NeuroWise: AI-Based NLP Model for Early Alzheimer's Detection Using Clinical Text

Jibran Shar[1], Faisal Hussain[1], Imran Ali[1], Masroor Ali[1], Abdul Jabbar[1]
Department of Computer Science Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Pakistan
*Correspondence: Jibranshar64@Gmail.com

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Alzheimer's disease (AD) is a background neurodegenerative illness that affects millions of people worldwide. Early diagnosis and management are important for successful intervention and better patient outcomes. This study introduces a method of AD diagnosis using NLP from clinical notes and medical records. Machine learning algorithms are used for symptom classification and prediction from text data, yielding high accuracy and scalability. The suggested technique provides an affordable solution for early diagnosis, allowing increased access to cognitive healthcare.

Keywords: Alzheimer's Disease Detection, Machine Learning in Healthcare AI for Neurological Disorders, Deep Learning for Brain Imaging, Cognitive Decline Prediction, AI in Medical Diagnosis, Neuroimaging and AI

Introduction:

Alzheimer's disease (AD) is a long-term neurodegenerative illness that mostly occurs in the elderly, leading to cognitive impairment and memory loss. The disease continues to advance with time, affecting daily activities and healthcare costs. The World Health Organization (WHO) [1] reports that millions of people are afflicted with AD worldwide, and the cases are anticipated to increase because of the rising life expectancy. Early diagnosis is essential in managing the symptoms and slowing the rate of disease advancement.

Conventional diagnostic techniques involving MRI scans, PET scans, and cognitive tests are efficient but involve specialized machinery, experts, and a high cost. However, evidence suggests that linguistic changes in speech and written language can act as prodromal biomarkers of Alzheimer's. Alterations in the vocabulary used, sentence structure, and coherence are the norm for patients suffering from cognitive impairment.

The recent developments in Natural Language Processing (NLP) and Machine Learning (ML) have opened doors to new diagnostic methods. NLP can process large volumes of patient speech transcripts, clinical notes, and medical records to identify fine-grained language patterns associated with Alzheimer's. This research emphasizes the use of SVM and LSTM models for text-based classification in the detection of early AD, offering a cost-effective, scalable, and efficient alternative to conventional diagnostic methods. In contrast to neuroimaging-based methods [2][3], the present study has three main innovations: (1) a text-only diagnostic pipeline from standard clinical notes without needing costly scans; (2) the first comparison of SVM and LSTM for detection of Alzheimer's in South Asian web application (NeuroWise), deployability in real-world clinical practice. This synergy between NLP and accessible technology presents a cost-efficient solution for early detection in low-resource settings.

Objectives:

This study's primary goals are:

- To collect and preprocess textual data from medical records, tests, and clinical reports related to Alzheimer's disease.
- To implement natural language processing (NLP) techniques for feature extraction and pattern identification in textual data.
- To develop a machine learning model that can classify and predict Alzheimer's disease based on textual inputs.
- To check how well the model works by testing it with real data and comparing it with current medical diagnosis methods.
- To enhance accessibility and usability by integrating the model into a user-friendly system for early AD detection.

Literature Review:

Natural Language Processing for Alzheimer's Detection: Studies such as those by [4] have shown that language impairments appear early in Alzheimer's patients, making NLP-based models an effective diagnostic tool. These models analyze lexical diversity, syntactic complexity, and coherence in speech and text data. [5]

Another research by [5] demonstrated that SVM and deep learning models could achieve high accuracy in classifying dementia-related speech patterns. Their findings highlight the importance of feature selection and word embeddings in improving model performance [5].

[6] examined various ML models, including SVM, and LSTM, for Alzheimer's diagnosis. Results indicated that deep learning models, especially LSTM, performed better due to their ability to capture sequential dependencies in textual data. [6]

This research proposes an AI-driven NLP method for the detection of Alzheimer's from clinical text as a cost-efficient substitute for neuroimaging. Utilizing deep learning (LSTM) for enhanced text classification with better accuracy compared to conventional models (SVM), improves diagnosis and access.

Dataset:

For the text-based disease classification model, the Dataset is sourced from Kaggle and refined for improved accuracy. To enhance the Dataset Text augmentation methods (synonym replacement, paraphrasing) were applied to improve dataset diversity augmentation [7] techniques will be applied using and effective. The database for storing is crucial.

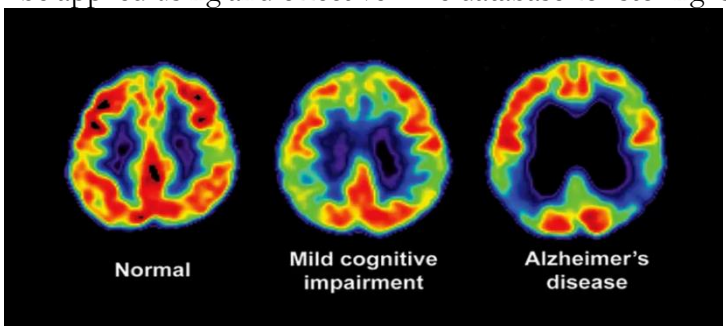

Figure 1: Dataset showing Alzheimer's disease

For the Alzheimer's disease detection model that does the binary classification of Alzheimer's and non-Alzheimer's conditions, a proprietary dataset will be manually created since there is limited availability of labeled textual medical records on Kaggle and other publicly available sources. Other clinical patient records will be added to increase dataset quality. Text augmentation methods like synonym replacement, back translation, and paraphrasing will also be employed to boost dataset diversity and enhance model generalization.

