Gisma University of Applied Sciences

Uncertainty-Aware Deep Learning for Early Detection of Alzheimer's Disease Using MRI Images Data

Jason Joel Pinto

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Abstract

Alzheimer's is a neurological disorder, which is a main cause for dementia [7]. There are a lot of researches are that being conducted right now all over the world for the Alzheimer disease. A disease such as alzheimer's is very hard to predict as studies show that it can be cause due to multiple factors. Now when it comes to Multi modal machine learning models, it integrates different data sources such as a persons demographic data, lifestyle, medical history, clinical assessment, and cognitive assessment etc. This has sparked a new idea to process the data and understand a patter to detect the disease at a early stage. To achieve this various advanced machine learning models are being used.

As new advancement are being done in the medical fields, the aged population is going to rise. And more and more people, their relatives and family members are going to face deadly diseases such as Alzheimer's. Studies has shown that the early detection of alzheimer's Disease is more likely to get treated or leads to less serious problems when compared to the medications started at a later stage [4].

For this study the data being used is based on the Alzheimer's research organization called Open Access Series of Imaging Studies (OSIS). Various traditional as well and deep learning models are used to find the best model as well as the best parameters in order to reach a most accuracy score possible. The measurement scores used to select the best model out of all will be Recall, Accuracy, F1-score and Precision.

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Introduction

Alzheimer's is a neurological problem that starts with a build up of proteins called amyloid plaques and neurofibrillary tangles. This leads to the brain cells to die over time and this leads to the shrinkage of the brain size[3]. Studies show us that about 5.4 million people in the States have Alzheimer's. And the studies show upward trend in the newer generations in getting Alzheimer's Disease. It is expected to increase by 10 million people. As of today every 68 second and new person is being diagnosed by Alzheimer's Disease. And the studies show that by 2050 this is going to decrease to 33 seconds[1]. Between the year 2000 and 2017 the deaths reported due to alzheimer's have been increased by 143 %[2]. Alzheimer's is a disease which get's worse over the years, it keeps on progressing and the worst thing it is not reversible. Once worsened a lot of time and efforts go into the alzheimer's diseace. Which might end up being one of the costliest disease for any countries economy[10]. Hence it becomes very important that it is diagnosed as a early stage so that it can be controlled and treated. If it is detected early then doctor's with the help of medications can make sure that brain damage is not worsened. Currently magnetic resonance imaging (MRI),functional magetic resonance imaging(fMRI), computer tomography and positron emission tomography (PET) are used in order to early detect the Alzheimer's disease. These technologies are very expensive, very time consuming task and not very accessible for everyone as it Requirement sophisticated machines.

Machine Learning can be used to find if there is a way where one can find if there is a way models can find patterns which makes it possible to detect the disease at even earlier stage. As there are various studies that are being conducted all around the world, there are various data that are available which can be used by the machine learning models to analyze and early detect the disease. Based on prior researches, the researchers have numerical data's related to a persons MRI's and biomarkers in a persons body. With help of these they find whether a person is demented or not. If these data are used and ML model be developed which will be able to predict the will be lead to inexpensive diagnosis and can be made easily available to more and more people. In addition to that the automated model will be more accurate and also removes all human errors.

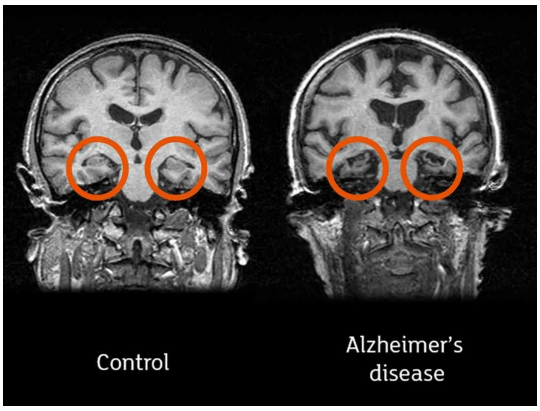

Figure 1.1: Comparison of a normal brain (left) and an Alzheimer's patient's brain (right).
Images credit: Professor John O'Brien, University of Cambridge and Newcastle University

A person with Alzheimer's disease will not be aware that he might be having a disease can ultimately lead to be a very dangerous disease. This is because the symptoms of Alzheimer's are very hard to find. It can be different to different people. The person can still do all the regular chores he does day to day without any problems. Having said that there will be some problems he might be facing while doing these activities, like for example not able to remember words, or not remembering names etc. People around him will definitely notice that this person has trouble remembering stuff. This is the reason why doctor as a first step usually conducts a medical interview where the person will be asked some questions. With the help of this he will be able to get a ball park idea whether he might have Alzheimer's or not. Some of the symptoms of Alzheimer's as follows,

1. Forgetting things, misplacing things, and missing meetings.
2. Forgetting names and events.
3. Not able to recall incidents happened in the past.
4. Problems with audio visual memory.
5. Being absent minded.
6. Agitation and restlessness

The symptoms of Alzheimer's becomes more evident when the disease progresses and one grows old. The person starts notices that the symptoms that he previously had are slowly slowly getting worse and worse. At later stages of AD it becomes very difficult to even communicate with the person as he does not remember anything. He forgets to even do the basic things that he has been taught to do since his childhood. This the stage when they will need continuous Assistance.

