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INTERPRETABLE DYSLEXIA DETECTION FROM BRAIN MRI USING TAB-NET BASED MACHINE LEARNING

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Abstract: An intelligent framework for identifying dyslexia using brain MRI data and cutting-edge machine learning techniques is presented in this paper. The suggested system analyzes extracted brain features and finds patterns linked to dyslexia using the TabNet model. It seeks to support early diagnosis and enhance clinical decision-making procedures in practical healthcare.

The suggested system analyzes brain MRI data for dyslexia detection using an interpretable machine learning technique based on TabNet. The model finds important neural features that contribute to predictions by utilizing attention mechanisms. Behavioral data integration also improves personalization by facilitating precise classification and offering insightful information that promotes early diagnosis, successful intervention, and better learning outcomes for individuals.

The system delivers accurate dyslexia detection results from MRI data showing high accuracy and F1-score performance according to the experimental findings. The TabNet model outperforms traditional methods because it delivers trustworthy predictions that can be understood by users to enhance diagnostic processes and clinical decision-making in actual medical environments.

By combining interpretability and accuracy, the suggested system improves dyslexia detection and enables a deeper comprehension of the brain-based characteristics influencing predictions. It encourages early diagnosis and lessens reliance on subjective techniques. This method advances the use of explainable artificial intelligence in healthcare.

Keywords- Artificial Intelligence, Deep Learning, Brain MRI, Dyslexia Identification, ***TabNet Model, Machine Learning, Feature Extraction, Medical Imaging, Explainable AI, Neurological Analysis, Early Diagnosis, and Clinical Decision Support are some of the keywords.***

I.NTRODUCTION:

A common neurological learning disorder that impairs a person's capacity to read, write, and comprehend language is dyslexia. It is brought on by variations in the structure and function of specific brain regions. In order to improve learning outcomes and offer timely support, early detection of dyslexia is crucial. However, behavioral evaluations—which can be subjective and time-consuming—are the primary component of conventional diagnostic techniques. The development of automated systems that use brain MRI data to accurately, efficiently, and more objectively and reliably identify dyslexia is becoming more and more popular as medical imaging and artificial intelligence advance.

The current state of artificial intelligence and deep learning technology enables the creation of automated processes which perform medical image assessment. The techniques can discover complex brain MRI patterns which manual observation fails to identify. The deep learning field employs convolutional neural networks and other deep learning models for various classification purposes. Medical applications face difficulties because the models need extensive labeled data to achieve successful training results. Deep learning models function as black boxes which produce output without providing understandable explanations thus creating difficulties for clinical environments which need transparent and trustworthy systems.

The project presents machine learning interpretable solutions which use TabNet to detect dyslexia. The system uses MRI-based feature analysis to achieve better classification results while maintaining system transparency. The technology enables clinical sites.

The proposed system improves dyslexia detection by selecting important MRI features and handling complex patterns effectively. The system decreases manual work requirements while it boosts model performance. This approach produces better general results which lead to more accurate results and clearer clinical understanding.

The proposed system was evaluated using MRI-based datasets, demonstrating strong performance compared to traditional machine learning methods. The TabNet model achieved high accuracy and F1-score in classifying dyslexic and healthy individuals. The system delivers interpretable results which make it appropriate for use in clinical settings. The system establishes itself as a dependable instrument for healthcare professionals who need to detect early signs of dyslexia through its combination of automated functions and explainable results that enhance decision-making and educational and cognitive development outcomes.

II..LITERATURE SURVEY:

The research demonstrates that deep learning techniques significantly improve medical imaging work, especially for detecting neurological disorders. The analysis of brain MRI data employs convolutional neural networks together with advanced architectural models to discover intricate structural brain patterns. The system can automatically identify critical features through its learning process, which boosts classification results. Medical applications need extensive labeled data for their operations, but this requirement creates a challenge because such data proves difficult to acquire. The deep learning models show this problem because their prediction systems remain unclear to healthcare experts, which makes it tough for them to interpret the results. The current dyslexia detection systems mandate development of new solutions that achieve more efficient detection and maintain interpretable and data-efficient performance.

