Machine Learning | CS 4774
Fall 2025 - 12/15

GradCAM Analysis on CNNs for Medical Imaging

Recorded Presentation and Project Demo: https://youtu.be/14LSr2qkkQ8

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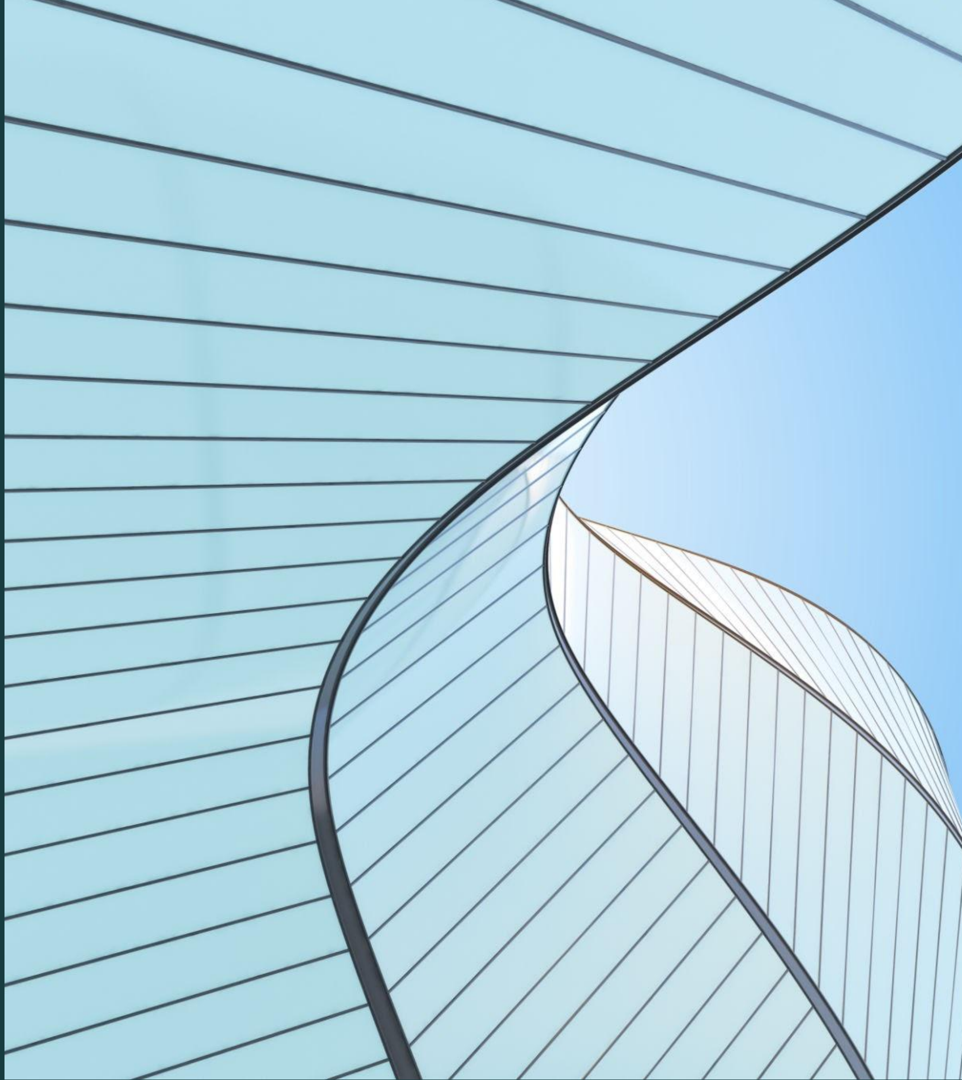


Presentation *outline*

Motivation

Why do we need to analyze ML models?

Motivation

- Diagnosing can be a time consuming, frustrating process for patients and providers
- A machine learning diagnosing tool can reduce the load on radiologists
- Deep learning models can increase diagnosing accuracy while providing a faster turnaround for patient-provider interaction

Motivation

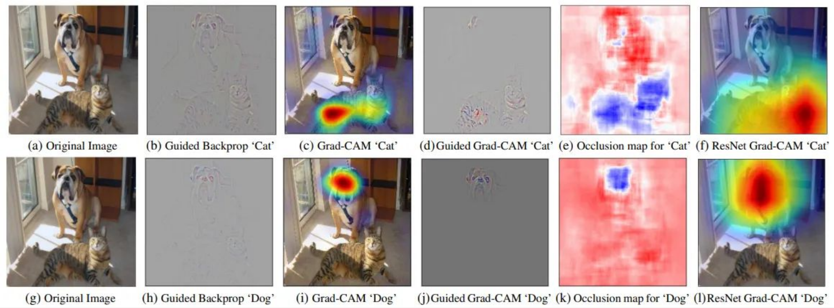
- How can doctors trust the predictions of ML models?
- GradCAM allows insights into what model is actually viewing
- Goal: Increase trust between doctors and model by understanding what features of CXRs the model is focusing on

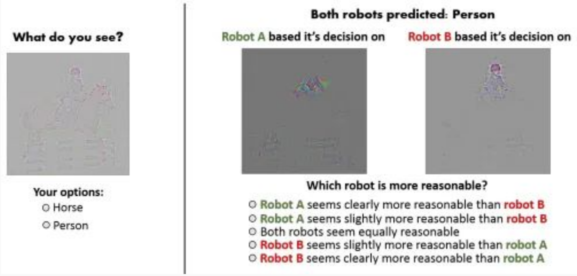
GradCAM

What is GradCAM analysis of a model?

