabilities to regional Indian languages.
- Advanced ML Models: Integrate transformer-based models (BERT, GPT) for more nuanced text analysis and correction.
- Eye-Tracking Integration: Incorporate eye-movement analysis for more accurate dyslexia assessment.
- Gamification: Add gamified exercises with achievement badges to improve user engagement and retention.
- Clinical Collaboration: Partner with educational psychologists to validate detection accuracy and improve the dataset.

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