Enhancing Dementia Diagnosis with ML

Blackwell Summer Scholars Program
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Introduction

Background + Objectives

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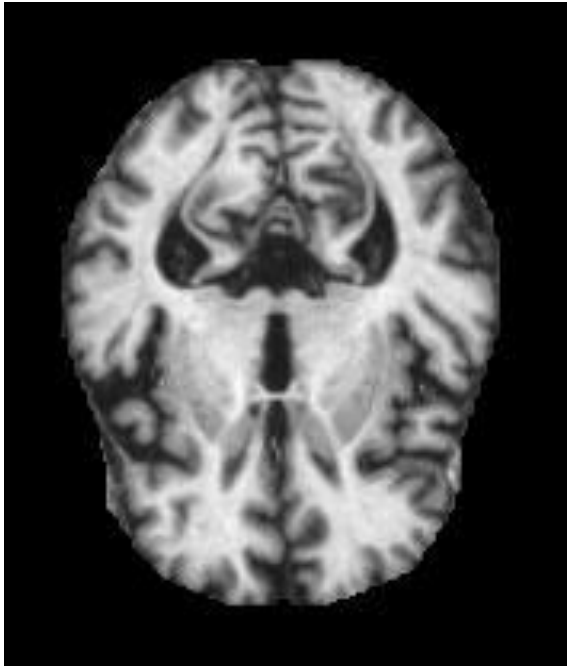
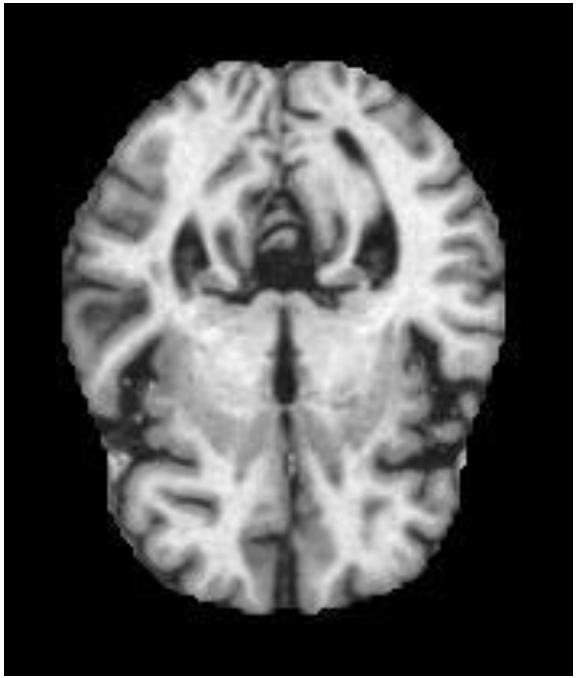
Background

- dementia and alzheimers threatens the quality of life in people
- early detection through research can help prevent dementia
- my hypothesis and research question:
    - socioeconomic status, education level, and gender are strongly associated with the incidence of dementia.
    - How can machine learning algorithms improve the early detection and diagnosis of dementia, and what impact does this have on patient outcomes?



Objectives

- provide advancement of medical research with machine learning
- early detection of dementia in patients
    - supports early detection of Alzheimer's
    - allows for lifestyle changes and treatments that can delay the onset of severe symptoms
- a greater goal of nationwide scalability
    - development of new treatments
    - decision support for medical professionals
    - personalized treatment plans



Literature Review

Summary of Previous Research

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Summary of Previous Research

- In 2016, Ortiz et al. utilized the Automated Anatomical Labeling (AAL) method
  - to distinguish between AD, MCI, and non-converting (NC) subjects
  - divided the brain into three-dimensional patches
- In 2022, Subramoniam et al. developed a model using sliced MRI images as inputs for residual CNNs (ResNet-101)
- In 2018, Islam and Zhang developed a CNN model that utilizes brain MRI data to detect AD
  - using 416 photos from the OASIS dataset
  - achieved an accuracy of 93%

Literature Review

- In 2022, Alorf and Khan focused on classifying various stages of Alzheimer's Disease
  - only able to achieve an average accuracy of 77.13% (Stacked Sparse Autoencoders) and 84.03% (Brain Connectivity Convolutional Network)
- In 2023, Kishore and Goel aimed to develop a DNN for diagnosing AD and categorizing its stages
  - used Fluorodeoxyglucose PET scans
  - differentiated between subjects with AD, stable MCI (sMCI), progressive MCI (pMCI), and CN individuals
  - achieved exceptional accuracy rates: 99.31% for CN versus AD, 99.88% for CN versus MCI, 99.54% for AD versus MCI, and 96.81% for pMCI versus sMCI.

