# CNN for
ALZHEIMER'S Detection

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BACKGROUND

- Dementia affects over 55 million people worldwide, with Alzheimer's being the most common form.
- Alzheimer's is frequently unrecognized or diagnosed late in its course, as initial symptoms may not become apparent during routine examination.
- The time to receive a diagnosis could range from a few weeks to more than a year.
- While there is no cure yet, our goal is to develop a robust model for early detection to enable timely intervention and slow its progression.
- To progress with the project, we had to get familiar with the direction in which Alzheimer starts to develop in the human brain researchers have found that it starts entorhinal cortex and hippocampus.

MildDemented · ModerateDemented · NonDemented · VeryMildDemented
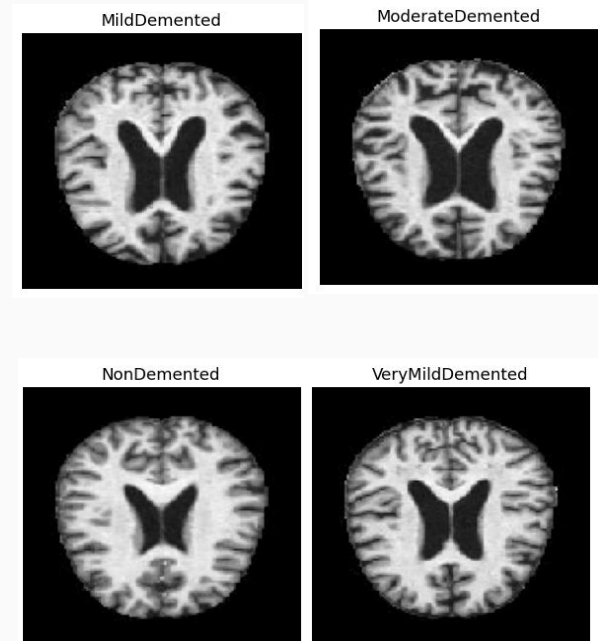
OBJECTIVES

Specific & Measurable Objective:
Develop a CNN-based model to classify MRI scans into healthy and diseased brains and further distinguish between early, intermediate, and advanced stages of Alzheimer's disease, aiming for >95% accuracy.
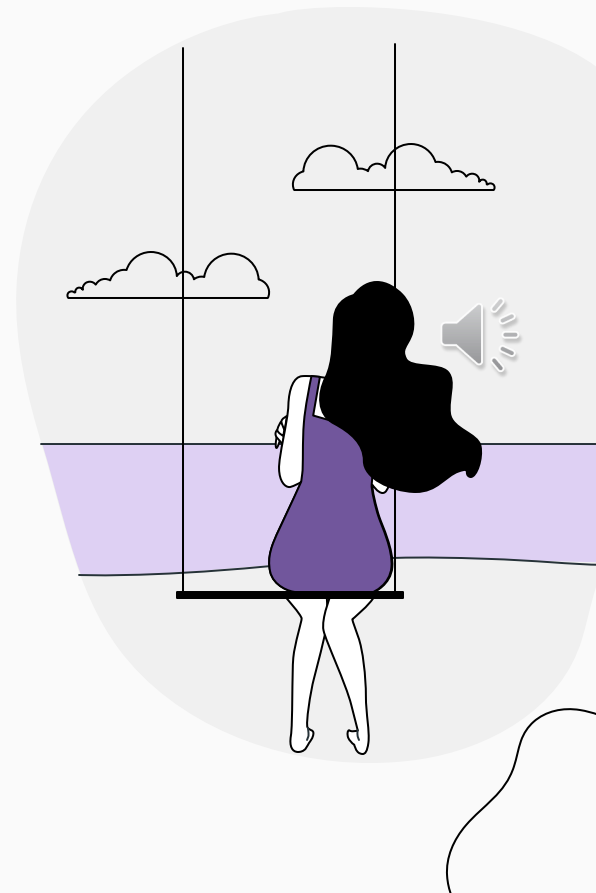
Goal of Early Intervention:
Create a robust classification model to support early detection of Alzheimer's disease, enabling timely interventions to slow its progression.
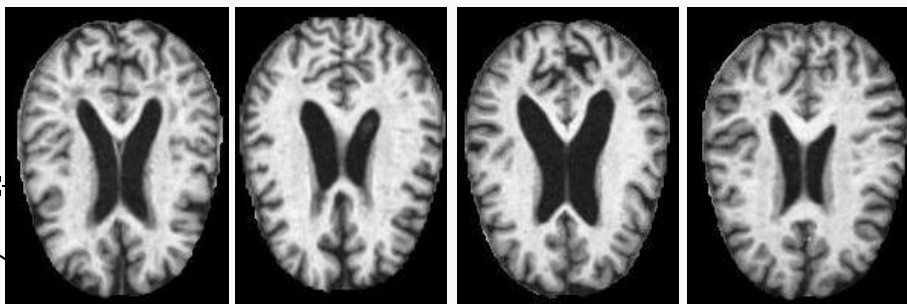
Real-World Impact:
Contribute to reducing the burden of Alzheimer's by assisting clinicians in prioritizing treatment strategies and improving patient outcomes.