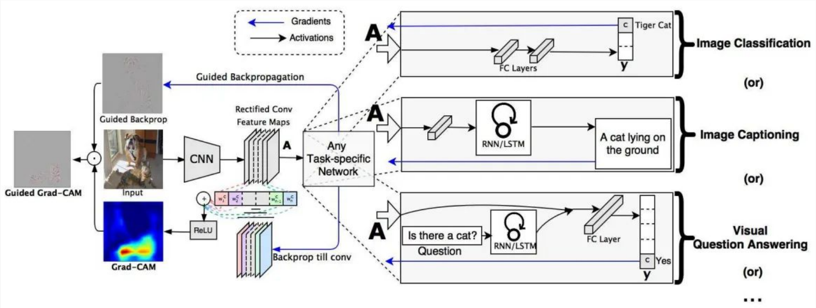
GradCAM

- Stands for Gradient-weighted Class Activation Mapping
- Looks at the gradients flowing into the last convolutional layer of the CNN
- Generates a heatmap of the gradients
- Develops trust between users and model

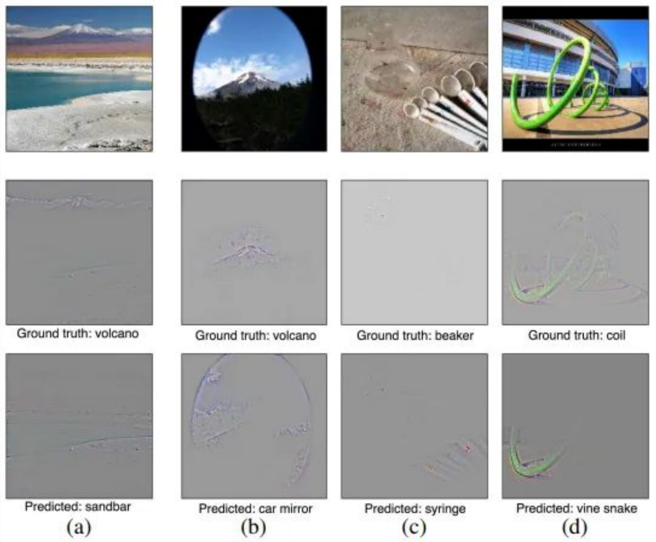




GradCAM



- Does not reduce performance of model
- Critical in high-risk fields such as medicine
- Despite providing insights, not an exact comprehensive explanation of the model
    - Further analysis should be done to garner more trust in the model and its predictions

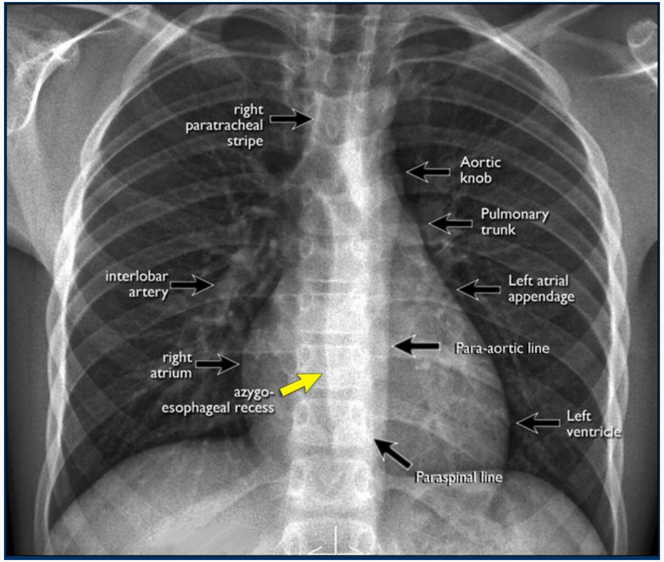


Lung Disease Features

What parts of the lung *should* the model focus on?

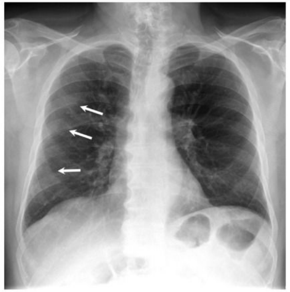
Normal Features

- CXR shows a lung with mostly black indicating mostly air
- Veins and blood vessels are visible through thin branches
- There should be no haziness or patches of white
- Thus, model should not focus on whiteness and instead focus on empty lung and prominent veins



COVID-19 Features

- **GGO**: hazy regions in the lung that do not completely obscure underlying structures
- Opacities should be around edges of lungs
- More focus towards the lower part of both lungs
- Thus, model should focus on lower parts and edges of the lungs