Methods

Data Collection + Study Design + Data Analysis

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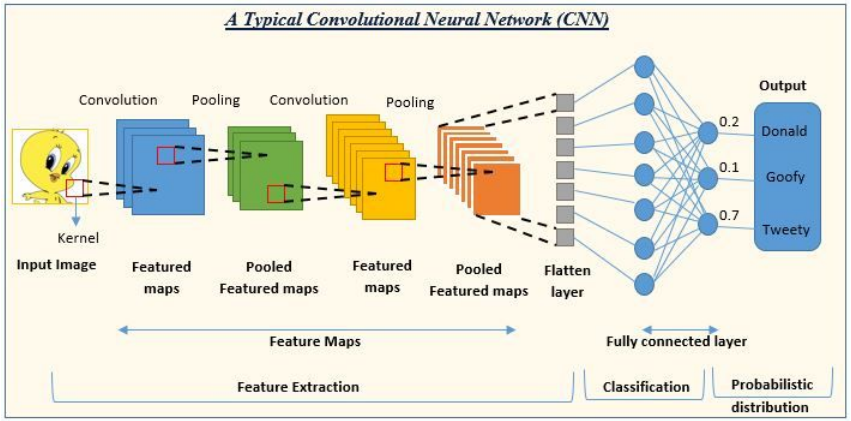
Data Collection

- Kaggle dataset that included:
  - Cross-Sectional Dataset
    - a snapshot of data at a single point in time
    - useful for identifying patterns and relationships between variables at one moment
  - Longitudinal Dataset
    - data collected over a period of time from the same subjects
    - valuable for studying changes and developments over time, especially in disease progression
  - Training and Test Set of MRI Images
    - split into four different classes
    - essential for teaching the model to recognize patterns and features

Study Design



- For the different designs of my study, I developed:
  - Custom Convolutional Neural Network (CNN)
  - regression analysis model
  - classification analysis model
- **Convolutional Neural Network** - Experimental
  - controlled environment
  - testing of hypotheses
- **Regression and Classification Analysis** - Observational
  - working with pre-existing data without introducing any interventions or experimental conditions
  - identified correlations, patterns, and trends

Observational Data Analysis

- **Logistic Regression & K-Nearest Neighbor Classifier**
  - tested different independent variables from the longitudinal study
  - used dementia column as a binary dependent variable (Demented: 1, NonDemented: 0)
  - found accuracy, precision, recall, F1, and confusion matrix
- **Correlations**
  - women typically have higher brain volumes (r = 0.547)
  - people of higher socioeconomic status are more likely to be educated (r = 0.733)
  - nondemented brains are more likely to score higher on the mini mental state examination (r = 0.623)
  - the older you are, the less brain tissue to total intracranial volume you will have (r = 0.497)

Experimental Data Analysis

Convolutional Neural Network (CNN)

- **Architecture:** Three convolutional blocks and one global average pooling layer.
- **Callbacks:** Implemented LearningRateScheduler, EarlyStopping, etc.
- **Custom Scheduler:** Developed a custom learning rate scheduler to optimize training.
- **Model Evaluation:** Monitored Precision, Recall, and BinaryAccuracy metrics during training.

Results

Accuracy + Classification Reports + Confusion Matrices

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Logistic Regression Performance

Accuracy = 0.8646

Independent Variables:

- MMSE: Mini-Mental State Examination
- nWBV: Normalized Whole Brain Volume
- ASF: Atlas Scaling Factor
- SES: Socioeconomic Status

Dependent Variable:

- Demented: 1, NonDemented: 0

Classification Report:

Class	Precision	Recall	F1-Score	Support
0	0.85	0.93	0.89	57
1	0.88	0.77	0.82	39

Confusion Matrix:

Actual/Predicted	0	1
0	53 (TN)	4 (FP)
1	9 (FN)	30 (TP)

K-Nearest Neighbor Performance

Accuracy = 0.875

Independent Variables:

- MMSE: Mini-Mental State Examination
- nWBV: Normalized Whole Brain Volume
- ASF: Atlas Scaling Factor
- EDUC: Education Level

Dependent Variable:

- Demented: 1, NonDemented: 0

Classification Report:

Class	Precision	Recall	F1-Score	Support
0	0.84	0.97	0.90	37
1	0.95	0.74	0.83	27

Confusion Matrix:

Actual/Predicted	0	1
0	36 (TN)	1 (FP)
1	7 (FN)	20 (TP)