PREPROCESSING

	Augmented	Original
MildDemented	8,960	896
ModerateDemented	6,464	64
NonDemented	9,600	3,200
VeryMildDemented	8,960	2,240

BREAKDOWN

- Combined 70% of the Augmented and Original dataset for training.
- Combined 15% of the Augmented and Original dataset for validation
- Combined 15% of the Augmented and Original dataset for testing
- Normalization ([0, 255] to [0, 1])
- Resized images to 224px x 224px
- Shuffled training dataset for better generalization
- Original: Avg. Size: 176.00 x 208.00 pixels, Avg. Aspect Ratio: 0.85
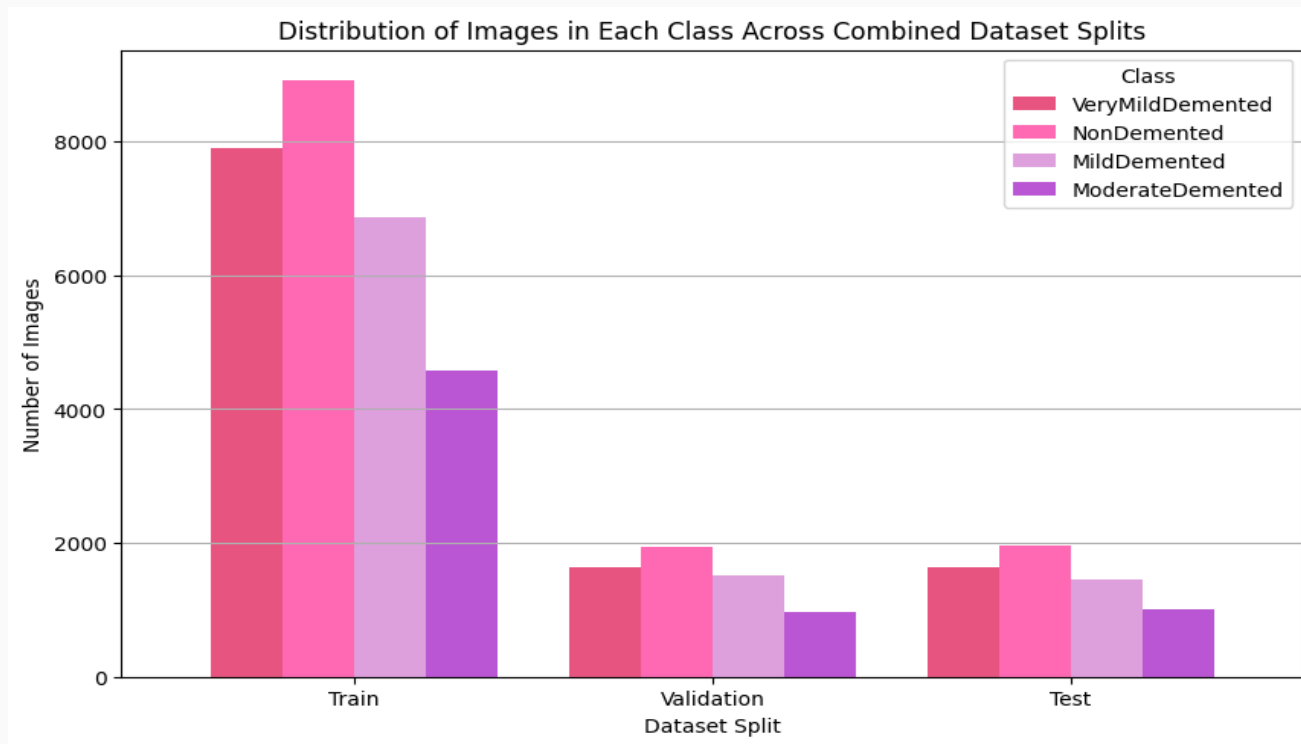- Augmented: Avg. Size: 196.23 x 188.12 pixels, Avg. Aspect Ratio: 1.04

