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Development of a Machine Learning Model for Diagnosis of Alzheimer's Disease Stages Using Brain Image Patterns

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ABSTRACT

The goal of this project was to increase the diagnostic accuracy of AI modelings in the detection of Alzheimer's disease. Alzheimer's disease is a complex condition that requires early diagnosis for effective treatment. However, current diagnostic methods can have limitations. In this study, we developed a more advanced research model to detect AD. By utilizing both linear regression models and neural network, our model achieved excellent results with a test accuracy of 81.34% for the neural network model and 93.05% for the linear model

Unlike earlier models that focused on binary classification of Alzheimer's disease, our model goes beyond that by classifying different stages and severities of Alzheimer's. We utilized a large dataset found on Kaggle called the "Alzheimer's Dataset" [1] consisting of 5,121 images of four classes (Mild Demented, Non Demented, Very Mild Demented, and Moderate Demented). This research redemonstrates the potential of machine learning to improve diagnostic accuracy for Alzheimer's disease.

Introduction

Alzheimer's disease is a debilitating neurodegenerative condition that poses significant challenges to individuals, families, and healthcare systems worldwide. It is characterized by memory loss, cognitive decline, and functional impairments. Accurate and timely diagnosis of Alzheimer's disease is crucial for early intervention and effective treatment. However, existing diagnostic methods often have limitations, relying on subjective observations and cognitive tests.

To overcome these limitations, there is a growing interest in exploring the potential of artificial intelligence and machine learning techniques for Alzheimer's disease diagnosis. These technologies offer opportunities to analyze complex datasets, such as brain imaging data, and find patterns that can aid in the diagnosis of the disease. By leveraging machine learning algorithms, researchers have achieved promising results in binary classification tasks, distinguishing Alzheimer's disease patients from healthy individuals.

Despite these advancements, most studies have primarily focused on binary classification, neglecting the crucial aspect of categorizing different stages and severities of Alzheimer's disease. The ability to classify various stages of the disease is essential for personalized treatment planning and interventions tailored to specific disease progressions.

Therefore, the primary aim of this research is to develop a machine learning model that goes beyond binary classification and accurately diagnoses different stages of Alzheimer's disease using brain imaging patterns. By considering the specific stages of the disease, we can provide healthcare professionals with valuable information to guide treatment decisions and interventions for patients at different disease progression levels.

To achieve this objective, we will utilize a large dataset called the "Alzheimer's Dataset," comprising brain images from individuals at various stages: Mild Demented, Non Demented, Very Mild Demented, and Moderate Demented. By employing Neural network and linear regression algorithms, we will train and evaluate our model's performance in accurately classifying the different stages of Alzheimer's disease based on the provided brain imaging data. By utilizing both linear regression and neural networks we may also compare their accuracies with each other as they both function differently. While linear regression models look at the individual pixels and assign weight to them, the neural network model looks at the entire image holistically and comares different pixels with each other in order to produce a result.

In summary, this study aims to address the limitations of current diagnostic methods for Alzheimer's disease by developing a machine learning model capable of accurately classifying different stages of the disease. By leveraging brain imaging data and advanced algorithms, we seek to enhance the diagnostic accuracy, enabling personalized treatment interventions for patients at various stages of Alzheimer's disease.

Results

Since this model should be applicable in real life it must be able to deal with images of different dimensions equally. The model was tested with different image pixel sizes raining from 10x10 all the way to 300x300. For the neural network approach, the test accuracy increased as the pixel size increased, with the highest accuracy achieved at 80x80 pixels (81.34%). The train accuracy also increased with pixel size, reaching a maximum of 89.84% at 80x80 pixels. However, the accuracy for smaller pixel sizes, such as 10x10 and 20x20 pixels, was relatively low (figure 1).For the linear model approach, the highest test accuracy was achieved at 210x210 pixels (94.77%), with a corresponding train accuracy of 99.92%. The accuracy of the linear model was generally higher than the neural network approach for all pixel sizes, with the exception of 50x50 pixels. This would make sense because Neural Networks have more parameters than Linear Models,
so that it takes less time to train an accurate Linear Model than a Neural Network Model.

The Linear Model was consistently increasing in accuracy from start to finish because more pixels to assign values to while comparing them. The Neural Network on the other hand would have even more pixels to compare making them take a lot longer to compute and have their accuracy impaired.

