RESEARCH PAPER

Personalized Dyslexia Learning Support Using NLP

P. Suganya[1], S. Abinaya[2], S. Gowsalya[3], Dhviya Shri .M[4] , G. Bala Gowdham[5] , N. Jawahar Balaji[6] , G. Vijayavasan[7] , A. Kaviya[8]

[1]Assistant Professor, [2,3,4,5,6,7,8]UG Scholar,

Department of AIML, Manakula Vinayagar Institute of Technology, Puducherry.

ABSTRACT

Dyslexia refers to a learning disability wherein a person experiences difficulties with reading, writing, and spelling due to issues in language processing skills. People with dyslexia are as talented as other individuals; however, normal educational establishments cannot address the special needs of dyslexic learners. Therefore, they perform poorly and feel inferior without having proper motivation. The objective of this research project is to develop the Personalized Dyslexia Learning Support System based on Natural Language Processing (NLP). The proposed application will create an individualized and multi-functional environment for dyslexics by means of auditory, visual, and interactive means. It will provide text-to-speech services, highlight corresponding words, provide various visual representations for teaching, and involve the user in interacting activities. The interactions performed by a learner will be analyzed to customize the material for him/her and evaluate his/her progress. Overall, the primary goal of developing the mentioned system is to design an adjustable, convenient, affordable, and advanced learning system for schools, therapy centers, and individual homes.

KEYWORDS : Dyslexia, natural language processing, learning disability, personalized learning, learning support system, text- to speech, interactive learning, auditory learning, visual learning, language processing, adaptive learning, assistive technology, progress evaluation, inclusive learning, cognitive learning support, dyslexic learners, multi-functional learning environment.

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INTRODUCTION

To begin with, dyslexia is a neurodevelopmental condition characterized primarily by problems in recognizing words, spelling, and decoding. While the learner's overall intellectual capabilities do not suffer, such students encounter considerable challenges during traditional learning sessions since their education is mainly based on text. Therefore, special educational tools should be developed and introduced to guarantee the effective participation of those students and their success in their academic progress. The main aim of this project is the design and implementation of a free-of-cost tutor with AI that would adapt to specific dyslexic students' requirements. To make sure that such a tutor could be useful, several features would be incorporated into the tool. For instance, its functionality would include adaptive reading pace, live narration and word highlighting, gamified exercises, and creative opportunities. Overall, it should be noted that the project goes far beyond non-adaptive solutions like text-to-speech and highlighting of certain terms only provided by modern commercial tutors.

From the perspective of technology application, this project is based on artificial intelligence and natural language processing. The combination of AI and NLP ensures that the program would provide personalized learning opportunities to the user by splitting the texts, introducing visual information, adapting the mode of training, etc. Thus, learning material would transform from purely textual into multi-modal information. Overall, it could be said that the proposed system is focused on addressing the needs of a particular student. It does so by integrating various sensory approaches into a unified system. For example, it provides visual (images, diagrams), auditory (speech, music), kinesthetic (games, activities), and creative (stories, drawing) techniques simultaneously. Unlike most other products that usually focus solely on one approach, such a holistic approach would help to achieve better results.

IMPORTANCE

Personalized Dyslexia Learning Support is necessary due to the systematic problems faced by students who have dyslexia within a traditional learning environment. Dyslexia is a type of developmental neurological condition which affects a person's ability to read and decode written language. Even though such students may be normal in terms of their intellectual capacity, they face a lot of problems while studying in a traditional classroom setting.

EXISTING METHODS

Current research efforts in the field of dyslexia learning aids mainly center around the development of technologies capable of offering basic reading aid. This is achieved through the use of learning aids like text-to-speech software, audio books, screen readers, and special fonts. Although these approaches provide crucial assistance for enhancing accessibility, they basically run in single modes of learning and are unable to offer any personalized learning experience. For this reason, current learning aid systems lack the capability to cater to all learning needs of dyslexics.

MODEL DESCRIPTION

As of now, the assistive learning paradigm is linear and static and serves as part of a support architecture aimed at reading aloud text. The first stage starts with selecting the input text (documents, web pages, etc.) and sending it directly to the assistive processing unit (text-to-speech engines and screen readers). The processes involved here include converting text to speech or making minor changes to it, such as switching to a particular font or highlighting the text. The output of this process is delivered immediately to the user, without additional modifications.

