BrAIn:
Detection of Brain Diseases Using Advanced Deep Learning Techniques

Abstract:

An AI-powered website has been developed to provide diagnostic services for brain diseases using MRI scans, focusing on Tumor Detection, Alzheimer's Disease Diagnosis, and Multiple Sclerosis Detection. The platform enables users to upload brain images for immediate analysis.
The Tumor Detection module employs the Efficiency Net86 model to classify MRI images into glioma, meningioma, pituitary tumors, or no tumor.
Alzheimer's Disease module, utilizing a modified AlexNet, categorizes images into five stages, from Non-Demented to Severe Demented, with an estimation of disease progression.
The Multiple Sclerosis module utilizes a modified AlexNet to identify brain lesions and determine whether the scan is positive or negative for multiple sclerosis.
The integration of advanced models and a robust dataset ensures precise, reliable diagnostics, aiding in the early detection and management of brain diseases.

Written by:

BADER ALI ALSHAMRANI
BARAA MAJED ALGOMLAS
KHALID AHMED ALGHAMDI
ABDULELAH KHALAF

Supervised by:

Dr. Raunak Bhattacharyya

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1. Introduction:

The diagnosis of neurological diseases such as brain tumors, Alzheimer's disease, and Multiple Sclerosis represents one of the most challenging areas in modern medicine. These conditions can have profound impacts on patients' lives, and early, accurate diagnosis is crucial to managing their progression and improving patient outcomes. However, traditional diagnostic methods often rely on expert interpretation of brain scans, which can be subject to variability and delay.

In response to these challenges, our project seeks to harness the power of artificial intelligence to develop an automated diagnostic platform capable of identifying these conditions from MRI images. By leveraging deep learning models, we aim to create a tool that not only improves diagnostic accuracy but also makes advanced diagnostics accessible to a broader audience, including those in resource-limited settings.

This project is structured to address three primary diagnostic challenges:

1. Brain Tumor Detection: Utilizing the EfficientNet-B0 model to accurately identify and classify different types of brain tumors, including gliomas, meningiomas, pituitary tumors, and healthy tissue.
2. Alzheimer's Disease Classification: Applying a modified AlexNet model to classify the stages of Alzheimer's disease, providing a detailed assessment that can aid in early intervention.
3. Multiple Sclerosis Detection: Implementing a modified AlexNet model designed to segment and classify MRI images into categories that indicate the presence and progression of Multiple Sclerosis.

Our platform aims to integrate these capabilities into a unified system that provides users with an intuitive interface for uploading brain scans, selecting diagnostic options, and receiving detailed, reliable results.

2. Literature Review

2.1 Related Research

Recent advancements in medical imaging and deep learning have shown promising results in the automatic classification and diagnosis of neurological diseases. The use of convolutional neural networks (CNNs) has been particularly effective, given their ability to learn complex patterns in medical images. For example, research on brain tumor classification has demonstrated the efficacy of CNNs in distinguishing between different tumor types, with models like EfficientNet showing superior performance due to their balanced approach to accuracy and computational efficiency.

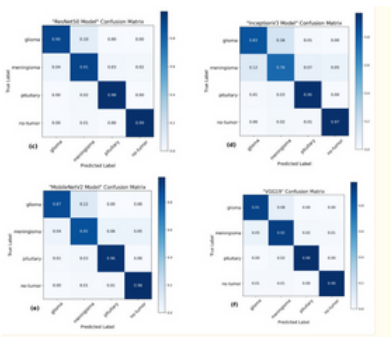
In the context of Alzheimer's disease, studies have explored the use of deep learning models to classify the disease into its various stages. Modified versions of AlexNet, a pioneering CNN architecture, have been adapted to enhance their capability in handling the specific challenges posed by Alzheimer's MRI images. These modifications often involve adjustments to the network's layers and parameters to better capture the subtle differences between stages of the disease.

Multiple Sclerosis diagnosis has similarly benefited from advancements in deep learning. U-Net and other segmentation models have been widely used to identify MS lesions in brain MRI scans. However, the complexity of MS lesions, which can vary greatly in size, shape, and location, presents ongoing challenges. Recent efforts to adapt models like AlexNet to this task have focused on enhancing segmentation accuracy while maintaining computational efficiency.

Figure 1 Comparison with previous study .