DATASET DISTRIBUTION

Distribution of Images in Each Class Across Combined Dataset Splits

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01.

MACHINE LEARNING MODELS

KNN

- KNN is an algorithm that classifies observations based on k nearest observations.

- The Euclidean distance is calculated for each instance in the testing set to all other instances in the training dataset. Then 5 nearest instances relative to each testing observation are used to classify that testing observation

- False Negative Rate: 0.21

Confusion Matrix (Test Set)
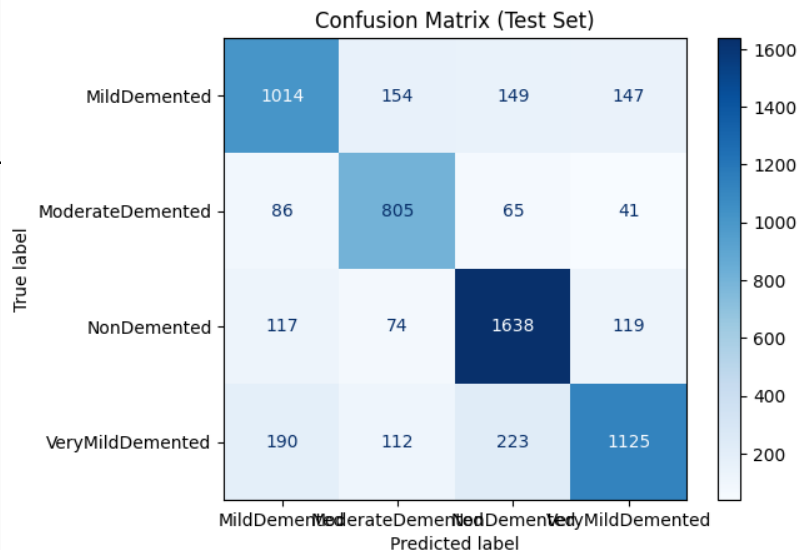
```
Classification Report:

                  precision    recall  f1-score   support

   MildDemented       0.72      0.69      0.71      1464
ModerateDemented      0.70      0.81      0.75       997
    NonDemented       0.79      0.84      0.81      1948
VeryMildDemented      0.79      0.68      0.73      1650

       accuracy                          0.76      6059
      macro avg       0.75      0.76      0.75      6059
   weighted avg       0.76      0.76      0.75      6059
```
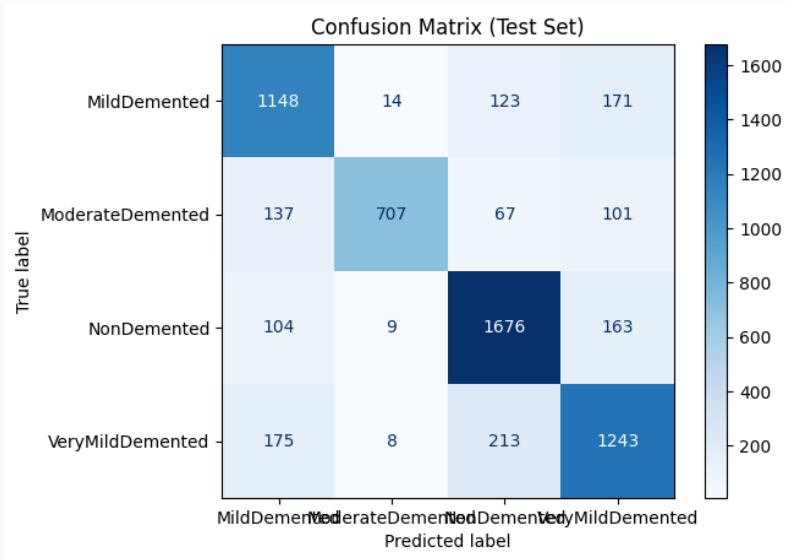
Random Forest
+ PCA

