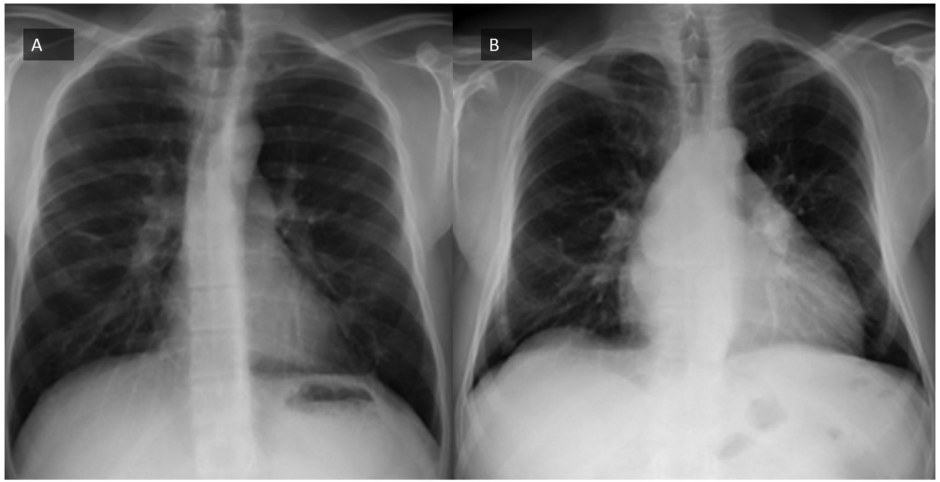
Detecting Cardiomegaly from Chest X-Rays



Brendan Nugent

Image from Bougais et al., 2020

Cardiomegaly

- Enlargement of the heart
- Commonly caused by coronary artery disease
- Morality:
  - After 1 year: 30%
  - After 5 years: 50%

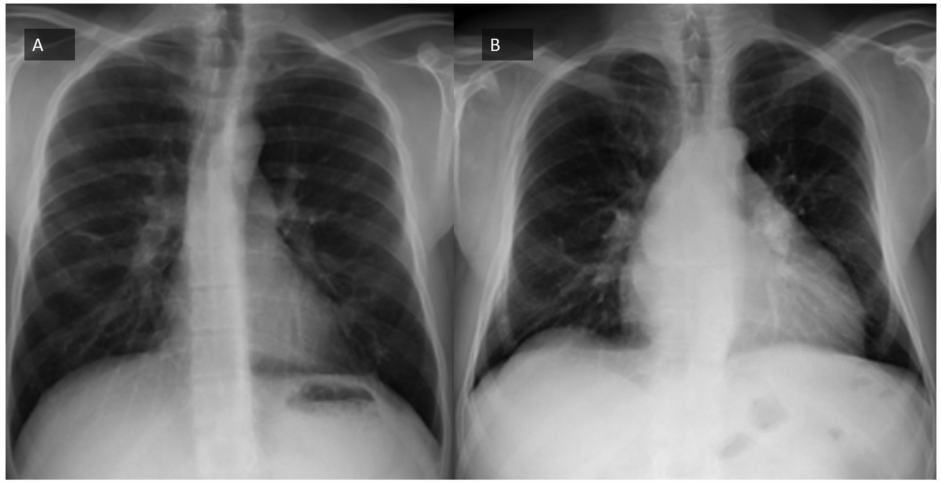


Image from Bougais et al., 2020

Diagnosing Cardiomegaly

- Diagnosis by medical imaging to determine size of heart
  - Cardiothoracic ratio > 50%
- One type of imaging is chest X-rays