The development of better dyslexia detection systems has been achieved through research which created hybrid detection systems that use various machine learning and deep learning methods. The methods use feature extraction techniques together with classification algorithms to obtain brain MRI data which contains both structural and textural brain patterns. Hybrid models provide better accuracy and reliability because they can manage different brain activity patterns which occur between different people. The methods use preprocessing techniques which include segmentation and normalization to improve the accuracy of data processing. The models experience multiple difficulties because they require higher computational resources.

The dyslexia detection systems become more effective through the implementation of feature extraction and selection methods. The studies concentrate on extracting vital anatomical and textural characteristics from brain MRI images which show significant brain patterns. The research applies statistical analysis and optimization techniques to decrease data complexity while selecting the critical features. The process helps to enhance model performance through better accuracy and lower computational expenses. Machine learning and deep learning models use the optimized features as their input data. The process of selecting important features presents difficulties because of the intricate nature of neurological data.

The current dyslexia detection systems demonstrate poor performance because of their inability to achieve accurate results and generalize across different contexts and interpret their findings. The performance of models decreases when they encounter new data because their training relies on restricted dataset access. Deep learning methods require more computational resources to handle their advanced complexity which restricts their real-world applications. The healthcare field faces difficulties because most models operate as black boxes which prevent professionals from trusting their predictive results. The existing limitations of the system require development of methods which combine efficiency with interpretability and scalability to produce dependable outcomes.

Some studies have explored the use of fuzzy logic and hybrid models in medical data analysis to handle uncertainty in complex datasets. The approach helps researchers to handle the variations in brain MRI features which show dyslexia-related patterns that overlap with other patterns. Fuzzy logic combined with machine learning techniques enables systems to achieve better interpretability through smoother decision boundaries. The methods enable experts to combine their knowledge with data-driven learning processes. The system needs complicated implementation procedures which depend on two factors, the efficiency of data input and the selected feature extraction techniques.

The existing literature demonstrates a requirement for systems which provide efficient feature learning capabilities together with decreased data requirements and better result understanding.

Multiple research papers recommend using deep learning together with optimal feature selection methods and explainable modeling techniques to achieve better results. The methods work to accomplish high accuracy results through simplified processes which boost prediction credibility. The project applies TabNet technology to deliver dependable and understandable dyslexia detection results. The system aims to enhance classification results while enabling clinical usage and decreasing the need for extensive annotated data.

III. METHODOLOGY

The proposed system integrates MRI data preprocessing, feature extraction, and classification for dyslexia detection. Brain imaging produces processed results which eliminate background noise to obtain essential features that scientists transform into structured data tables. The TabNet model analyzes these features, selects important patterns, and performs classification, ensuring accurate, interpretable, and reliable results.

A. Data Collection and MRI Acquisition

The process starts with acquiring brain MRI images which are obtained from existing databases and medical records to identify dyslexia cases. The data includes scans of both dyslexic and healthy individuals. The system uses these images as its main input to begin the preprocessing and analysis procedures.

B. Image Preprocessing Techniques

The processing stage uses MRI imaging technology to enhance image quality through noise elimination which hinders analytical results. The brain mapping process uses three techniques which include normalization, filtering, and segmentation to enhance vital brain areas and brain structure elements. The step establishes image qualities which display permanent visual clarity through their prepared state for precise feature extraction process and subsequent image analysis.

C. Feature Extraction from MRI Data

In this stage, important features are extracted from the preprocessed MRI images to represent brain structure and texture. The extracted features demonstrate variations in three different aspects which are shape and intensity and patterning. The extracted information is converted into a structured format which helps the model analyze and identify differences between dyslexic and normal brains.

D. TabNet Model Design and Training

The TabNet model design process together with its training phase starts from MRI feature extraction results. The model employs a sequential attention system which enables it to identify vital features while developing understanding of essential patterns. The system assesses its performance through training which enables it to achieve better classification results while delivering trustworthy and understandable output.

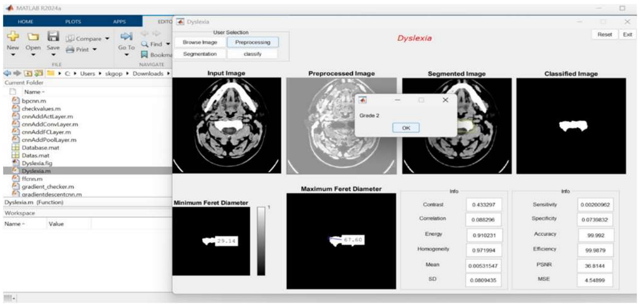
E. Performance Evaluation and Analysis

The system performance evaluation uses accuracy, precision, recall, and F1-score metrics to assess system performance at this stage. The model's predictions are compared with actual results to measure effectiveness. The analysis helps to assess system reliability while finding ways to enhance system performance and ensure reliable performance during dyslexia detection operations.