- PCA reduced the dimensions of the data while preserving the variance in the data.
- Used components that explained 95% of the variance
- The reduction in dimensions speed up the machine learning process.
- Performed Random Forest on the transformed dataset
- Random Forest trains multiple decision trees on a random subset of the training data then averages the results to make predictions
- False Negative Rate: 0.19

Confusion Matrix (Test Set)

	MildDemented	ModerateDemented	NonDemented	VeryMildDemented
MildDemented	1148	14	123	171
ModerateDemented	137	707	67	101
NonDemented	104	9	1676	163
VeryMildDemented	175	8	213	1243

Classification Report:

	precision	recall	f1-score	support
MildDemented	0.73	0.79	0.76	1456
ModerateDemented	0.96	0.70	0.81	1012
NonDemented	0.81	0.86	0.83	1952
VeryMildDemented	0.74	0.76	0.75	1639
accuracy			0.79	6059
macro avg	0.81	0.78	0.79	6059
weighted avg	0.80	0.79	0.79	6059

02.

Deep Learning Models

Deep Learning Models we observed

Custom Sequential Models

and

Pretrained Models

- ResNet101
- MobileNet

CNN 🔊

This CNN is a basic model that consists of 5 layers.

The first four layers uses Convolutional 2D layers. 16 kernels have been set-up, (3x3) size per kernel with images of 224 x 224 pixel and 3 channels (RGB) .

The model is then compiled using Adam optimizer, sparse cross entropy loss function and trained for 10 epochs.

Result Interpretation: The CNN model performed extremely well even with this simple architecture.
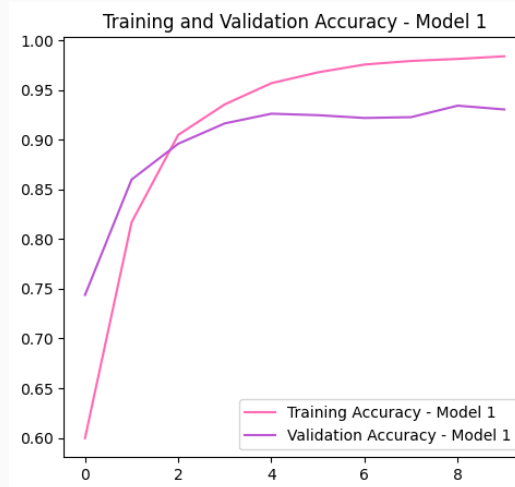

```
Classification Report:

                     precision    recall  f1-score   support

      MildDemented       0.96      0.86      0.91      1467
  ModerateDemented       0.97      1.00      0.98      1007
       NonDemented       0.91      0.92      0.91      1972
  VeryMildDemented       0.85      0.91      0.88      1613

          accuracy                           0.91      6059
         macro avg       0.92      0.92      0.92      6059
      weighted avg       0.92      0.91      0.91      6059
```
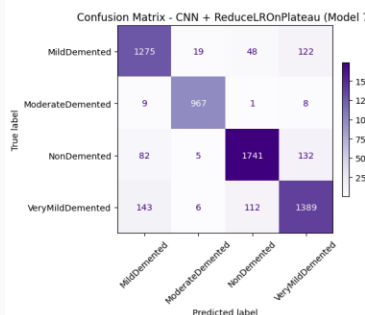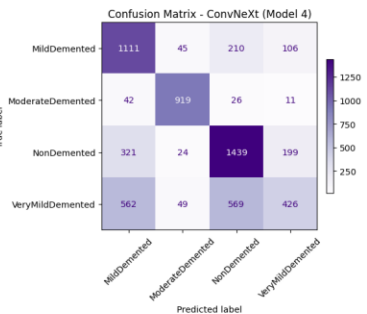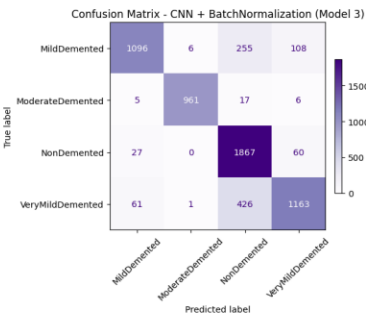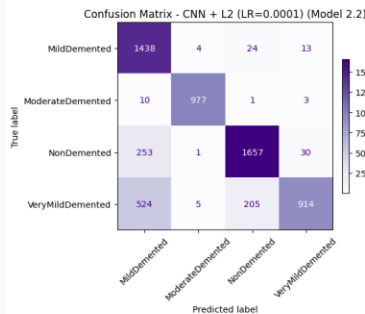
MobileNet Model