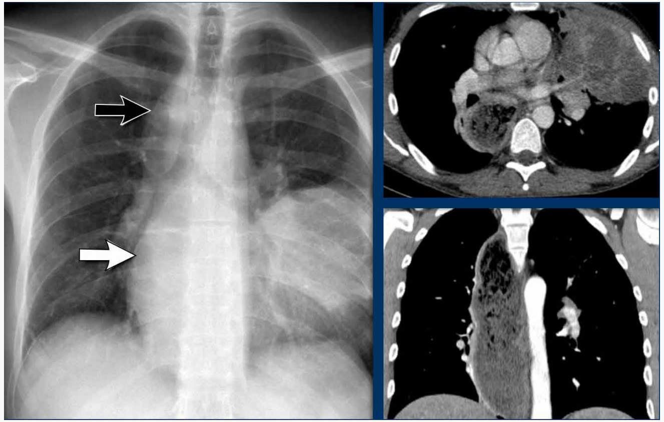
(a) Patchy GGOs with peripheral distribution in the right lung [28]

(b) Peripheral GGOs in mid- and lower-third of thorax [29]

(c) Bilateral GGOs more prominent in the right upper lobe and right paramediastinal region [30]

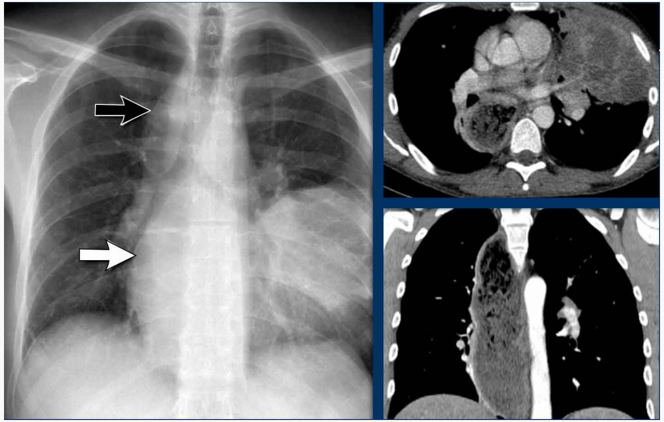
Viral Pneumonia Features

- More spread out areas of whiteness
- Hazy margins and net-like patterns within the lungs
- Less focus on the lower parts of the lung and more focused on the entire lung
- Thus, model should focus on net-like patterns and focus should be on higher parts of both lungs



Other Lung Disease Features

- Patterns and abnormalities could be shown in a single lung instead of both
- Extreme whiteness with a hard cutoff could indicate blockages caused by cancer
- Thus, model should highlight these abnormalities and see that they do not follow a consistent pattern with other diseases

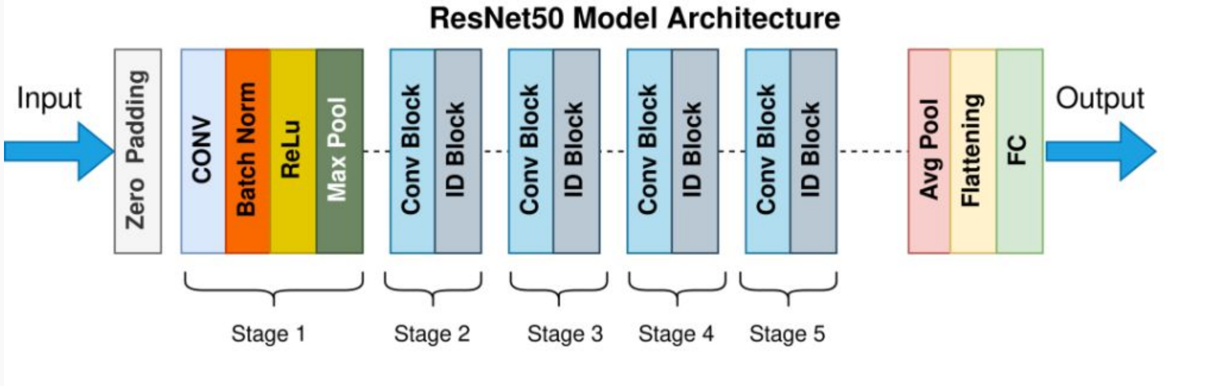


Model Details

What is the structure of our model?

ResNet50 Architecture

- CNN with 50 layers
- Optimizer: Adam (learning rate: 0.0001)
- Loss function: Cross-entropy
- Batch size: 32
- Regularization: Dropout