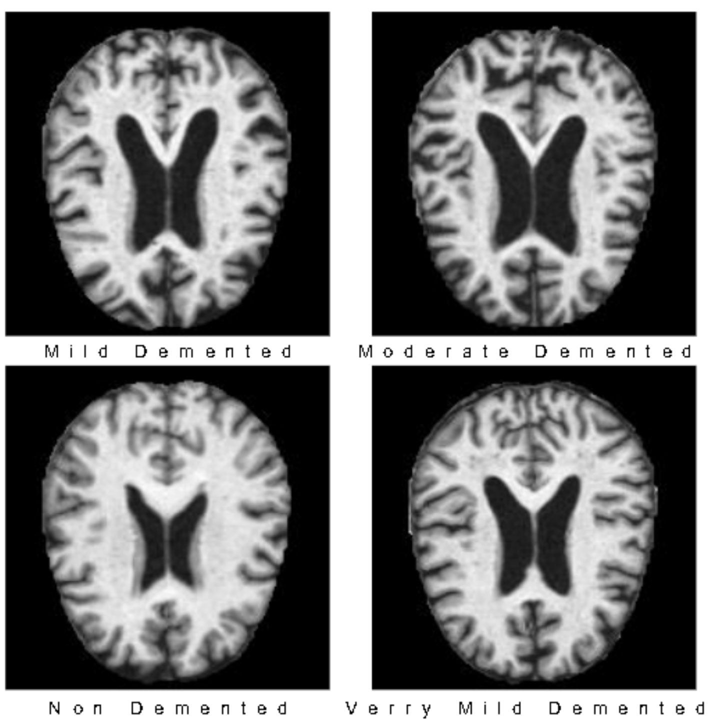

Figure 1. Alzheimer's differentiated forms. Examples of the four image types from the data set AD.

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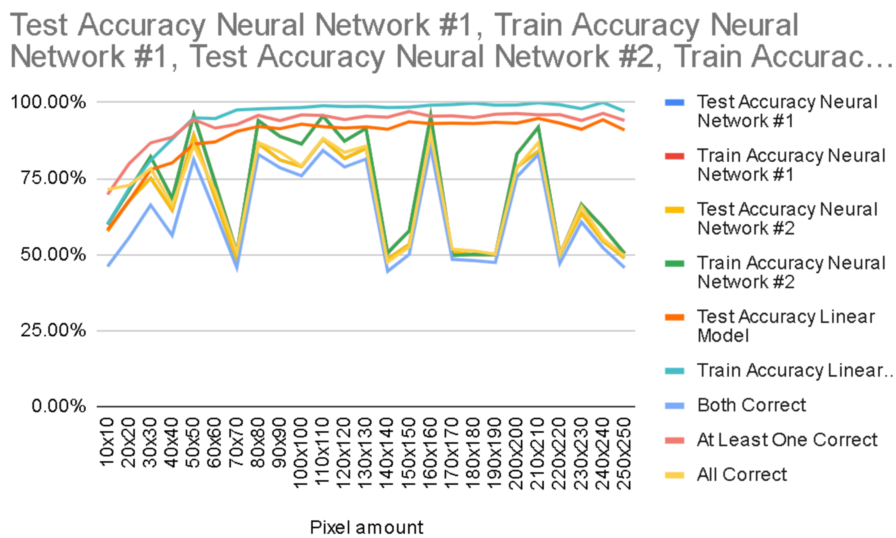

Figure 2. Results of model. Graph showing the percentages of accuracies compared to increasing pixel sizes. The model was using a recurring method to increasingly increase the pixel resize amounts.

Discussion

The search for more accurate diagnostic methods has been ongoing for decades, with current methods susceptible to error. However, recent advances in artificial intelligence and machine learning offer promising alternatives for Alzheimer's disease diagnosis, providing new forms of measures and promising improvements in accuracy.

In this study, we present a machine learning model that uses a combination of linear regression (as previous studies show it as the most effective model for binary classification so we wanted to use it to test its effectiveness in non-binary classification scenarios [7]) and neural networks to diagnose different stages of Alzheimer's disease using brain image patterns. This is a more challenging and clinically relevant task than previous studies that have mainly focused on binary classification. We used a large dataset of brain images called the Alzheimer's Dataset database, consisting of 5,121 images of four classes (Mild Demented, Non Demented, Very Mild Demented, and Moderate Demented). Our study demonstrates the potential of machine learning to improve diagnostic accuracy for Alzheimer's disease.