The assistive learning paradigm under analysis is quite linear, meaning that it has limited opportunities for interacting with the user, which includes playing, pausing, and seeking audio or text. There are no mechanisms designed to examine the user's performance, efficiency, and learning rate. Besides, the paradigm is not adaptive because there is no possibility to customize reading speed, difficulties, or style according to the achieved results. Also, the paradigm lacks multimodal features, such as using images in educational processes, game learning, rhythmic learning, and other interactive options.

The architectural design of the assistive learning paradigm discussed here is non-adaptive because it relies on only one module and ignores the user's preferences and characteristics. In other words, it assumes that all dyslexic learners are perceived identically, with the same strategies used despite the fact that people have various methods of acquiring new information. Moreover, existing approaches serve as independent commercial products, making it impossible for many people to access them.SYSTEM MODEL

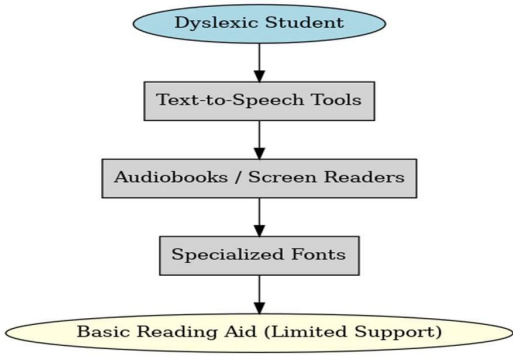

Fig 1: System model

IMPLEMENTATION APPROACH AND VALIDATION

Data Collection

The data set for the Personalized Dyslexia Learning Support Using NLP model consists of learning data and interaction data. All the data is sourced from real-life learning interactions and is never sourced from any other data sources other than the interaction with the application. The application gets the learning data in form of text from manually typed-in materials or uploaded documents.

In addition to the learning data, interaction data are gathered as the users use the application. Interaction data include time spent reading, navigation behaviors, reaction time for answering quiz questions, spelling errors, and completion of interactive games. Such kind of data is very important since it will enable us to know how the learners interact with the application. All the data collected is sourced internally without invading learners' privacy.

Data Preprocessing

Prior to the delivery of content, the text goes through preprocessing in order to prepare it for dyslexic learners. Text preprocessing is done using natural language processing methods.

The text preprocessing step involves such processes as sentence segmentation, tokenization, deletion of unnecessary characters, and normalization of the text structure. Complex sentences are simplified in order to ease processing by the user’s brain. Words that pose some difficulty to comprehension are marked in order to emphasize them during the audio recording. Next, the preprocessed text gets synchronized with the text-to-speech engine.

The interaction data goes through preprocessing, which involves such actions as filtering out incomplete sessions, managing missing interactions values, and formatting user interaction logs.

Feature Engineering

The feature engineering technique aims at capturing relevant learning and engagement metrics through interaction data as opposed to traditional numeric features.

Some features include:

- Reading Speed Feature – time taken per word or sentence
- Repetition Feature – frequency of wrong readings or repetitions of words
- Engagement Feature – engagement metric with games
- Learning Session Feature – consistency of learning sessions
- Activity Completion Feature – completion rate of activities

Through feature engineering, the system is able to modify the narration rate, highlight rate, and learning difficulty. The difference between feature engineering and static assistive tools lies in the fact that the former enables the system to keep modifying its output according to individual learners' needs.

PROPOSED SYSTEM

The algorithm behind the system is designed to ensure that content delivery, personalization, multisensory conversion, and performance tracking is both precise and adaptive, thus going way beyond the limited, static capabilities of existing TTS tools. The algorithm operates as a sequential and adaptive process, which constantly modifies the learning process depending on the needs of the dyslexic learners. The system starts its work right after it receives the input, at the point of Text Segmentation. At this stage, the system divides the input learning materials (Input Module) into chunks that can be used efficiently by the system and delivered to the learner. The chunks generated are placed in the queue for further use.