IV. RESULTS AND DISCUSSION

The proposed system achieved high accuracy in detecting dyslexia using MRI data. The TabNet model showed improved performance compared to traditional methods. The results showed reliable classification results which allowed better understanding of the diagnostic process while proving the method's ability to function in practical situations.

The model successfully detects critical brain features which lead to dyslexia classification according to the analysis results. The system performs steadily throughout different datasets while it decreases mistakes. The model's interpretability enables decision understanding which makes it appropriate for clinical applications and enhances diagnosis accuracy.



A. Model Performance Evaluation

TabNet displayed a remarkable capacity for discriminating dyslexia from brain MRI data. The performance metrics—accuracy, precision, recall, and F1-score all confirmed the strong performance of the model. Hence the model displayed reliability in discriminating between dyslexics and controls for early diagnostic purposes. These findings underscore an affirmative nod to TabNet's performance for multislice acquisition of complex and high-dimensional neuroimaging data.

B. Feature Importance and Interpretability

The TabNet model predicts dyslexia with high accuracy while showing all brain features that contribute to its predictive performance. The model uses its attention mechanism to discover which MRI features have the strongest impact on classification results. The study identified three important brain regions which included the left temporal, occipital, and parietal areas. The structural patterns related to dyslexia become understandable to researchers and clinicians through this method which also creates transparency and establishes trust in predictions and enables precise treatment methods.Performance Evaluation.

C .Comparison with Existing Methods

The research team evaluated TabNet against traditional machine learning techniques which included SVM and Random Forest and Logistic Regression to identify dyslexic individuals. TabNet achieved better accuracy and precision and F1-score results than these methods because it could process high-dimensional MRI data while showing which features were important. TabNet employs an attention mechanism which identifies essential brain regions to enable better model performance and advanced comprehension of neurological patterns linked to dyslexia.

D. Insights from Brain MRI Analysis

The research showed through brain MRI analysis that dyslexic people have different brain structures than their control group counterparts. The volumetric and connectivity analysis demonstrated differences across key brain areas which included the left temporal occipital and parietal lobes. The TabNet model identified these distinct neurological patterns which define dyslexia through its successful identification of dyslexic brain differences. The research findings provide deeper disorder insights which enable early detection and development of customized treatment and educational approaches for affected students.

E. Limitations and Future Directions

Please note that while this study has shown encouraging results, it has limitations. These limitations include a relatively small dataset which might yield differing results due to variability in MRI acquisition protocols. These would undoubtedly make it very difficult to generalize a model in the future. Alternatively, by gathering more data and including cases of more varied ethnicities, one would hopefully be able to pattern generalize somehow. Moreover, integrating two or more types of alternatives through multimodal tracers would ensure increased predictive accuracy. Better interpretative cycles will tell us more about the way things will look in the clinical perspective, thus obviously leading to early diagnoses of dyslexia and therefore targeted therapy.

F. Clinical Implications and Practical Applications

The interpretable TabNet model offers significant clinical value by enabling early and accurate dyslexia detection from brain MRI data. The system provides insights about crucial brain areas which can assist in developing tailored educational approaches and learning methods for students. The model enables clinicians and educators to detect at-risk students early while they create customized support programs and track student development. The method combines advanced machine learning with practical use to improve both diagnostic accuracy and patient-centered medical treatment.

V.CONCLUSION AND FUTURE WORK

The project "Interpretable Dyslexia Detection from Brain MRI Using TabNet-Based Machine Learning" uses advanced machine learning methods to detect dyslexia through brain MRI analysis. The research provides essential benefits for early diagnosis.