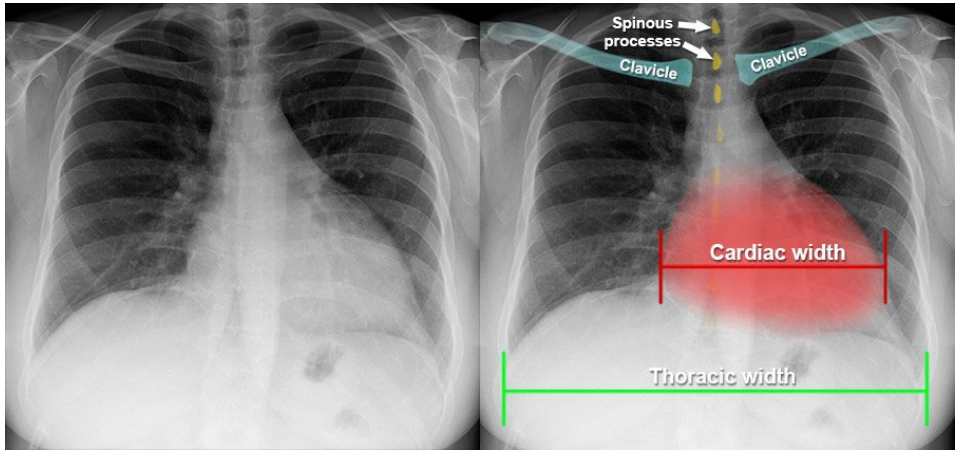


Image from Radiology Masterclass

The Goal

Create a model that detects the presence of cardiomegaly from a chest X-ray with an accuracy of 75% and a recall of 70%.

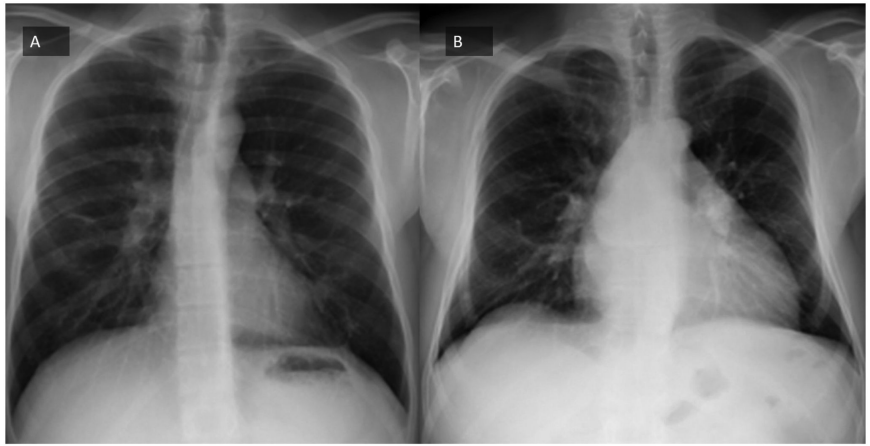
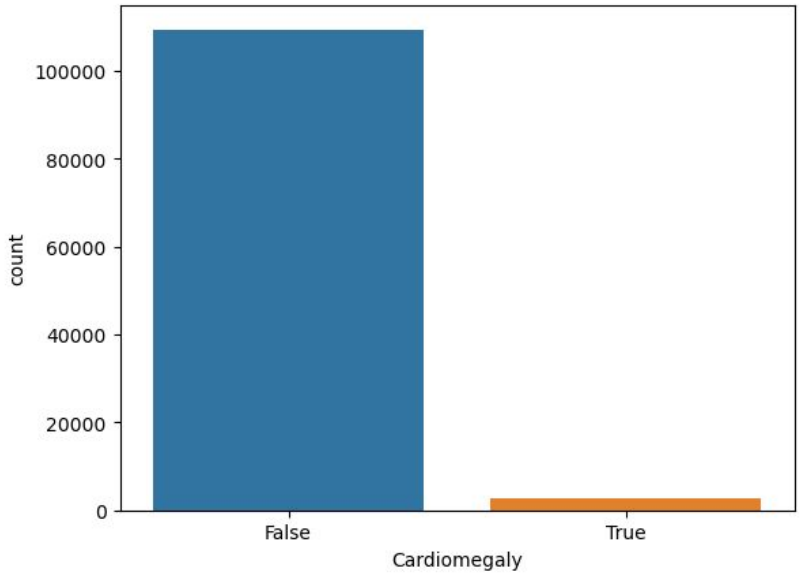