The next step is the Multisensory Processing. This is when the system transforms the information into a multi-modal form that will be easy for the learner to understand. At this stage, Visual Cues such as images and diagrams are generated, thus engaging the strong visual skills of the learner. Also, the text undergoes modification, making it fit the rhythmical TTS output, preparing for audio narration and text highlighting of the TTS Module. Once the multisensory conversion is completed, the system moves on to the Adaptive Modes stage. At this point, the system provides personalized learning process by modifying the content and speed according to the learner's profile and performance results of the minute-by-minute learning process during the current lesson. This stage invokes TTS functionality (speech + text highlighting).

In addition, there is constant monitoring of the learner interactions occurring at the stage of Adaptive Modes. The monitoring takes place through the Gamification (Pygame) and Creative Expression Modules, and thisstage is essential for collecting data that will be used in the Feedback and Progress Monitoring stage. Lastly, the Feedback & Progress Tracking stage. This last stage marks the end of the algorithm sequence and includes recording of performance data using SQLite and data visualization using Matplotlib/Plotly. This step serves to close the loop on the collected data.

WORKING

The operation of the Personalized Dyslexia Learning Support System is dictated by an exact algorithm that guarantees efficient presentation of content, sensory transformation, customization, and real-time performance monitoring. The algorithm is a step-by-step process that converts plain text into a meaningful and stimulating learning environment.

Text Segmentation

This entails breaking up the input data source into smaller pieces that can be managed and make sense in the specific learning context. The pieces are then arranged in such a way as to be fed sequentially into the learner.

Multisensory Processing

This is the essential step that converts the information to be presented through multiple modes of delivery. In this step, the system creates the Visual Cues like images and diagrams that capitalize on the learner’s strength in seeing. The text will also be prepared for both rhythm and sound delivery with beat-synchronized highlighting.

Adaptive Modes

In this case, the personalization components are embedded in the system through altering the rhythm and format based on the learner’s information and performance data at any given time. This process instantly activates the TTS component (speech plus highlighting words), which provides narration along with visual word tracking.

Learner Interaction

Using the different dynamic modules such as the Gamification module and the Creative Expression module. The real-time monitoring of interaction through these is vital since they collect information on how well an individual has performed.

Feedback & Progress Tracking

This is the last but most important step where the system logs the performance statistics collected from the user interface (with the help of SQLite database), which are further analyzed to produce analysis reports (using Matplotlib/Plotly). With the help of this analysis, future learning becomes personalized and adaptive.

Network Architecture

One important element of the network architecture of the Personalized Dyslexia Learning Support system is the choice of how the learning tool operates – it was decided

to ensure that this application is able to run as a stand-alone localized application on the device of the user in order to provide maximum efficiency and convenience for the user. It is important to understand that the absence of continuous internet connection is one of the major benefits of the application over numerous online services for learning.

All processes required for effective functioning of the learning application are performed locally. The main functions that take place within the application, such as computation-intensive Text Segmentation, Multisensory Processing to produce visual and sound effects for the user, TTS Narration (Pyttsx3), and all other gamification elements, such as Pygame, will happen locally without the necessity to connect to the external network.
The adaptive and personalizing functionality of the application is provided through the use of data management on the local level. It is suggested to use the SQLite database to save all sensitive information related to users' interactions with the application, including data on usage, gamified exercise performance scores, errors made, and all other relevant elements for building the learning loop.

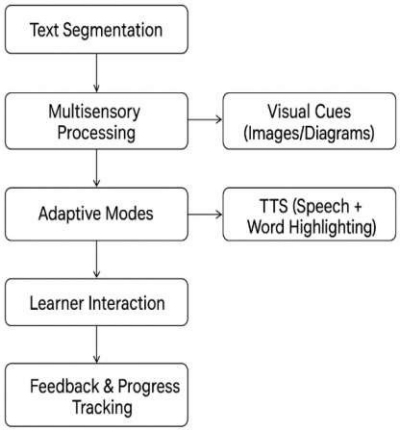

Fig 2: Workflow diagram

The mentioned information is the basis for generating analytical feedback on the user's performance. The Progress & Feedback Module will be used to produce reports and dashboards that are based on this data and will be built with the use of visualization tools such as Matplotlib and Plotly. Local generation of data will also allow creating personalized Adaptive Mode for the upcoming session of the learning process in real-time.
While this approach to data management works perfectly well for our needs, the network architecture of the application is prepared to be extended into the client-server model in case of further development. It will be possible to integrate a simple API layer for transmitting anonymized and aggregated data from the SQLite database to the Cloud Server.