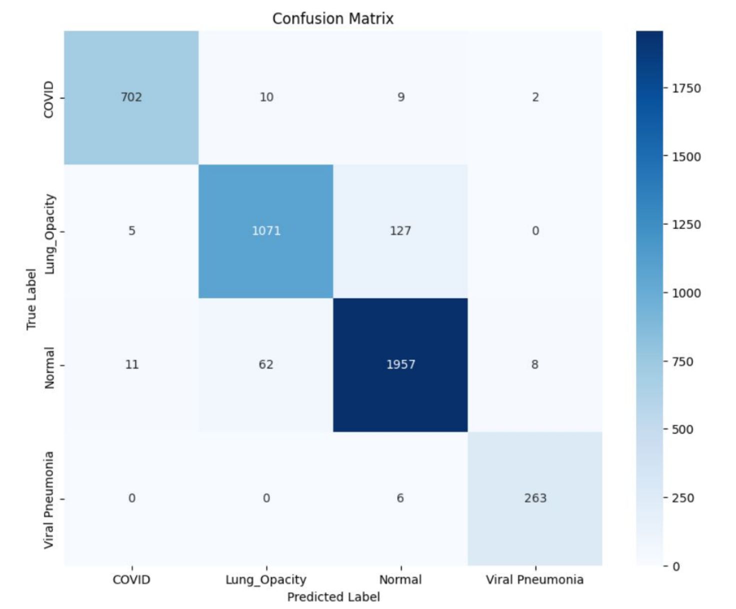
Resnet-50 Model architecture

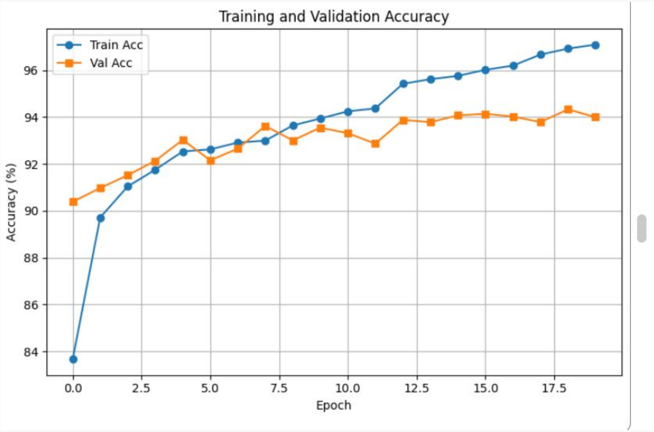
ResNet50 Model Results

How did these models perform?

Model Results

93.62% validation accuracy



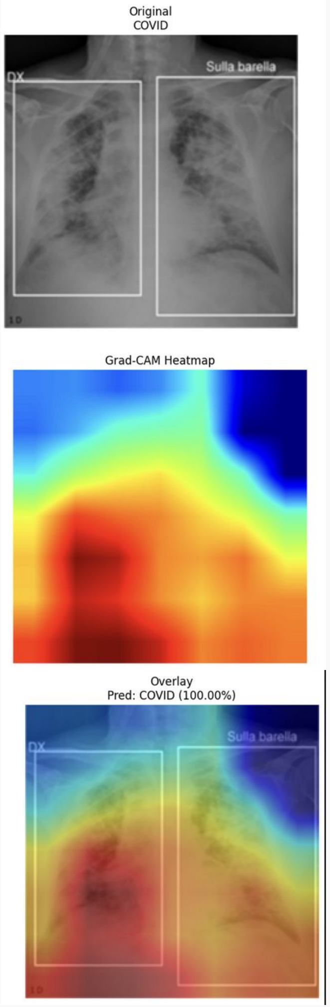


ResNet50 GradCAM Analysis Findings

What parts of the CXRs did the model actually focus on?

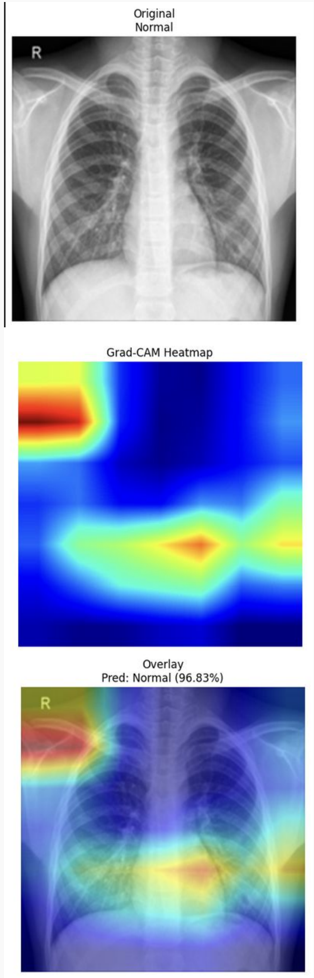
COVID-19 Sample

- Model focuses on lower regions of both lungs
- Model focuses on areas of darkness between white patches
  - Could be the model analyzing the structure of the GGOs
  - Structure of GGOs could indicate whether sample is a COVID sample or not