The MobileNet model achieved excellent performance with 99% accuracy and strong precision, recall, and F1-scores across all classes, indicating effective classification. Training and validation accuracy curves showed minimal overfitting, supported by consistent performance on the test set.

Training and Validation Accuracy

Training and Validation Loss
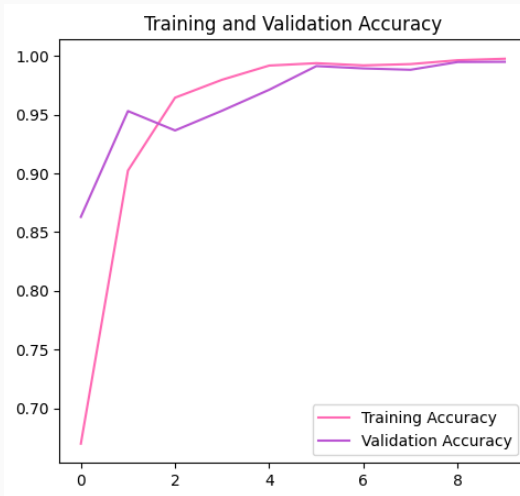
Classification Report:

	precision	recall	f1-score	support
MildDemented	1.00	1.00	1.00	1452
ModerateDemented	1.00	1.00	1.00	996
NonDemented	0.99	0.99	0.99	1960
VeryMildDemented	0.98	0.99	0.99	1651
accuracy			0.99	6059
macro avg	0.99	0.99	0.99	6059
weighted avg	0.99	0.99	0.99	6059

03.

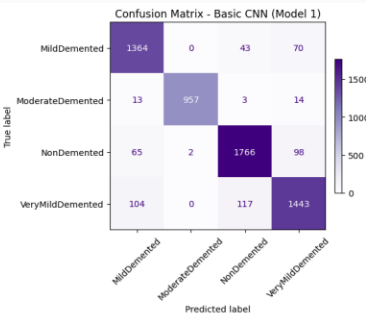## Results and Comparisons

Side by Side Comparison

Traditional Machine Learning Models

Confusion Matrix (Test Set)

Confusion Matrix (Test Set)

Confusion Matrix - MobileNet (Model 0)

Confusion Matrix - Basic CNN (Model 1)

Confusion Matrix - CNN + L2 (Model 2)

Confusion Matrix - CNN + L2 (LR=0.0001) (Model 2.2)

Confusion Matrix - CNN + BatchNormalization (Model 3)

Confusion Matrix - ConvNeXt (Model 4)