Image from Bougais et al., 2020

The Data

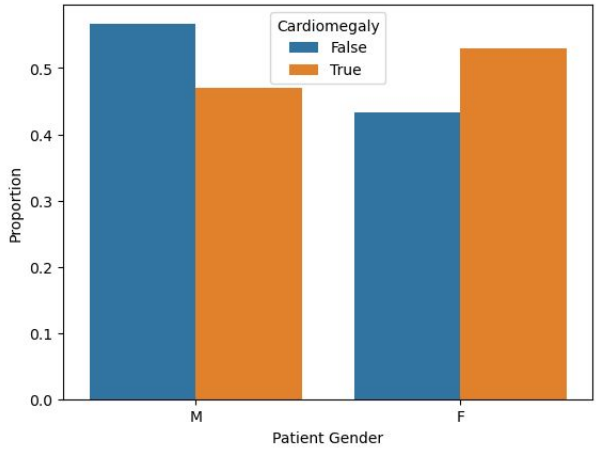
- 112,120 images of chest X-rays
- Published by the National Institutes of Health
- Labeled through natural language processing by Wang et al.
  - Estimated 90% accuracy
  - Labels include: atelectasis, consolidation, infiltration, pneumothorax, edema, emphysema, fibrosis, effusion, pneumonia, pleural thickening, nodule mass, hernia, and cardiomegaly

Label

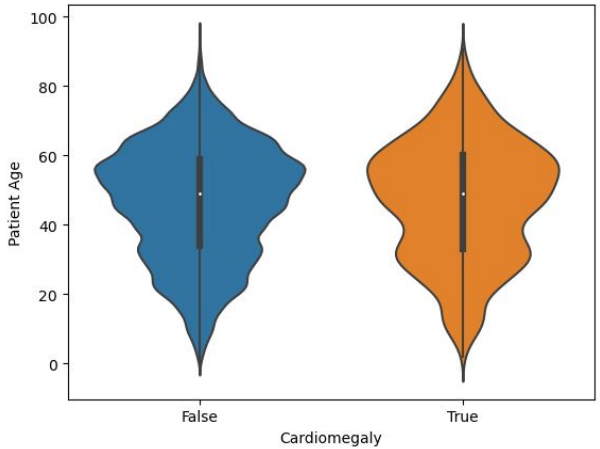


2776 (2.5%) of the 112,120 images showed cardiomegaly

Patient Gender and Age

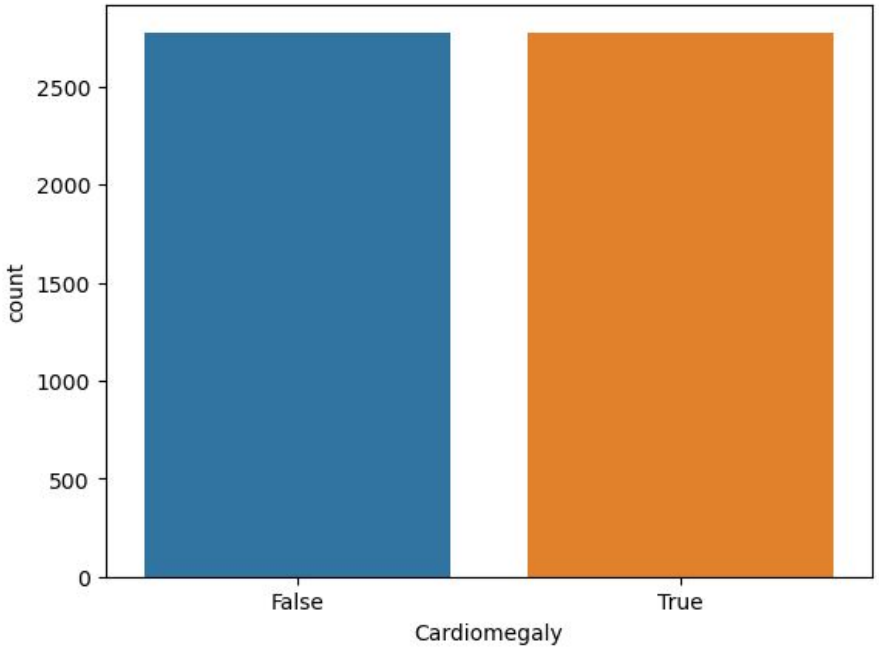


Cardiomegaly was more common among female patients.