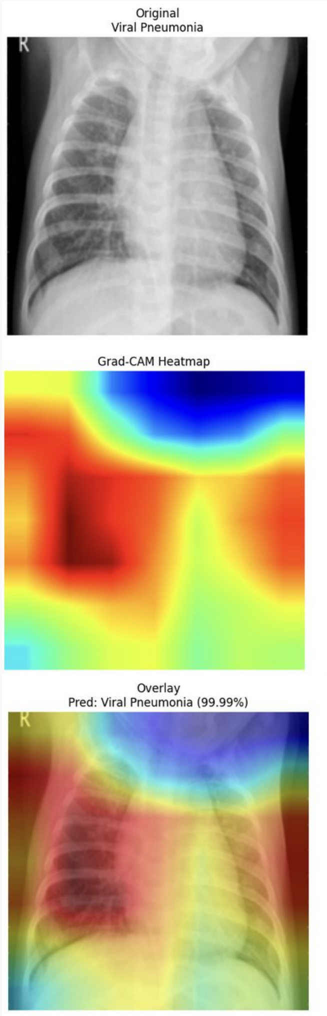
Normal Sample

- Model ignores the areas of darkness indicating no abnormalities
- Instead focuses on areas of whiteness
- In this case, areas of whiteness are the heart and external features
    - This could indicate that no abnormalities were detected by the model



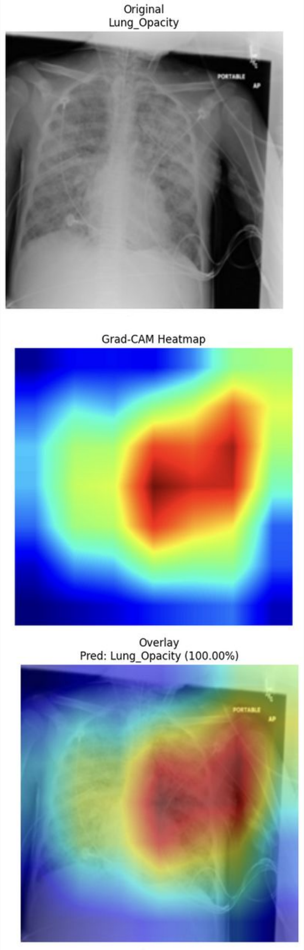
Viral Pneumonia Sample

- Model highlighted hazy net-like webbing in the left lung
- Also highlighted upper parts of both lungs in contrast with COVID-19 sample
- Net-like webbing plus cloudiness in both lungs indicates presence of viral pneumonia



Other Lung Disease Sample

- Model highlighted only one lung instead of both lungs
- More focused on upper part of the right lung
- Stark whiteness in upper right part of lungs is different compared to hazy opacities of COVID or net-like patterns of viral pneumonia

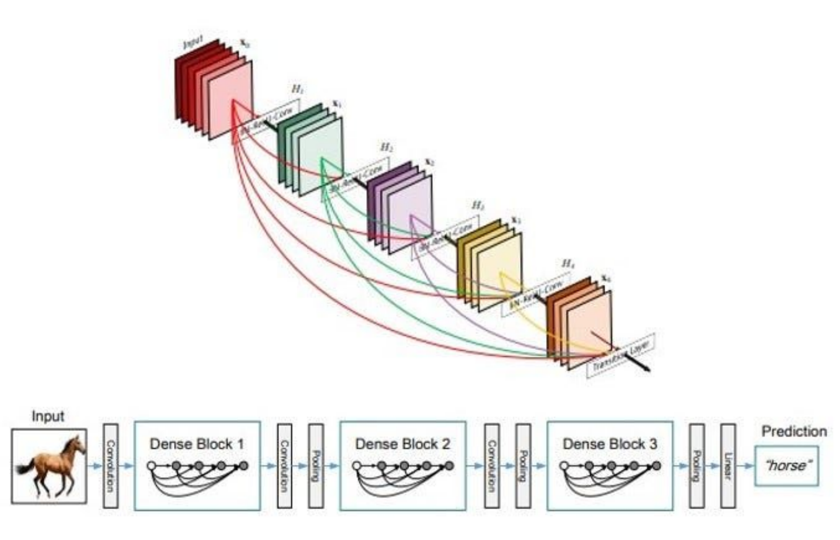


Model Comparison

How did the three models compare?

DenseNet121 Architecture

- CNN with 121 layers, intended for medical imaging application
- Starts with convolution and pooling layers
- Followed by 4 dense blocks, containing 6, 12, 24, and 16 layers respectively
- Optimizer: Adam (learning rate: 0.0001)
- Loss function: Cross-entropy
- Batch size: 32
- Regularization: Dropout



Simple CNN Architecture

- Similar to how the CNN was constructed in Homework 3
- Four convolution layers followed by a flatten and two linear layers.
- Loss function: Cross-entropy
- Batch size: 32
- Regularization: Dropout

```
class SimpleCNN(nn.Module):
    def __init__(self, num_classes):
        super(SimpleCNN, self).__init__()
        self.features = nn.Sequential(
            nn.Conv2d(3, 32, kernel_size=3, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2),
            nn.Conv2d(32, 64, kernel_size=3, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2),
            nn.Conv2d(64, 128, kernel_size=3, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2),
            nn.Conv2d(128, 256, kernel_size=3, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2)
        )
        self.classifier = nn.Sequential(
            nn.Flatten(),
            nn.Linear(256 * 14 * 14, 512),
            nn.ReLU(),
            nn.Dropout(0.5),
            nn.Linear(512, num_classes)
        )

    def forward(self, x):
        x = self.features(x)
        x = self.classifier(x)
        return x
```

Model Results

ResNet50:

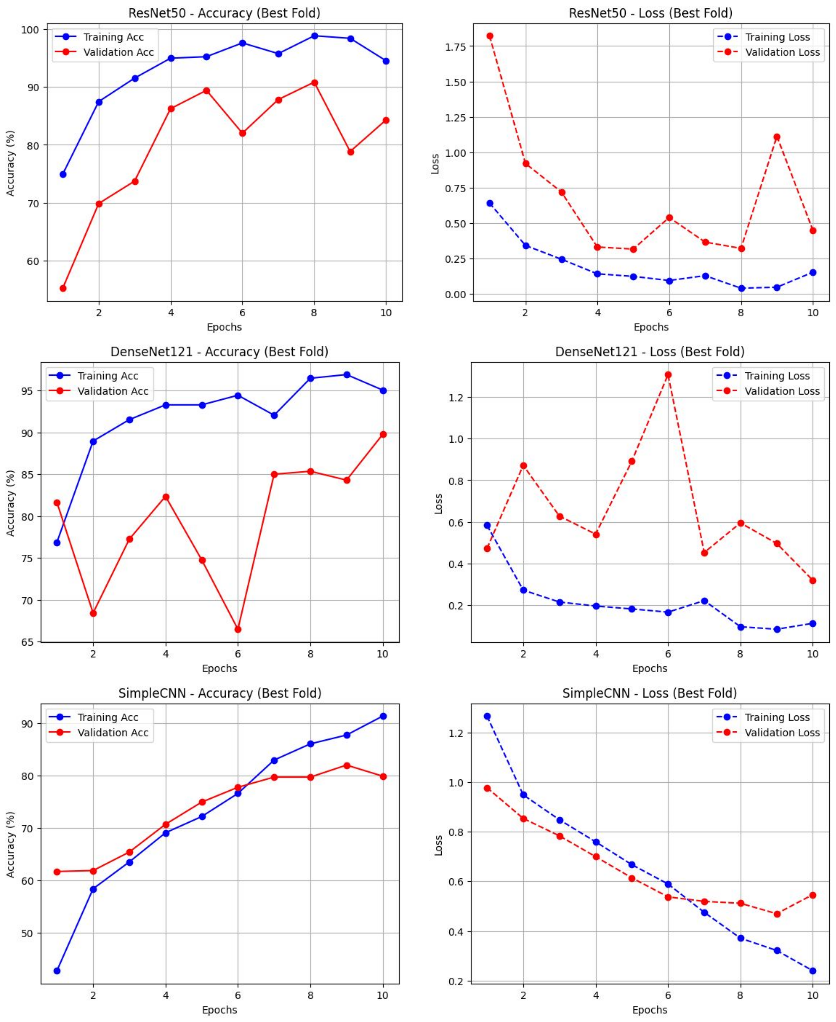
- 88.33% test accuracy

DenseNet121:

- 88.33% test accuracy

SimpleCNN:

- 77.00% test accuracy



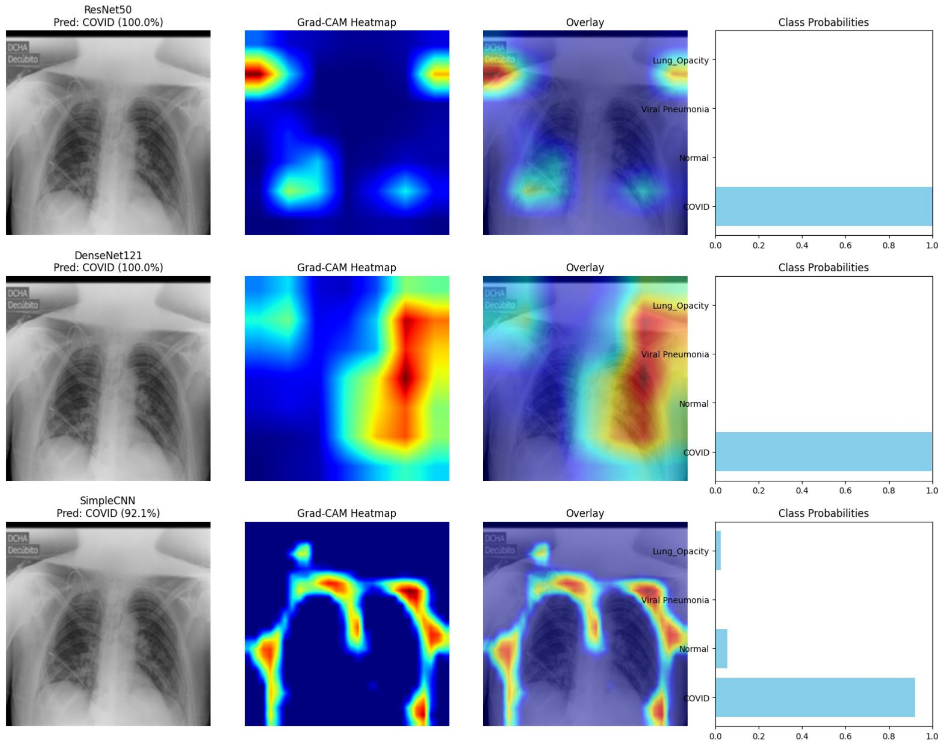
Covid Sample

ResNet50:
- Model focuses on lower regions of both lungs

DenseNet121:
- Focuses solely on right lung edge to make prediction

SimpleCNN:
- Seems to focus on the outer lining of the lung

All models focus on the lower part or edges of lungs



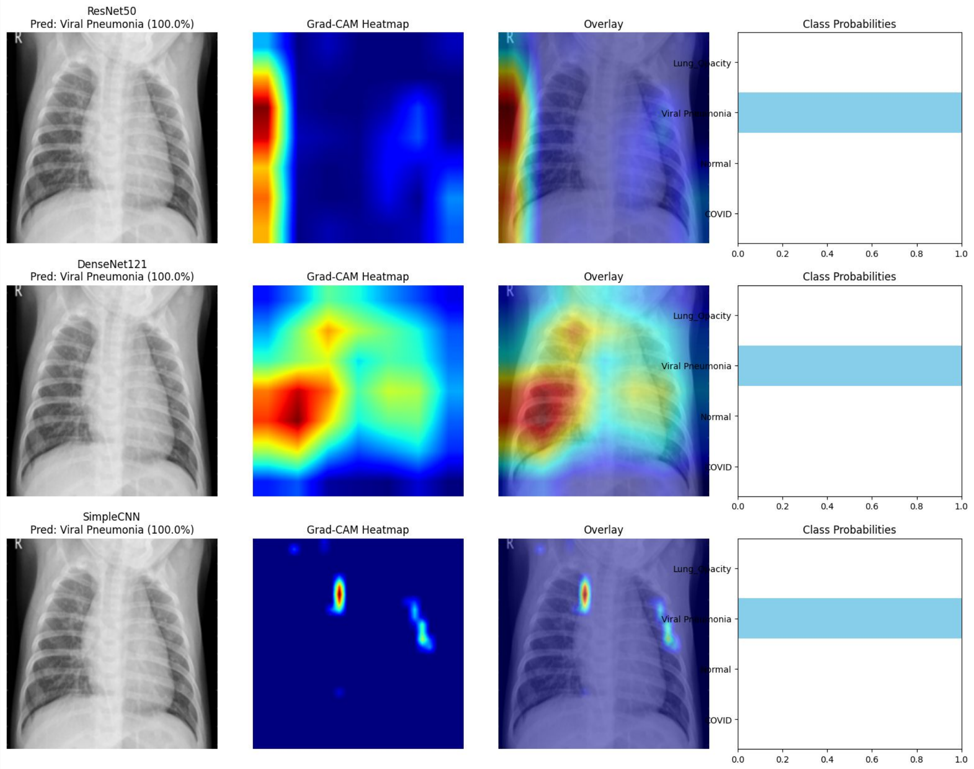
Pneumonia Sample

ResNet50:
- Focus on Left edge of Left Lung

DenseNet121
- Focuses more on entire Lung

SimpleCNN:
- Seems to focus on an arbitrary Point in the upper left lung

DenseNet121 seems to have done a better analysis as it focuses on the entire lung noticing cloudiness