Confusion Matrix - CNN + ReduceLROnPlateau (Model 7)
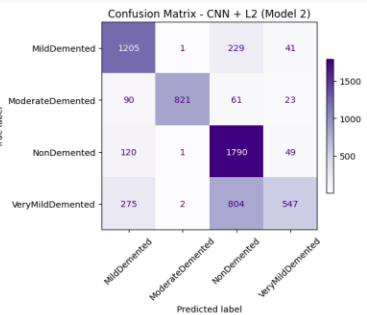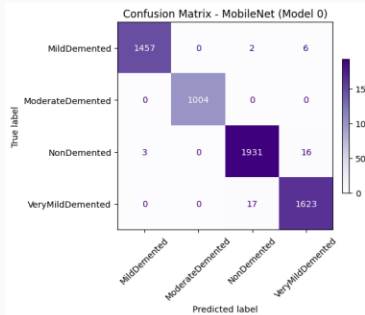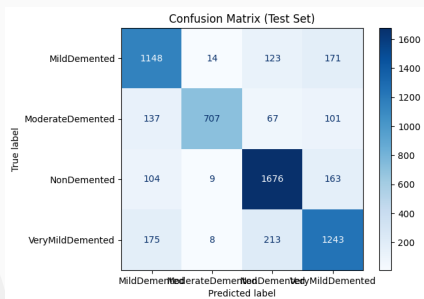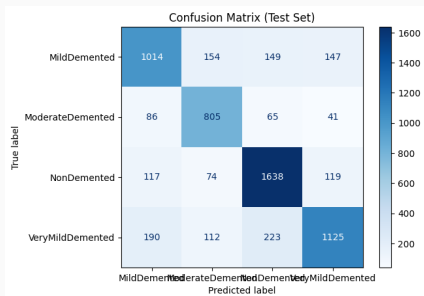
RESULTS 🔊

The top performer was MobileNet
The standout model with near-perfect scores excelled in both precision and overall balance as it contain by far less parameters than counterpart pre-trained models ResNet 101 and ResNet 50.

Trade-offs (CNN L2 + Custom Learning Rate) :
As the learning rate was decreased we saw a shift in the performance accuracy, but we also saw a decrease in precision.

Dropout Layer:
As model become complex we can drop out layers that eventually reduce noise and overall complexity.

Models	Performance Based on Accuracy	Precision (Micro Avg)	Insights
KNN	0.76	0.75	The model struggles with false positives but performs slightly better in balancing precision and recall.
Random Forest + PCA	0.79	0.81	PCA aids in dimensionality reduction enabling it to perform reasonable well applying Random Forest.
MobileNet	0.99	0.99	MobileNet showed superior ability to detect true positives with minimal false predictions.
CNN	0.91	0.92	CNN with convolution, max pooling and drop out layer combat overfitting by reducing the model's complexity.
CNN L2 + Learning Rate of 0.01	0.75	0.90	Prioritized precision, thus making highly selective leading to an in-balance.
CNN L2 + Learning Rate of 0.001	0.89	0.77	Showed robustness but precision was compromised.
CNN with Batch Normalization	0.90	0.91	Achieved a balanced with training stability.

ISSUES

| Issue	Description	Possible Solution
Vanishing Gradient	A phenomenon where the gradients that are used to update the network become extremely small as they are back-propagated from the output layers to the earlier layers.	Use of proper learning rate, appropriate activation functions or batch normalization.
Exploding Gradient	A phenomenon where the gradients that are used to update the network continue to get larger which causes a large weight update and results in the Gradient Descent to diverge.	Use of proper Learning rate. Weight Regularization like L1 regularization and L2 regularization.
- Huge Image Dataset - Model Training Overhead	The image dataset is too large that it was slowing down the training process of the CNN and Machine Learning Models.	Data sharding, the data was split into 4 separate "shards" to parallelize the computational across separate CPUs. And also using TPU power.

04.