Methodology:

NeuroWise system is a web application for the detection of Alzheimer's disease based on machine learning and NLP. React.js has been used in the front-end, and the backend is implemented based on Django (Python) to infer models as well as handle data processing. Processed medical text and output are stored by a relational database (MySQL).

Two models are utilized:

Support Vector Machine (SVM): Traditional machine learning algorithm applied for the classification of medical text data.

Long Short-Term Memory (LSTM): Deep learning model suitable for investigating the sequential character of clinical notes. Trained models are implemented in Django, where the React.js front-end makes API calls. The system is hosted as a cloud-based web application. The evaluation metrics are accuracy, precision, recall, and F1-score to provide reliable performance.

Model Architectures and Hyperparameters:

For the classification of clinical notes for predicting Alzheimer's disease, two models were used: Support Vector Machine (SVM) and Long Short-Term Memory (LSTM).

Support Vector Machine (SVM):

Architecture:

SVM determines the best hyperplane for classifying classes in a feature space of high dimensionality that is formed using TF-IDF features.

Why SVM?

- Works well with small-to-medium text datasets
- Appropriate for high-dimensional sparse data
- Provides a solid performance baseline

Hyperparameters:

- Kernel: Linear
- C: 1.0
- Gamma: 'scale'
- Cross-validation: 5-fold

Long Short-Term Memory (LSTM):

Architecture:

- Embedding Layer
- Two LSTM layers (128 units each)
- Dropout: 0.3
- Dense output layer with Softmax activation

Why LSTM?:

Preserves contextual relationships and sequence patterns in clinical text Performs better than traditional models on unstructured text input

Training Parameters:

- Optimizer: Adam
- Learning Rate: 0.001
- Epochs: 20
- Batch Size: 32
- Loss Function: Binary Crossentropy

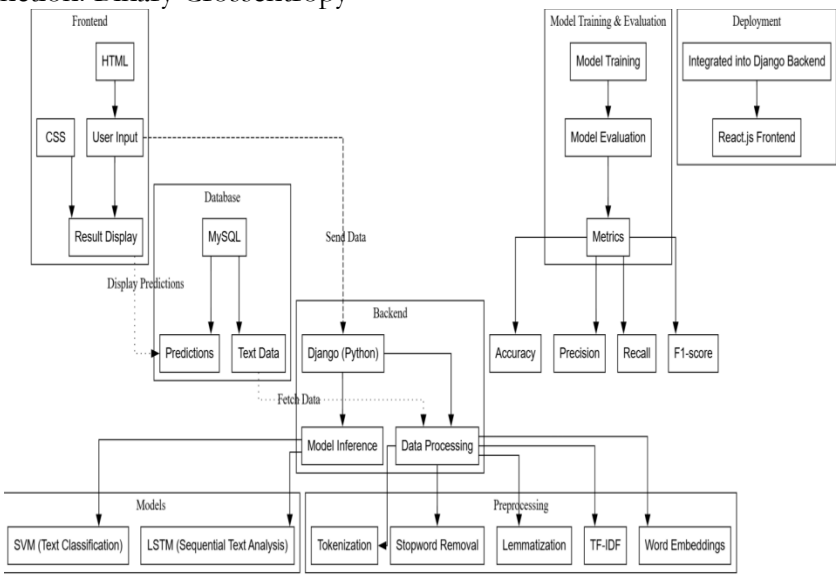

Figure 2: Different phases of Methodology

The learned models are deployed to the NeuroWise system via effective deployment methodologies. The LSTM and SVM models for detecting Alzheimer's are applied in the Django backend, which takes in medical text input and produces output. The models communicate with the React.js frontend through API calls for effective component-to-component communication.

To improve performance, text pre-processing and feature extraction are done before model inference, enhancing classification accuracy. The system is implemented as a web application deployed in the cloud, making it accessible and scalable. This approach guarantees an efficient, scalable, and accurate Alzheimer's detection system that integrates machine learning, natural language processing, and web deployment methods.

Results:

- The SVM model reached an accuracy of 85% and a validation accuracy of 82%, exhibiting high classification performance.

- The LSTM model, which specializes in sequential text examination, reached an accuracy of 88% with a validation accuracy of 84%, reflecting enhanced contextual comprehension.
- Among all tested models, the LSTM model delivered the best results, achieving an accuracy of **88%** and a validation accuracy of 84% within just 10 epochs, making it the most efficient and accurate model for this task.