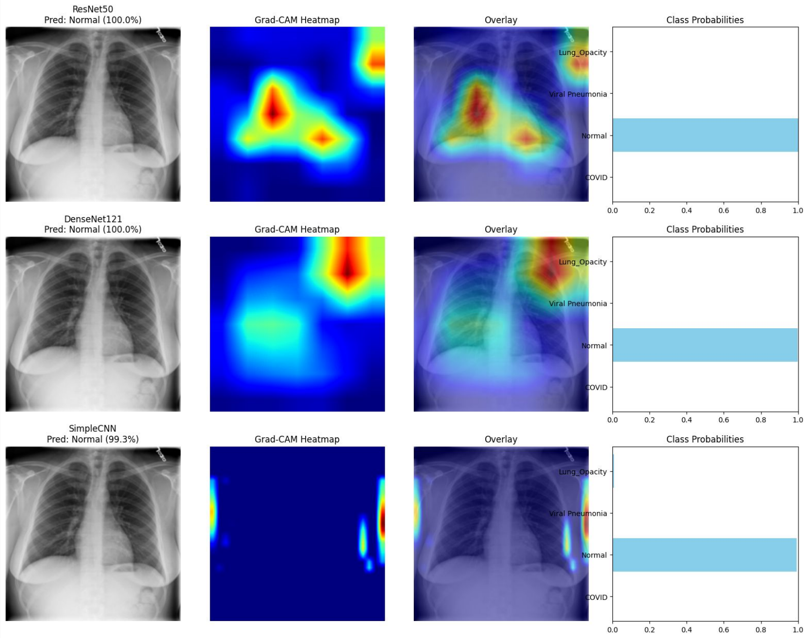


Normal

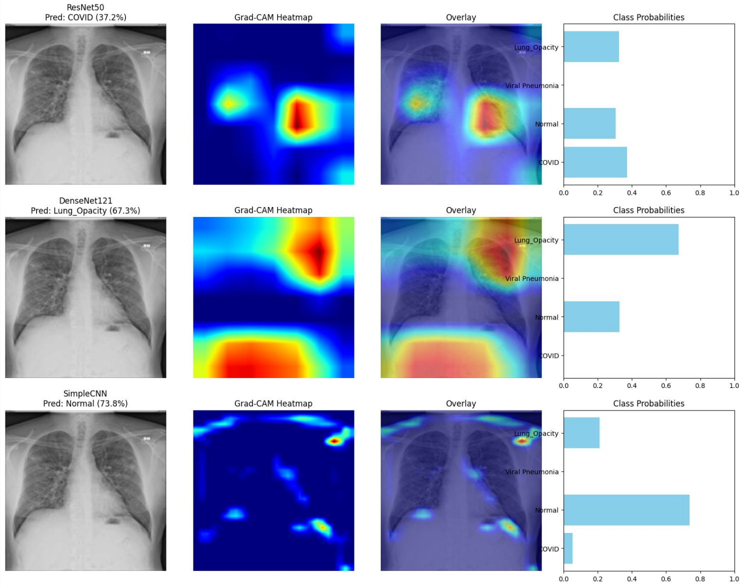
ResNet50:
- Focuses on the middle area in Each lung

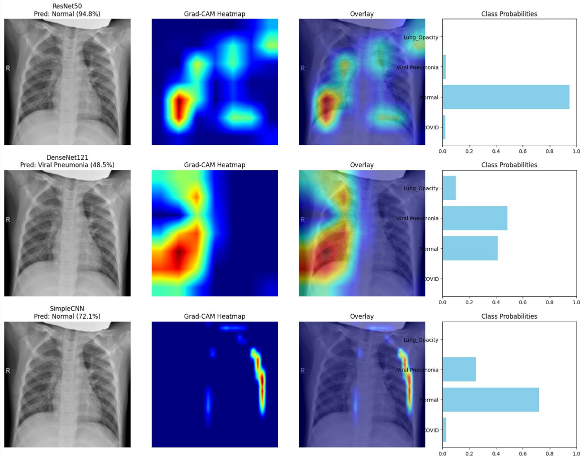
DenseNet121:
- Focuses in the middle and the top right of the lung

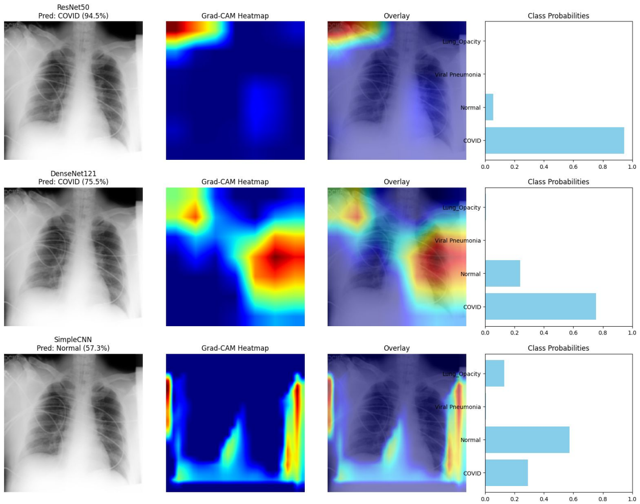
SimpleCNN:
- Focuses on the edges of the image



Some Odd Samples



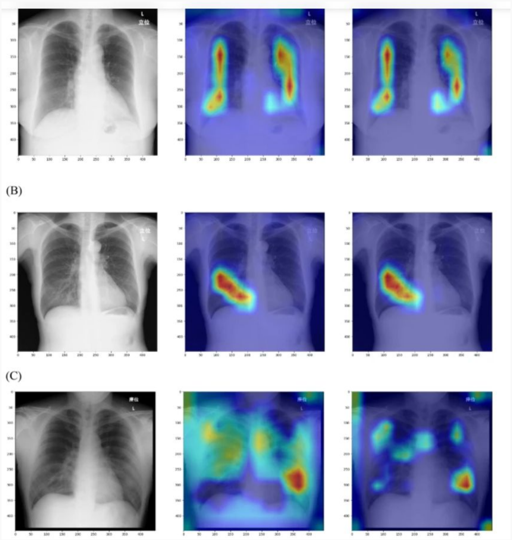




Conclusion

Conclusion

- Models are able to pick up general areas of interest but not specific patterns
- Doctors cannot fully trust the model yet and must verify manually
- However, model could guide doctors towards a diagnosis which still saves time compared to iterating through all possible lung diseases
- Model analysis can be improved through other methods and more training data



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Credit

- Arjun
  - Researched identifying features of different types of lung disease
  - Analyzed labelled CXR scans to understand what the different features would look like in samples
  - Developed slides and analysis of ResNet50 model in context of lung diseases
- Wadie
  - ResNet50 Model implementation and result analysis
  - GradCAM analysis
- Henry
  - Model Comparison implementation, analysis, slides
  - GradCAM analysis

Thank you

We hope you learned something about ML models in medicine analyzed using GradCAM methods!