CONCLUSIONS

CONCLUSION

Parameters

Deep learning models with a lower number of parameters (< 10 million) such as MobileNet and CNN performed better than models with a higher number of parameters (ResNet101 and ConvNext).
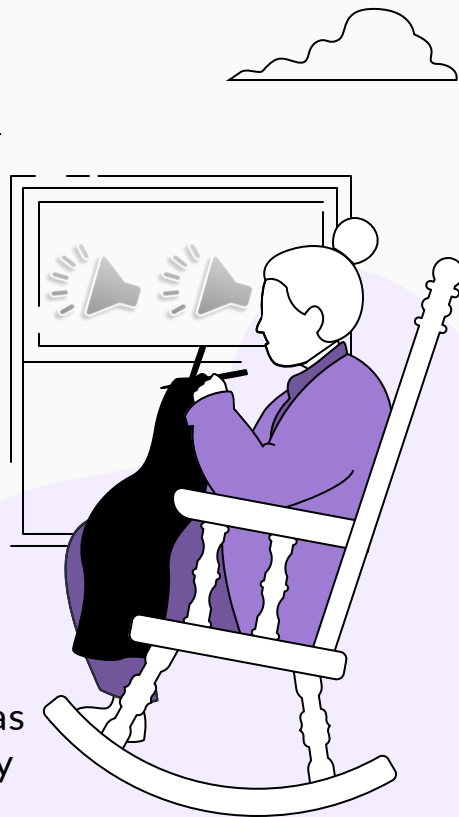
Learning Rate

Increasing the learning rate will result in an overfitting model and thus lead to an exploding gradient.

FUTURE DIRECTION

Validation Accuracy vs Trainable Parameters
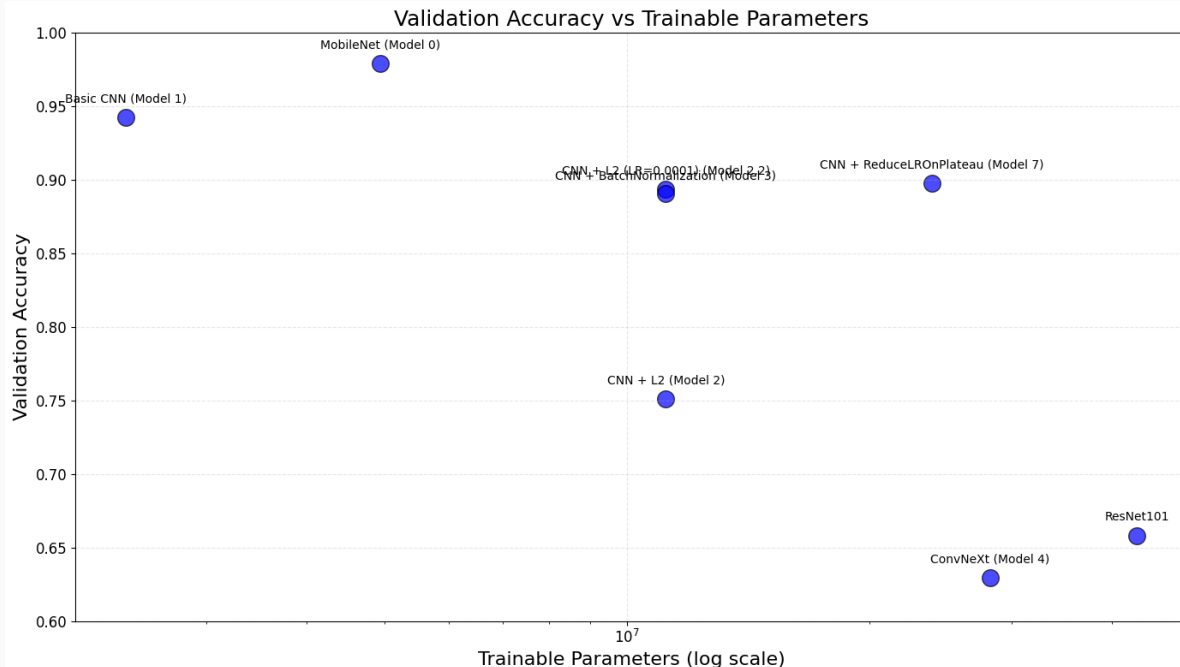
- **Model Selection**: Future work could focus on models with fewer parameters, as the Validation Accuracy vs Trainable Parameters shows they balance efficiency and accuracy effectively.

THANK YOU FOR YOUR TIME!