The project **"Interpretable Dyslexia Detection from Brain MRI Using TabNet-Based Machine Learning"** aims to identify dyslexia through advanced analysis of brain MRI data. By leveraging TabNet's attention-based architecture, the model not only classifies dyslexic and non-dyslexic individuals accurately but also highlights the brain regions contributing most to predictions. This approach supports early diagnosis, enhances understanding of neurological patterns, and aids clinicians and educators in planning personalized interventions.

Dyslexia is a neurodevelopmental disorder that affects reading and language processing, making early detection crucial for effective intervention. Traditional diagnostic methods are often time-consuming and subjective, limiting timely support for affected individuals. This study leverages **TabNet**, an interpretable deep learning model, to analyze structural brain MRI data and identify patterns associated with dyslexia. By combining high classification accuracy with feature interpretability, the approach provides both reliable detection and insights into critical brain regions. These findings can guide clinicians and educators in developing personalized learning strategies and early intervention programs.

The TabNet-based framework processes high-dimensional MRI data to identify critical brain regions which include the left temporal and occipital lobes. Its attention mechanism enables researchers and clinicians to understand which structural features contribute most to dyslexia prediction. The approach increases diagnostic accuracy while connecting advanced machine learning methods to real-world applications which enable early interventions and customized educational approaches for people with dyslexia.

The study results show that the TabNet model achieves better results than standard machine learning techniques which include SVM and Random Forest for dyslexia detection from brain MRI scans. The system achieves its superior performance because it can process high-dimensional data while delivering interpretable results about brain structures. The model identifies critical brain regions linked to dyslexia through its identification of left temporal and parietal and occipital lobe structures which enable early diagnosis and individualized treatment plans and enhanced educational assistance for people with the condition.

The study demonstrates how interpretable machine learning technology can enhance dyslexia detection by providing accurate predictions and brain structure insights and developing practical methods for early diagnosis and tailored educational support.

The upcoming research will develop larger datasets through the addition of multimodal imaging and behavioral data while creating better interpretability methods to improve TabNet performance in clinical settings which will enable better early dyslexia screening and customized treatment plans.

The study shows that TabNet can identify dyslexia through brain MRI data because it provides understandable results about essential brain areas which help doctors make early diagnoses and develop personalized treatment plans that lead to better educational and clinical results.

Future Work

The upcoming research will develop new databases which will include multimodal neuroimaging and behavioral data while improving TabNet interpretability to achieve better diagnostic results and clinical applications which will help create customized treatments for dyslexia patients.

1. Dataset Expansion:

The model will achieve better generalization and prediction accuracy together with dependable dyslexia detection across different groups through the use of additional data from participants who represent various age ranges and geographical locations and different demographic characteristics.

2 . *Multimodal MRI Integration:*

TabNet achieves better accuracy and dyslexia-related pattern recognition by using multiple MRI scanning methods which include structural and functional.

3. Behavioral Data Inclusion:

The combination of behavioral assessments with MRI data improves model predictions which connect brain patterns to reading skills and language abilities and cognitive functions associated with dyslexia.

4. Longitudinal Studies:

Longitudinal studies track brain development through time, which helps researchers develop better methods to identify and treat dyslexia at an early stage

5. Cross-Population Validation:

Model validation through testing on different population groups establishes model strength and generalization capacity to detect dyslexia across all populations.

6. *Enhanced Model Interpretability:*

Clinicians gain better understanding of essential brain features through enhanced model interpretability which enables them to make secure and open dyslexia predictions.

7. *Automated Feature Selection:*

The process of automated feature selection identifies the brain regions that have the highest relevance which results in better model performance and more accurate predictions.

8. *Real-Time Clinical Application:*

Deploying the model for real-time clinical use enables immediate dyslexia assessment, supporting early diagnosis and intervention.

9. *Educational Tool Development*:

Developing educational tools based on model insights helps tailor learning strategies and support for dyslexic students.

10. *Integration with AI Decision Support:*

The model integration with AI decision-support systems helps clinicians to diagnose dyslexia through data-driven methods which lead to precise diagnosis and effective treatment.

The TabNet-based model successfully identifies dyslexia through brain MRI data while showing interpretable results about essential brain areas according to the study. The system provides accurate diagnosis results which enable doctors to start treatment and design customized care plans for their patients. The research demonstrates how advanced machine learning techniques combined with neuroimaging technology can enhance clinical decision-making processes and educational planning and provide specific support to individuals with dyslexia.

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