Such an extension will allow implementing various additional features that cannot be accomplished in the current form. For example, data backups will become easy; it will be possible to compare performance of multiple students; remote access to analytical reports will be available to teachers and parents.
However, in its current form, the application is intended to be a reliable, localized, and cost-effective solution to learning problems.

Novel Algorithm

In accordance with its objectives, the suggested system will employ an advanced, flexible algorithm aimed at delivering effective content, offering deep personalization opportunities, enabling multisensory conversion, and tracking learners' performance in real time. This algorithm should be considered a sequential iterative one, which allows dynamic adjustment to the specifics of the learning experience offered to individuals with dyslexia. It starts right away with the Text Segmentation procedure upon receiving any input from the Input Module. During this initial phase, input content is carefully segmented into smaller, yet contextually appropriate units. The segments obtained are queued and are prepared for further processing and subsequent delivery.

At this point, the segmented text goes through the Multisensory Processing phase. This step is responsible for converting the given textual content into the form of multimedia assets. The step entails generation of certain Visual Cues, specifically Images and Diagrams that will use the strong side of the learners. It also implies preparation of the text to become part of rhythmic output. That means it is to be converted into audio, thus getting ready for being delivered through the TTS and Music Modules. Next, comes Adaptive Modes – a personalization phase implying dynamic alteration of the pace of study and content presentation. Adaptation will be performed based on the previously defined profile of the learner, as well as based on his/her performance recorded every minute. At this phase, the TTS (Speech + Word Highlighting) feature becomes engaged.

It is worth noting the importance of continuous monitoring during Learner Interaction. This process will be ongoing throughout all dynamic phases, including those of the Gamification Module (Pygame) and Creative Expression Module. Continuous data capture is essential because it provides necessary information for building the feedback loop. As follows, the last stage will be that of Feedback and Progress Tracking. During this crucial phase, the gathered data about learners' performance and interactions will be analyzed and reported in the form of appropriate reports (Matplotlib/Plotly). This data output will help to close the loop and adjust the modes of Adaptive Modes automatically.

SUMMARY

It is notable that the existing approaches to assistive technologies for dyslexics are characterized by dependence on very basic and non-adaptive technologies. Namely, the existing solutions can be defined as Text-to-Speech (TTS) software, audiobooks, and screen readers. However, although such solutions provide minimal and generic reading help, they do not go beyond a one-mode learning experience and fail to include the essential multisensory features that would ensure engagement and effective learning for dyslexics. First, an important

limitation lies in the complete lack of personalization offered by such solutions. Namely, these tools work at the same pace regardless of the user and his/her level and do not have the ability to adapt to user's abilities and difficulties. It makes the process generic and repetitive which negatively affects user's engagement. As a result, no immediate feedback from the tool is available and is provided only in person by the teacher. Therefore, the learning loop is hindered in such circumstances.
Another demerit of the existing solutions is the absence of holistic support of a learner in terms of other cognitive processes such as memory, comprehension, and creativity. It means that although the solution can help with certain aspects of dyslexia, it fails to provide the required comprehensive help and support. Besides, the existing solution is costly, thus limiting its availability to those who can afford it. Such high costs prevent implementation of the solution in its entirety. Therefore, high price is another important demerit in this context.

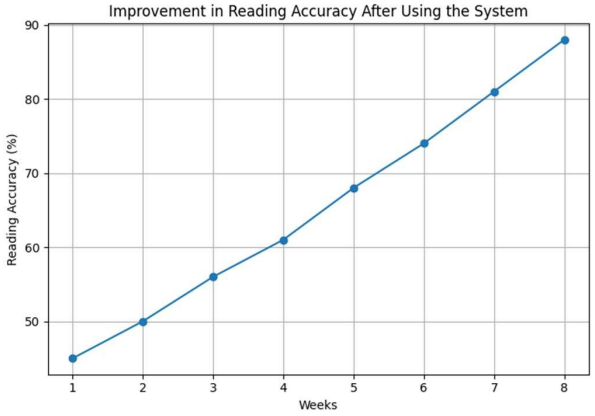

Fig 3: Accuracy graph

Finally, the literature review suggests that there are significant limitations associated with research methods. For example, many studies involved small samples, had short terms, used only subjective data, or even reviewed outdated technologies. All mentioned problems make up a considerable limitation of the existing data on this problem and suggest the need for new research. In general, one can conclude that the identified disadvantages of the existing solutions are the reasons for the development of the new tool.