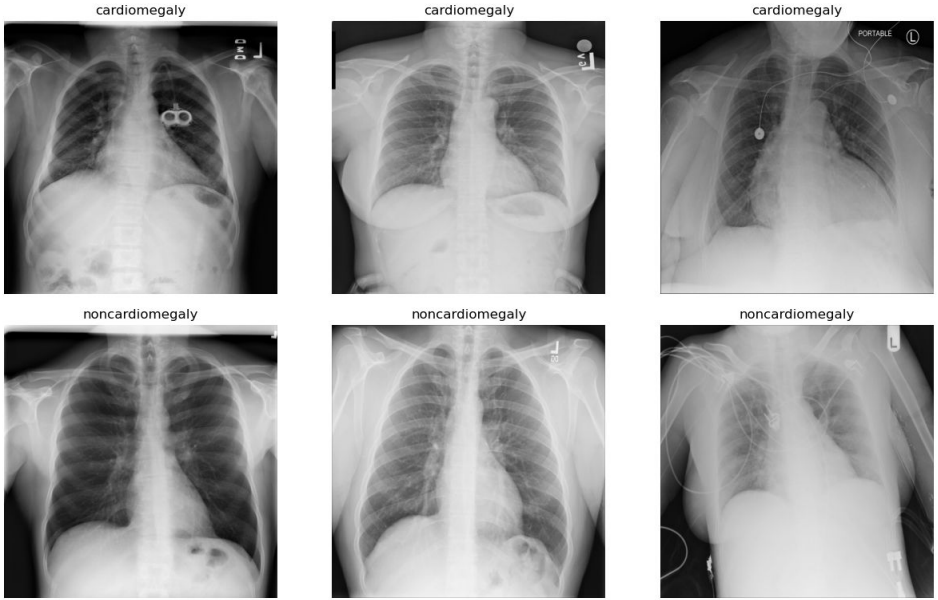
The age distributions were practically identical.

Undersampling



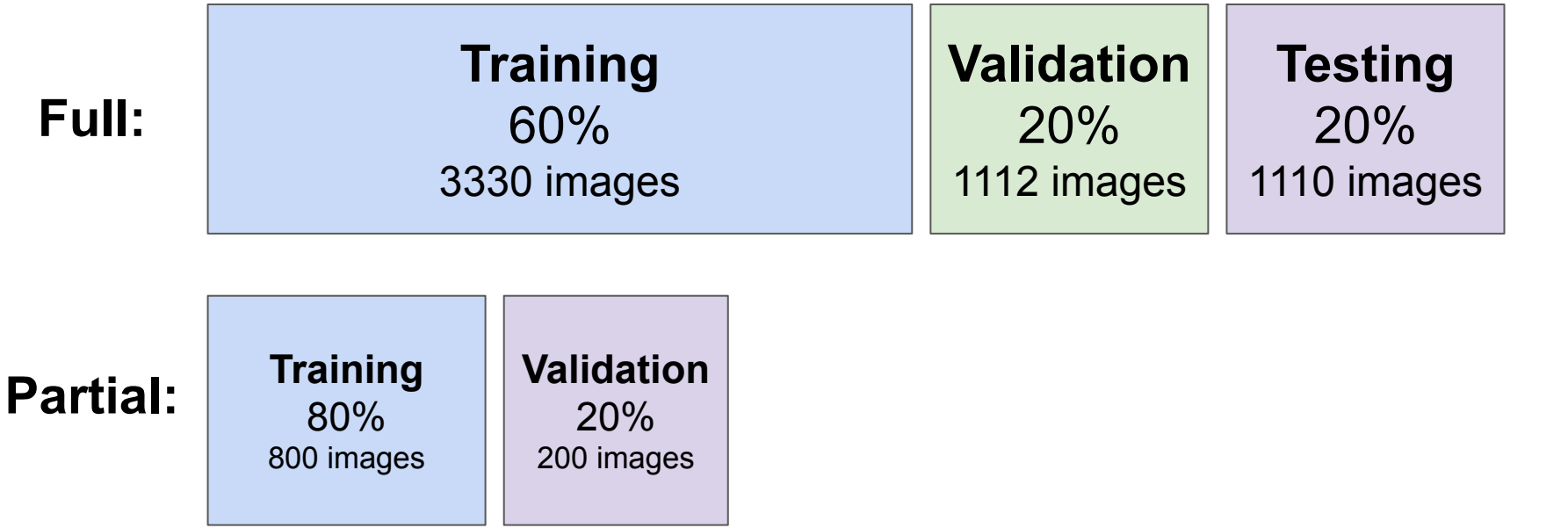
- 2776 images with cardiomegaly
- 2776 images without cardiomegaly