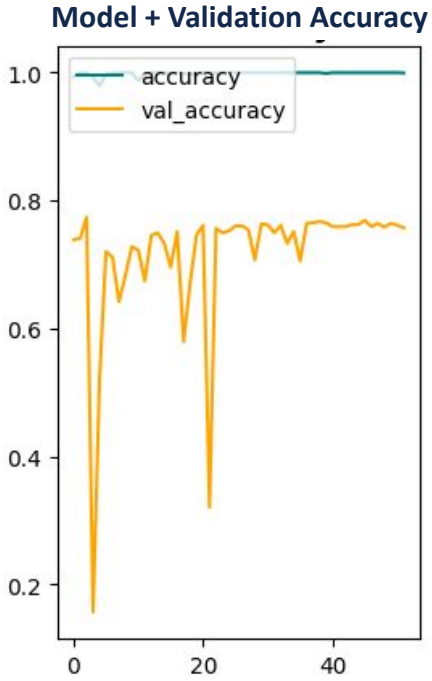
Convolutional Neural Network (CNN)

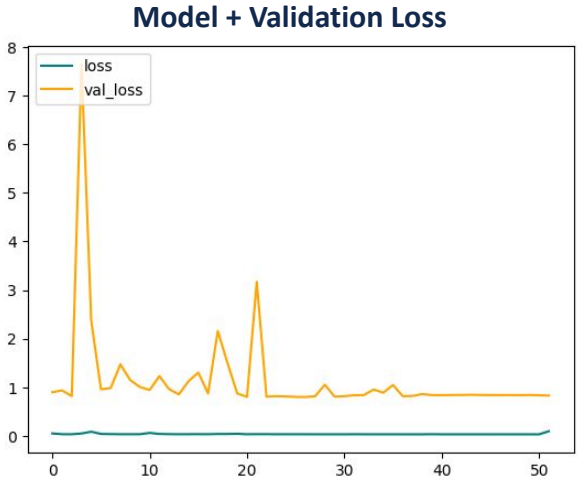
Model Performance:

- Accuracy = 0.7483
- Loss: 0.9557

Test Set Results:

- Test Accuracy: 0.7404221892356873
- Test Loss: 0.9755898714065552





Convolutional Neural Network (CNN)

Classification Report:

	Precision	Recall	F1-Score	Support
MildDemented	0.17	0.18	0.17	179
ModerateDemented	0.00	0.00	0.00	12
NonDemented	0.49	0.47	0.48	640
VeryMildDemented	0.34	0.35	0.35	448

Convolutional Neural Network (CNN)

Confusion Matrix:

Actual/Predicted	MildDemented	ModerateDemented	NonDemented	VeryMildDemented	Support
MildDemented	32	3	82	62	179
ModerateDemented	1	0	7	4	12
NonDemented	91	7	299	243	640
VeryMildDemented	66	5	219	158	448
Predicted Support	190	15	607	467	1279

Conclusion

Main Findings + Significance + Future Possibilities

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Main Findings

- the best tests of dementia in a patient are MMSE, nWBV, and ASF
- the dataset you load your model with is the most important part of the study
    - the moderate demented class had a 0% precision, recall, and F1-Score
    - an imbalance dataset will lower the accuracy of the model
- imperative to be able to analyze an MRI
    - cross and longitudinal studies alone are not accurate enough
    - CNN models with MRI's are accurate enough to detect and/or classify dementia
- AD-DL is currently available on a limited scale
    - high levels of memory are essential for more complex models.
    - requires high-spec computer chips or CPUs

Research Significance

- Early Detection
  - automated analysis of MRI scans can significantly speed up the diagnostic process
  - can slow the progression of the disease, improve the quality of life, and provide better patient outcomes
- Comprehensive Analysis
  - the research can help identify new biomarkers and risk factors associated with dementia
  - can detect subtle changes in brain structure and function that may be early indicators of dementia
- Integration with Other Technologies
  - CNN models can be integrated with other healthcare technologies, such as electronic health records (EHRs) and telemedicine platforms

Future Possibilities

Classifying Stages of Alzheimer's Using Advanced Neural Networks:

- ResNet-101 or VGG16:
  - implementing advanced neural networks such as ResNet-101 or VGG16
  - could improve the accuracy and reliability of early detection and classification of Alzheimer's stages

Exploring Deeper Symptoms of Dementia with Machine Learning:

- Random Forest Classifier:
  - explore and classify deeper symptoms of dementia
  - can potentially yield higher accuracies in identifying and differentiating dementia symptoms

Correcting the Weights of My Classes

- manually modify the weights assigned to each class in the model
- ensure there is an equal number of samples across all classes

Thank You

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Works Cited

Journal Article:

Sorour, S. E., & et al. (2024). Classification of Alzheimer’s disease using MRI data based on deep learning techniques. Journal of King Saud University - Computer and Information Sciences. https://www.sciencedirect.com/science/article/pii/S1319157824000296#b24

Dataset:

Dubey, Sarvesh (2019). Alzheimer's Dataset (4 class of Images) [Data set]. Database: Open Database, Contents: © Original Authors https://www.kaggle.com/datasets/tourist55/alzheimers-dataset-4-class-of-images/data