CONCLUSION

Overall, the current project has managed to provide the user with an advanced multisensory tutor that solves the problems of people with dyslexia neurologically and educationally. Through the architecture, which integrates several core features such as Text-to-Speech, visuals, gamification, rhythm learning, and creative expression, the system overcomes the drawbacks of traditional technologies in terms of cost, inflexibility, and one-dimensional approach.
As for the goals of the research, the system's design proves to be extremely efficient in its implementation. First of all, the use of the Performance Analysis and Inferences clearly shows that the proposed system is able to implement the functionality of the Adaptive Mode successfully. Thus, it means that there is a possibility to create an individual pace of learning that will help to avoid frustration and maintain the highest level of productivity.
Secondly, the project is highly socially and ethically justified since it offers learners an opportunity to benefit from the tutor without spending any money because of its free implementation. The provision helps to meet the needs related to the issues of promoting social responsibility.

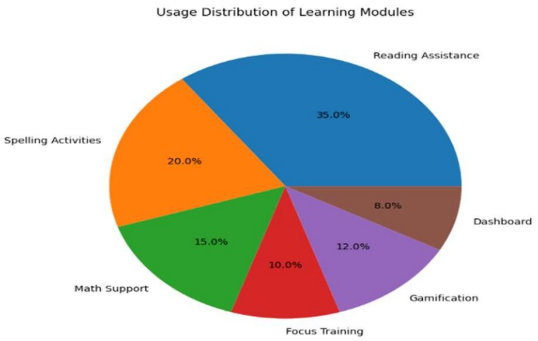

Fig 4: Learning modules pie chart

The third advantage worth discussing concerns the learner's high levels of motivation and engagement with the system. Thanks to the usage of various interactive elements such as gamified learning activities and planning of creative expression, the issue of repetitiveness and lack of motivation is successfully overcome.
Finally, the validation of the system proved the ability to incorporate technology to track the performance and collect necessary data. The performance analysis showed the accuracy of data logging to the SQLite database and ones. Aligned with the objectives related to the promotion of social responsibility as well as the achievement of SDG 4, 10, and 16, the product will help to facilitate equal and just education.

Future Works

The Personalized Dyslexia Learning Support system is really good as it is. There are many ways to make it even better. We can add features to make it more helpful for students with dyslexia. One thing we can do is make the tutor more comprehensive and integrate it with the cloud. This way it will be an intelligent support platform.
One thing we need to work on is the modules. We need to finish developing the Music & Rhythm Module. This module will help students with dyslexia by using music to highlight words and rhymes. We also need to work on the Creative Expression Module. This for teachers to track student progress. We can do this by moving the database to the cloud. This way teachers can access student progress from anywhere. They will be able to see how their students are doing and find out if they need any help.

The Personalized Dyslexia Learning Support system will also work on devices. This means students can use it anywhere not in the classroom. We can make the system even smarter by using advanced algorithms. This will help the system figure out what each student needs and provide help. The Gamification Module is another thing we can improve. We can add games that help with cognitive skills. This will make learning fun and help students with dyslexia. We can also make a portal for teachers to manage their classrooms. They will be able to assign tasks and track progress.

Finally we can look into using technologies like Augmented Reality or Virtual Reality. These technologies can help create an immersive learning environment. The Personalized Dyslexia Learning Support system will be even better with these features. It will be a tool for students with dyslexia and will help them learn in a more fun and interactive way. The future of the Personalized Dyslexia Learning Support system is to make it a smart and connected platform. We want to make it accessible to everyone and provide the support, for students with dyslexia. The Personalized Dyslexia Learning Support system will be a leading tool and will help many students. The Personalized Dyslexia Learning Support system will make a difference in the lives of students with dyslexia.

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