Prior studies have used machine learning for Alzheimer's disease diagnosis, and some have achieved high accuracy for binary classification. For example, Sarraf and Tofighi [4] achieved an accuracy of 89.3% for distinguishing Alzheimer's disease patients from healthy controls using a support vector machine classifier. Liu et al. [2] used a convolutional neural network to classify whether or not a patient had Alzheimer's disease with an accuracy of 87.1%. Liu et al. [3] employed a deep learning model to predict the progression of Alzheimer's disease with a binary classification accuracy of 89.7%. Kavitha et al. [5] also performed a study using similar datasets to ours from Kaggle, achieving an accuracy of 83% in binary classification of early Alzheimer's in patients. Another study conducted by Patil et al. [6] achieved a phenomenal 98% accuracy using Convolutional Neural Network models. However, these studies focused solely on binary classification, which means that they cannot differentiate between different stages of the disease, making diagnosis more challenging. As they are all limited to binary classification datasets they don't properly explainin the severity of Alzheimer's in patients. In contrast, our study is unique in that it aims to diagnose different stages of Alzheimer's disease while still producing highly accurate results.

Our study's purpose is to demonstrate the potential of machine learning for non-binary Alzheimer's disease diagnosis and develop a model that accurately diagnoses different stages of the disease using brain image patterns. The major results indicate that our model achieved excellent accuracy, with a test accuracy of 81.34% for the neural network model and 93.05% for the linear model. These findings highlight the potential of machine learning to improve diagnostic accuracy for Alzheimer's disease, which is critical for early diagnosis and effective treatment that may be different based on the severity of Altzhimers a patient may have.

By going beyond binary classification and accurately diagnosing different stages of Alzheimer's disease, our study demonstrates the potential of machine learning for improving Alzheimer's disease diagnosis. Analyzing brain images and patterns, our model achieved a maximum accuracy of 94.77% at 210x210 pixels (Figure 1), highlighting its effectiveness in accurately diagnosing the various stages of Alzheimer's disease. This multi-stage detection capability offers valuable insights for personalized treatment planning and interventions tailored to specific disease stages. Furthermore, our approach opens up possibilities for early detection and intervention, potentially leading to better patient outcomes.

While our study demonstrates promising results, further research is needed to validate our findings and enhance the model's performance in clinical settings. Factors such as dataset size, generalizability to diverse populations, and the impact of confounding variables on the model are all questions that may be looked at in the future. Future research may attempt to apply different imaging methods in order to achieve more detailed Altzhimer's stage analysis.

Materials and Methods

We developed a machine learning model that combines logistic regression model and neural network. Logistic regression models are a slight variation of linear models which operate by assigning weights to certain pixel colors and then determining what the total weight of the image most nearly correlates to . Neural Networks (NN) on the other hand operate in an entirely different way by rather than looking at pixels individually they look at pixels comparatively with other pixels surrounding them. A NN was used for feature extraction, followed by a dense neural network for classification. The model was trained on the Alzheimer's Dataset (4 class of Images) dataset and evaluated using the percentages of correct predictions when the test set is applied.

To further enhance the performance of our model, we incorporated the Multiplicative Weight Update (MWU) algorithm during the training process. The MWU algorithm updates the weights of the model in each iteration based on the prediction error. It assigns a weight to each training example, with all the weights starting off at a value of 1. The algorithm then changes the weights based on the prediction error, giving more weight to models that are predicting better outcomes.

Every model has 1 weight and votes for 1 class per image. We sum up the weights of the models that voted for each class. The class that has the highest summation is the one we use to predict. By using a MWU algorithm the entire program works more efficiently and results are now based off of multiple algorithms together while still keeping more accurate algorithms with more say in the classification result.

The MWU algorithm allows our model to adapt quickly to changes in the data predictions, as it updates the weights in an adaptive way. This helps in preventing overfitting and underfitting, as the algorithm adjusts the weights based on the prediction error. By incorporating MWU, our model is able to achieve better accuracy and generalization performance, which is important in real-world applications.

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