The Images



1024 x 1024 grayscale pictures

Preparing Splits



Preprocessing

ResNet50's preprocess_input function

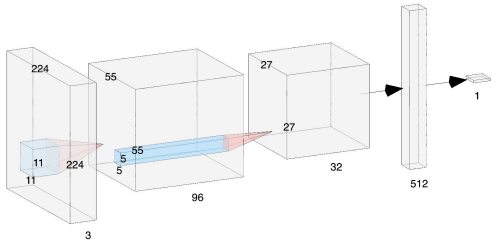
- Zero-centers each color channel with respect to ImageNet dataset
- Does not scale Values

Data augmentation

- Rotated images
- Shifted height and width

Convolutional Neural Nets

Simple CNN



AlexNet

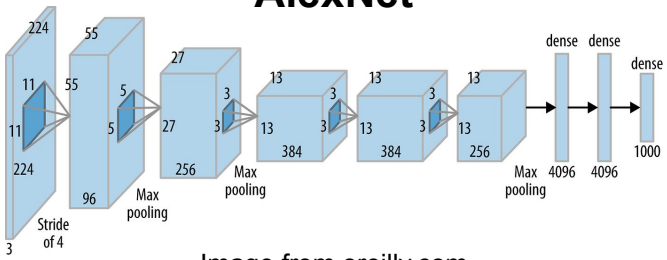


Image from oreilly.com

ResNet50

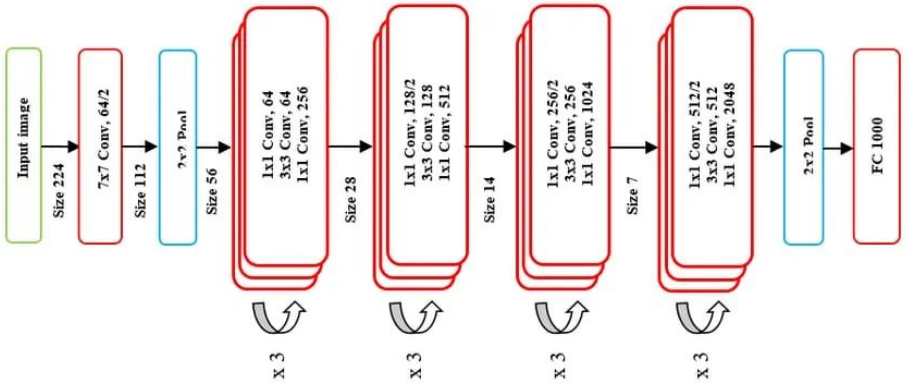
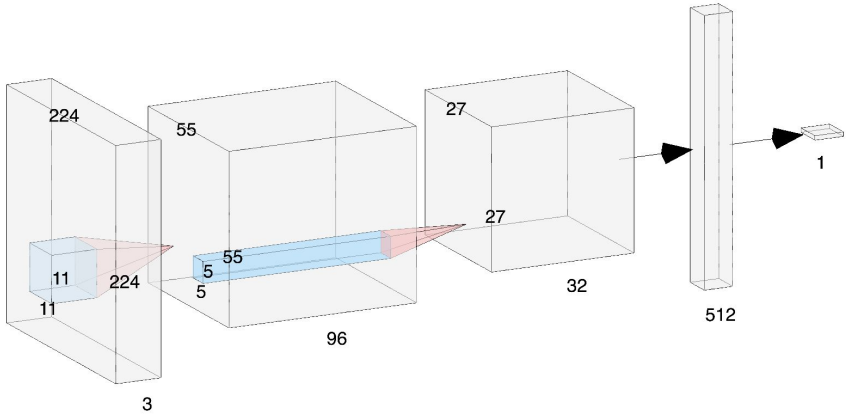


Image from [Bendjillali et al.]