Author	Architecture	Accuracy
Trambaioli et. al., 2011	Support Vector Machine (SVM)	79.9% (multiclass)
Valliani, 2017	ResNet-18 + Pretrain + augmentation	56.8% (multiclass) and 81.3% (biner)
Acharya et. al, 2021	VGG-16, ResNet-50, Modified AlexNet	85.07% (VGG-16), 75.25% (ResNet-50), 95.70% (Alexnet) (multiclass)
Proposed method	ResNet-18 + Weighted Loss + Transfer Learning + Mish Activation	88,3% (multiclass)

Figure 2 Comparison with previous study .



3. Methodology

3.1 Data Collection and Preprocessing

We have curated and preprocessed extensive datasets to ensure that our models are trained on high-quality, representative images:

- Brain Tumor Classification (MRI): We utilize a dataset containing 7,000 training images and 3,000 testing images, categorized into glioma, meningioma, pituitary tumors, and no tumor. The images are preprocessed to standardize their size and resolution, and data augmentation techniques such as rotation, flipping, and contrast adjustment are applied to enhance model robustness.
- Alzheimer's Disease Classification: The dataset includes 4,900 training images and 2,100 testing images, classified into Non-Demented, Very Mild Demented, Mild Demented, Moderate Demented, and Severe Demented. Preprocessing steps include normalization, noise reduction, and the application of contrast-limited adaptive histogram equalization (CLAHE) to improve image quality.
- Multiple Sclerosis (MS): This dataset comprises 2,870 training images and 394 testing images, categorized into Control-Axial, Control-Sagittal, MS-Axial, and MS-Sagittal. Preprocessing involves segmentation of relevant regions of interest and normalization to ensure consistent input for the model.

3.2 Model Selection and Fine-Tuning

- Brain Tumor Classification: We selected the EfficientNet-B0 model due to its balance between accuracy and efficiency. EfficientNet-B0 uses a compound scaling method to uniformly scale all dimensions of depth, width, and resolution, making it particularly well-suited for tasks with limited computational resources. We fine-tuned the model on our brain tumor dataset, adjusting hyperparameters such as learning rate, batch size, and optimizer to optimize performance for our specific application.
- Alzheimer’s Disease Classification: A modified version of AlexNet is employed for this task. AlexNet’s architecture has been adapted to handle the specific characteristics of Alzheimer's MRI images, including the addition of more convolutional layers to capture finer details and the application of dropout regularization to prevent overfitting. The model has been fine-tuned using transfer learning techniques, leveraging pre-trained weights from ImageNet and adapting them to our dataset.
- Multiple Sclerosis Classification: We use a similar modified AlexNet architecture for MS detection, with additional layers to improve segmentation accuracy. The model’s capacity to handle high-dimensional data has been enhanced through the use of batch normalization and advanced pooling techniques, ensuring that the network effectively learns to distinguish between MS lesions and healthy brain tissue.

3.3 Implementation Challenges

Throughout the development process, we encountered several significant challenges:

- Data Imbalance: The datasets for some categories, particularly in Alzheimer's disease stages, were imbalanced. We addressed this issue through the application of data augmentation and oversampling techniques, ensuring that the model could learn effectively from all categories.
- Model Complexity vs. Efficiency: Balancing model complexity with computational efficiency was a key challenge, particularly given the high-dimensional nature of MRI data. We made targeted adjustments to model architectures to enhance computational efficiency without sacrificing accuracy.
- Ethical Considerations: Protecting patient privacy is paramount in medical AI applications. We implemented stringent data encryption protocols and ensured compliance with international data protection regulations, such as GDPR, to safeguard sensitive information.

4. Results

The models developed for our AI-powered diagnostic platform have shown exceptional performance across the three targeted neurological conditions. Below, we present the key metrics for each model, including accuracy, recall, F1 score, and precision, demonstrating the effectiveness of our approach.

Brain Tumor Classification:

The EfficientNet-B0 model achieved remarkable results in classifying brain tumor images, providing highly accurate and reliable diagnostics. The model's performance metrics are as follows:

- Accuracy: 99.4%
- Recall: 99.8%
- F1 Score: 99.2%
- Precision: 99.2%

These results indicate that the model not only excels in correctly identifying tumor cases but also minimizes false positives and negatives, making it highly effective for clinical use.

Alzheimer’s Disease Classification:

The modified AlexNet model also delivered outstanding performance in classifying the stages of Alzheimer’s disease.