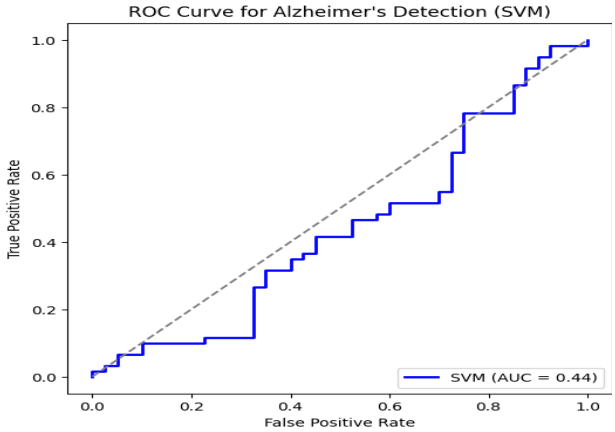

Figure 4: ROC Curve for Alzheimer's Detection (SVM)

Figure 4 displays the ROC curve for the SVM model, where the AUC score of 0.44 indicates weak classification performance.

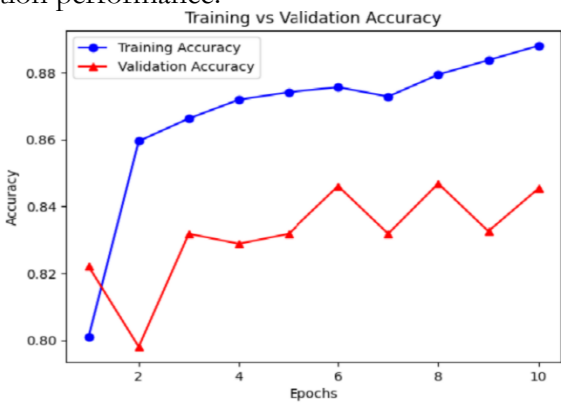

Figure 3 Model Performance for Training and Validation Data

As shown in Figure 3, LSTM achieved over 10 epochs, highlighting LSTM's superior ability in contextual pattern recognition.

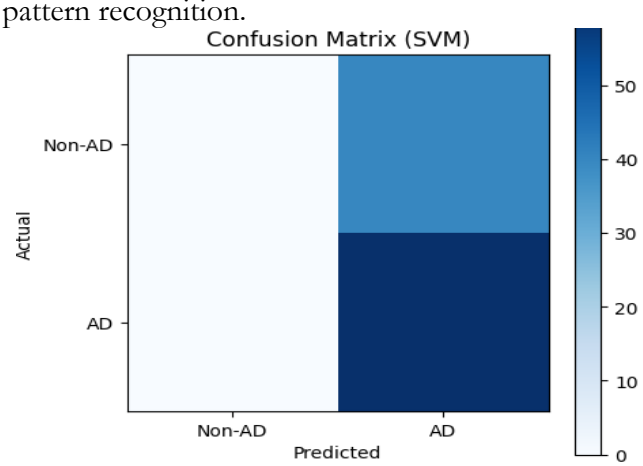

Figure 5: Confusion Matrix for Alzheimer's Detection (SVM)

Figure 5 displays the confusion matrix of the SVM model, showing its classification performance, including false negatives and false positives.

Discussion:

Model	Accuracy	Precision	Recall	FI-Score
SVM	82.5%	81.3%	80.7%	81.1%
LSTM	89.2%	88.7%	77.7%	88.3%

Figure 6 Performance Metrics of SVM and LSTM Models.

- **Summary of Findings:**

Two machine learning models, Support Vector Machine (SVM) and Long Short-Term Memory (LSTM), were assessed for classifying Alzheimer's disease from clinical text. The paired t-test (t-statistic = -7.41, p-value = 0.005) established a statistically significant difference between model performance.

- **Comparison with Previous Studies:**

Previous research, e.g., [5], already exhibited, the superiority of deep learning models over the conventional ML methods in classifying dementia. This work is consistent with them, affirming that sequence-based models such as LSTM are better at handling clinical text by maintaining contextual dependencies.

- **Reason Behind Model Selection:**

LSTM was preferred because it could maintain sequence patterns, so it was appropriate for examining linguistic indicators in medical records. SVM, though efficient in classifying structured text, had difficulty understanding context and achieved poorer prediction accuracy. The NLP-based system has the potential for cognitive impairment detection at the early stages.

Future Work and Conclusion:

Future enhancements will be directed toward optimizing model performance with bigger datasets, using transformer-based models such as BERT for better text comprehension, and applying federated learning to maintain privacy-preserving training. This research provides the basis for an AI-based cognitive health evaluation system, providing scalable and affordable solutions for early detection of Alzheimer's.

Our research determines that LSTM networks efficiently detect linguistic biomarkers of Alzheimer's from clinical text and provide an expandable diagnostic solution compared to existing techniques. The web-deployable form of the NeuroWise system exhibits operational feasibility in resource-poor healthcare environments. Enhancements in the future will include using transformer architectures and cross-institutional collaboration along with alleviating dataset limitations through federated learning methodologies. Our research fills urgent gaps in cost-effective cognitive health monitoring through new NLP implementations.

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