Simple CNN Architecture

- Convolutional layer with 96 filters of size 11x11 with a stride of 3, activated by relu
- Max pooling layer
- Convolutional layer with 32 filters of size 5x5, activated by relu
- Max pooling layer
- Dense layer with 512 neurons activated by relu
- Output layer with 1 neuron activated by sigmoid function



AlexNet Architecture

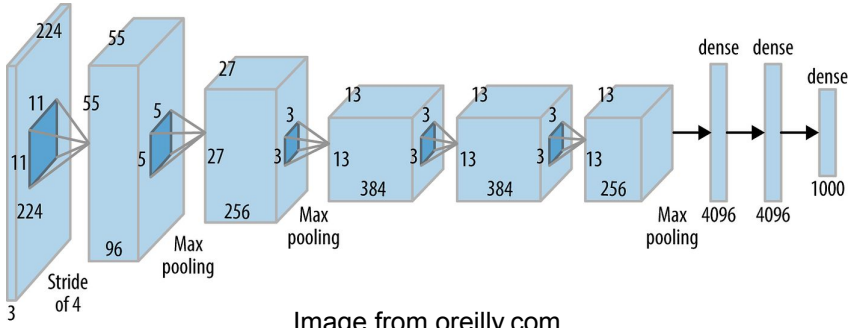


Image from oreilly.com

- 5 Convolutional blocks that include batch normalization and max pooling
- 3 fully connected layers

ResNet50 Architecture

- Minimizes degradation through residual blocks containing Skip Connections
  - Provides a shortcut for gradients to pass through to prevent vanishing gradients
- Convolutional bock
- 4 residual blocks
- 1 fully connected layer

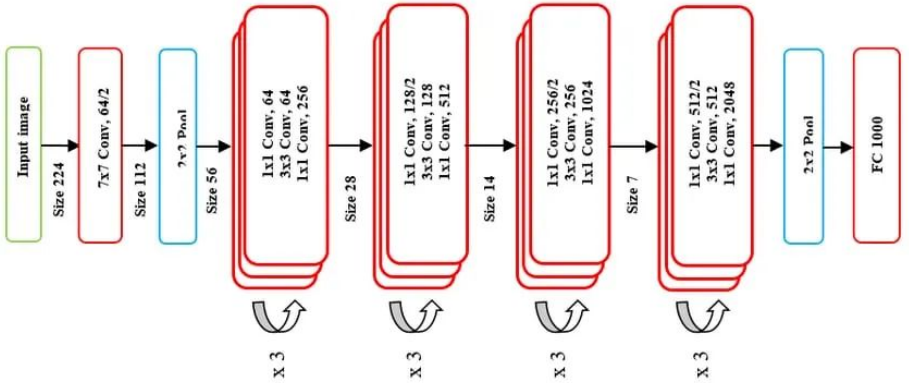


Image from Bendjillali et al.

Adapted ResNet50 Architecture

- Convolutional bock
- 4 residual blocks
- **2 fully connected layers**
  - Dropout = 0.4