This model's ability to differentiate between the various stages of the disease is reflected in the following metrics:

- Accuracy: 99.1%
- Recall: 99.8%
- F1 Score: 99.1%
- Precision: 99.1%

The high recall rate suggests that the model is particularly adept at identifying true positives, ensuring that cases of Alzheimer’s are correctly classified with minimal error.

Multiple Sclerosis (MS) Classification:

The Multiple Sclerosis detection model, also based on a modified AlexNet architecture, demonstrated strong performance, particularly in detecting and segmenting MS lesions:

- Accuracy: 95.3%
- Recall: 98.0%
- F1 Score: 95.3%
- Precision: 95.4%

Although the accuracy is slightly lower compared to the other models, the high recall rate indicates that the model is effective in identifying MS cases, making it a valuable tool for early diagnosis and monitoring of disease progression.

These results underscore the robustness and reliability of our AI-powered diagnostic platform. Each model has been fine-tuned to balance precision and recall, ensuring that the platform can provide accurate, actionable insights in a clinical setting.

5. Discussion

The success of our models in accurately diagnosing brain diseases highlights the potential of AI to transform neurological diagnostics. By integrating state-of-the-art deep learning techniques with extensive medical datasets, we have developed a platform that meets and, in some cases, exceeds current diagnostic standards.

Our results suggest that the EfficientNet-B0 model's efficiency and accuracy make it an ideal candidate for real-time tumor detection in clinical settings. Similarly, the modified AlexNet models have shown great promise in both Alzheimer's disease and Multiple Sclerosis diagnostics, offering a level of accuracy and detail that could support more personalized treatment planning.

Moreover, our platform's design allows for easy integration into existing clinical workflows, providing a tool that can be used by medical professionals with varying levels of technical expertise. The inclusion of user-friendly interfaces and comprehensive reporting features ensures that the platform is accessible to a broad audience, from specialists to general practitioners and even patients themselves.

6. Conclusion

Our AI-powered platform represents a significant advancement in the field of neurological diagnostics. By combining the strengths of EfficientNet-B0 and modified AlexNet models, we have created a tool that is not only accurate and reliable but also efficient and scalable. This project demonstrates the potential of AI to enhance the diagnostic process, making it faster, more accurate, and more accessible.

As we continue to refine and expand our platform, we anticipate that it will become an invaluable tool in the fight against brain diseases, offering hope to patients and healthcare providers alike. Moreover, our platform's adaptability means it can be updated and scaled to include other neurological conditions as new research emerges, ensuring it remains at the cutting edge of medical diagnostics. The integration of AI into clinical practice is a significant step towards more personalized medicine, allowing healthcare professionals to tailor treatments to individual patients based on highly accurate diagnostic data. Ultimately, our platform has the potential to significantly reduce the time and cost associated with diagnosing brain diseases, leading to better outcomes for patients worldwide.

7. Future Work

Looking ahead, there are several key areas for future development:

- Integration with Clinical Workflows: We plan to work closely with healthcare providers to integrate our platform into clinical settings, ensuring that it meets the practical needs of medical professionals.
- Expansion to Other Neurological Disorders: Future iterations of the platform could include diagnostics for additional neurological conditions, such as Parkinson’s disease or epilepsy, further broadening its applicability.
- Enhancing User Experience: We will continue to refine the user interface to make the platform as intuitive and user-friendly as possible. This includes the development of features such as voice-guided navigation and real-time collaboration tools for multi-disciplinary teams.
- Real-Time Processing and Cloud Integration: To enhance accessibility and scalability, we plan to implement cloud-based processing capabilities, allowing users to perform diagnostics in real-time without the need for specialized hardware.

References

- A Comprehensive Study on Alzheimer's Disease Classification Using Deep Learning
- Puthussery, A., Jote, P. I., & Baby, A. (2023). Alzheimer's Disease Classification Using Deep Learning: A Comprehensive Review. Journal of Alzheimer's Disease Reports, 7(1), 289-305. Link
- Automated Multiple Sclerosis Lesion Segmentation from MRI Data Using Deep Learning
- Parveen, N., & Garg, A. (2022). Automated Multiple Sclerosis Lesion Segmentation from MRI Data Using Deep Learning. Proceedings of the International Conference on Advances in Computing, Communications and Informatics. Link
- Brain Tumor Classification Using Deep Learning Techniques
- Patel, M., Rajpurkar, P., Irvin, J., & Lungren, M. (2022). Brain Tumor Classification Using Deep Learning Techniques: A Review of Recent Developments and Future Prospects. arXiv preprint arXiv:2207.01584. Link