Motivation

Figure 2.1: Person suffering from Dementia

Alzheimer's is considered as one of the most challenging disease in the modern medicine research. And this disease not only effects the individual but also impacts the people around him/her that is family, doctors and also the hospitals. As the people effected by this disease are increase at a rapid rate around us, there is a need to develop a better way to diagnose and prevent this disease. Particularly, there is a high demand for a system that will detect the disease at a early stage. So that the medical team can stop the disease from getting worse at the old age which might cause a big economic burger for the patients.

The motivation to write this thesis came from the fact that there are sophisticated diagnostics options available at the moment which are very expensive, time-consuming and they are not accessible for of people. But the main problem is even after spending a lot of money on these diagnostic procedures, it cannot detect it at a very earlier stage. Doctors use MRI's and PET scans which are very accurate but they machines used for this are very special and needs an expert to use them. Additionally, even after analyzing a persons brain in these scans, the disease is not detected at a early stage because the small changes that are happening in the brain are very different to find when compared to the normal aging of a persons brain.

With the advanced Machine Learning techniques we can try to fix these problems that are currently there. By using the datasets that available online the advanced Machine Learning models can find patterns in the datasets which is hard to find using a naked human eyes. This will help in detecting the Alzheimer's disease at a very earlier stage.

Personally for me this paper is driven by the fact that I have seen many people around me struggling with Alzheimer's disease in their old age. I have seen it first hand how much time, money and effort does it take for their family to take care of them in that situation. As it is a disease that gradually gets worse, they slowly start losing their memory and identity. Having witnessed this I have seen how much effort goes into taking care of a Alzheimer's patient. This has motivated me to provide my Contribution to this communicate and make a difference. Hence, my aim in this research is to create a model will be able to predict the possibility of the disease at a earlier stage.

Contribution

The contribution of this thesis paper is to use the advanced Machine Learning algorithms to find a solution to problems of early detection of the Alzheimer's disease. This is to provide a novel extension to the community of deep learning models to the Alzheimer's stage classification.This will include implementing various different advance machine learning models to improve the predicting of the disease based on the MRI images that we are using for this research. The main contributions are such as:

1. **Inclusion of Uncertainty-Aware Framework:** In this research patient's MRI images will be analyzed which are divided into various stages of Alzheimer's and build a Classification Model using these images. Many high performing models are already presend online but in this thesis we will looking one of them and which performed the best and implement Monte Carlo Dropout Uncertainty calcucation so that the confidence of the model can be analyzed. This will help in knowing how confident the model is when predicting the class.

2. **Improved Model Interpretation:** The addition made to the code to include the Uncertainty indication will help in knowing how confident the model is when predicting the classes. This will also help in the clinical environment where the professionals looking at the results of the models they will not blindly accept the stage of alzheimer's disease, they can check if the model was confident when predicting the class. If not they can furthur review with their senior doctors about the case.

3. **Addition of Uncertainty Score in Predicted Results:** In this thesis a very much necessary steps in the deep learning models when it comes to medical usage are being looked at and included. These additional metrics will ensure that models performance is not evaluated only based on the accuracy but important factors like Uncertainty or confidence is considered so that cases with high uncertainty can be taken for further studies instead of just labeling whatever the model is classifying it as. A well structure visualization framework is put into action to highlight uncertainty for each and every individual predicted images. These information on the visualization will allow clinicians to find and focus on unique and unknown cases, which will allow them to make more informed decision-making.

4. **Utilization of Publicly Available Datasets:** The MRI images used for this study is a cleaned dataset which is availabel on kaggle which is sourced from ADNI websites which are the MRI images of actual people with true labels. Since it's is very reliable source this study uses real world data to train the model at the same time following all the ethical guidelines.

5. **Visualization of Uncertainty in Predictions:** By focusing on machine learning approaches, the research aims to provide scalable and cost-effective solutions for early AD diagnosis. This could significantly improve accessibility, especially in resource-constrained settings where sophisticated imaging technologies are not viable.

6. **New addition will make it possible for this to be applied in a clinical setup:** By introduction Uncertainty into account when classifying the Alzheimer's Disease into multiple classes this thesis reseach will help reducing the rist of wrong diagnosis in a medical setup who are ready to introduce AI into for their diagnostics setup. It is especially important in medical field as misdiagnosis might

cause a major problems in a persons life.

7. **Contribution to the AD community as well as open sourcing these projects:** The code used for this thesis will be open to everyone to view and as this will allow to access and reproduce this models for further studies. By adding Uncertainty to these already well performing models this reasearch further improves the the communities acceptence of these new technologies into their system, as it also allows human proffessionals to take things into their hands the models is not so sure how to react the unexpected situations.

Literature Review

In the recent years have seen a impressive amount of progress in the utilization of the deep learning models for the Alzheimer's Disease detection based on the MRI data. And alot of advancement focus on how to improve, how accurately the model predicts the Disease of how accurately it classifies the images or data into different classes. Whereas the integration of Uncertainty calculation is something that is not explored too much, nevertheless. In this Literature review the previous research papers are being studied and will be compared and seen if there are any gaps in the study that can be full filled.