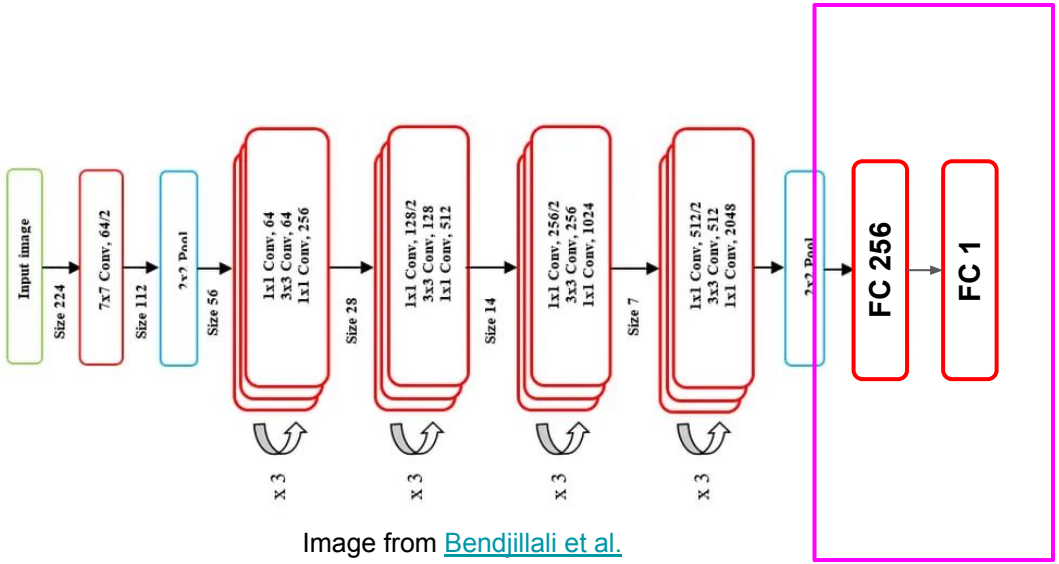


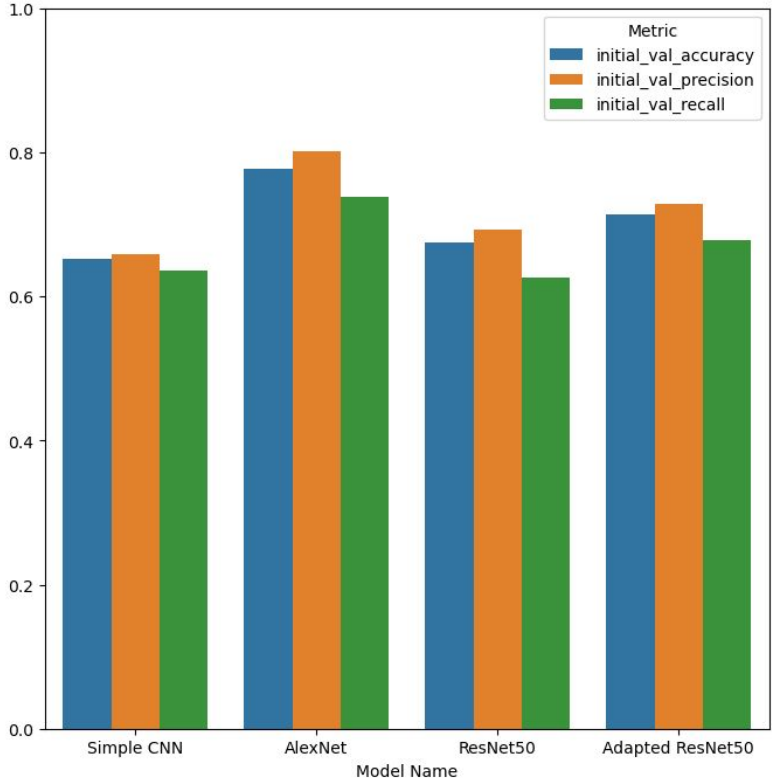
Image from [Bendjillali et al.]

Initial Modeling

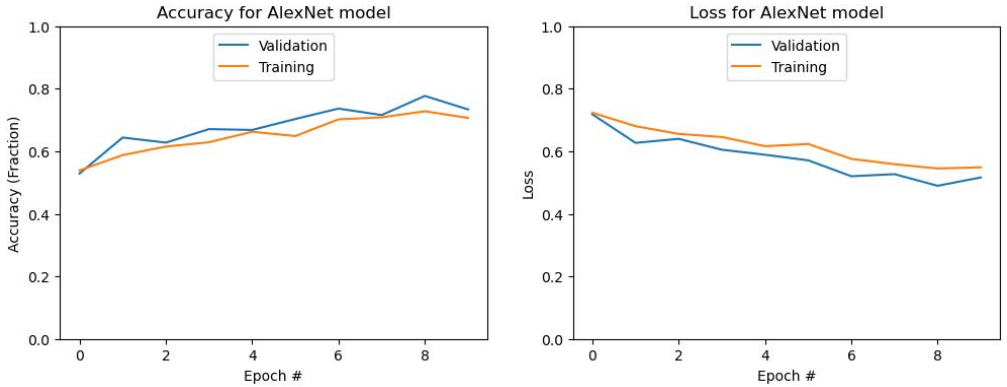
Epochs = 10, learning rate = 1e-4

AlexNet:

- Accuracy: 0.7770
- Recall: 0.7374



Initial Modeling



AlexNet may benefit from more epochs in training.