4.1 Overview of techniques used on MRI

All thanks to the impressive technology of the Magnetic Resonance Imaging(MRI), Alzheimer's disease (AD) can be detected at a very early stage compared to earlier. The 3 Dimensional high quality images of brain captured using MRI machines provide a view of our brain with which we can find the patterns in the parts of the brain like temporal regions and hippocampal region which helps in diagnose of the Alzheimer's Disease. By taking a look at the white matter integrity and functional connectivity, the help of diffusion tensor imaging (DTI) and functional magnetic resonance imaging (fMRI) make amazing contributions to this. Methods such as cortical thickness measurement and voxel-based morphometry have been widely used for quantitative analysis of structural changes and brain volume[12].

Recently, there have been studies that are going on to create synthetic longitudinal MRI images for Alzheimer's disease using a conditional diffusion model. Diffusion models are are excellent at producing high-quality images with consistent training, which are used in this strategy. The models can produce realistic target pictures that mimic the course of the disease by using the time interval and the source MRI scan as conditioning elements. This strategy may be able to get around the drawbacks of current techniques like GANs and VAEs, which can have unstable, undiversified, or hazy results. The suggested model offers a useful tool for Alzheimer's disease research and clinical applications, producing high-fidelity synthetic MRI scans with encouraging findings[6].

4.2 Using Deep Learning for Alzheimer's Detection

The most common type of dementia that causes a lot of trouble for millions of people worldwide is Alzheimer's disease (AD). In order to manage symptoms and maybe reduce the progression of the disease, early recognition of AD is essential[9].Conventional diagnosis techniques depend on radiologists' subjective and time-consuming manual review of brain imaging data. And that is where Deep Learning brings an serious advantage over the time consuming tasks. Deep Learning models

can predict these kind of tasks with the mater of seconds.

With the use of deep neural networds we have see an amazing results in the recent years. Using the MRI data, and deep learning neural networks in prediction of the early detection of the Alzheimer's Disease has been a very promision method with great acccuracy. The convolutional neural networks as well as the recurrent neural netword have have drastically improve the prediction for this desease when compared to the traditionaL Machine Learning alternatives. This is because the Deep Learning models are able undertand the complex nature of the high dementional data that are used in training these models and to capture the brain image[8]. Recent improvements in the this field, specially deep leaning have changed the landscape of the Alzheimer's Detection. It is able to provide an objective and efficient solution.

As shown in Table 4.2, the primary focus of these studies has been on improving classification accuracy. However, none of the studies address the reliability of predictions, which is crucial for clinical deployment.

4.3 Uncertainty Estimation in Medical Imaging

Uncertainty estimation techniques, such as Monte Carlo (MC) Dropout and Bayesian Neural Networks, have been explored in other areas of medical imaging but are largely absent in Alzheimer's disease detection. Table **??** provides an overview of studies incorporating uncertainty estimation in medical imaging.

These studies demonstrate the potential of uncertainty estimation in improving model reliability and interpretability. However, their application to Alzheimer's disease detection remains unaddressed.

4.4 Research Gaps

While the studies reviewed demonstrate high accuracy, they fail to address:

1. **Uncertainty Awareness:** Essential for clinical implementation.
2. **Generalizability:** Robustness across datasets.
3. **Visualization:** Intuitive display of predictions for clinicians.

4.4.1 Summary

This review highlights that while deep learning has achieved significant advancements in Alzheimer's disease detection, its integration into clinical practice requires improvements in model reliability, interpretability, and generalizability. By addressing these gaps through the incorporation of uncertainty estimation techniques, this thesis aims to enhance the trustworthiness and applicability of deep learning models in healthcare.

Methodology

Your methodology goes here.

Results

Your results go here.

Discussion

Your discussion goes here. 123456

Table 4.1: Comparison of Studies on Alzheimer's Disease Detection

Study	Dataset	Model	Accuracy	Limitations
Sharma, Sarang (2022)[11]	Kaggle	Deep Learning model	91.75%	Lacks uncertainty estimation
Desai, Maitri(2024)[5]	OASIS	Multi-Task CNN	91.0%	Limited generalizability
Sarraf et al. (2016) [**sarraf2016**]	ADNI	AlexNet	89.5%	High false negatives
Islam and Zhang (2021)	Custom MRI Dataset	ResNet-50	94.7%	No reliability assessment

Table 4.2: Studies Incorporating Uncertainty Estimation in Medical Imaging

Study	Domain	Technique	Uncertainty Measure
Kendall and Gal (2017) [**kendall2017**]	Segmentation	MC Dropout	Epistemic, Aleatoric
Leibig et al. (2017) [**leibig2017**]	Diabetic Retinopathy	Bayesian NN	Model uncertainty
Wang et al. (2019) [**wang2019**]	Lung Nodule Detection	MC Dropout	Prediction confidence

Conclusion

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Appendix Title

Appendix content goes here.

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