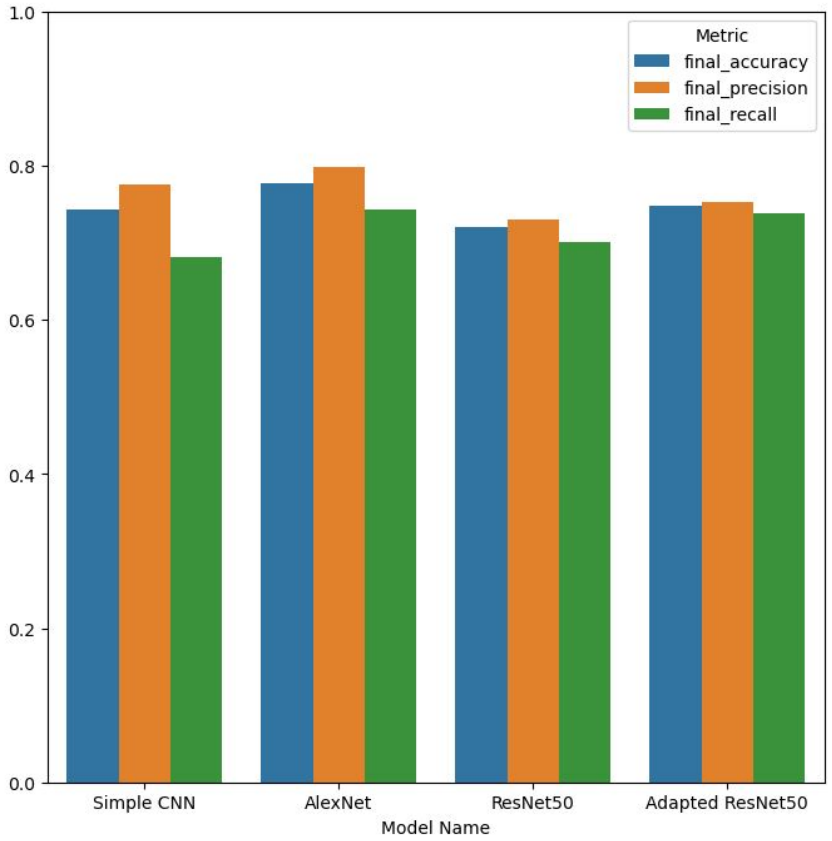
Tuning Learning Rate and Batch Size

Model	Optimal Learning Rate	Optimal Batch Size
Simple CNN	1e-4	45
AlexNet	1e-5	15
ResNet50	1e-5	15
Adapted ResNet50	1e-4	45

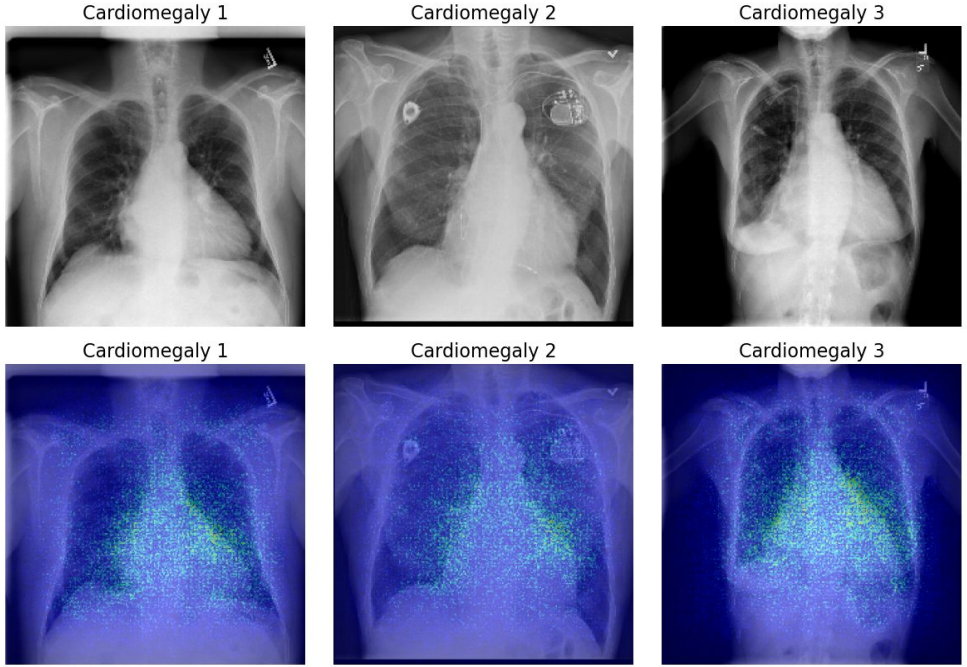
Final Evaluation

All models improved, but AlexNet remains the highest performing.

	Accuracy	Recall
Validation	0.8013	0.7734
Testing	0.7775	0.7423



Saliency Maps



Plotted saliency maps for 3 images using tf-keras-vis.

The model recognizes the borders between the heart and the lungs.

Conclusions

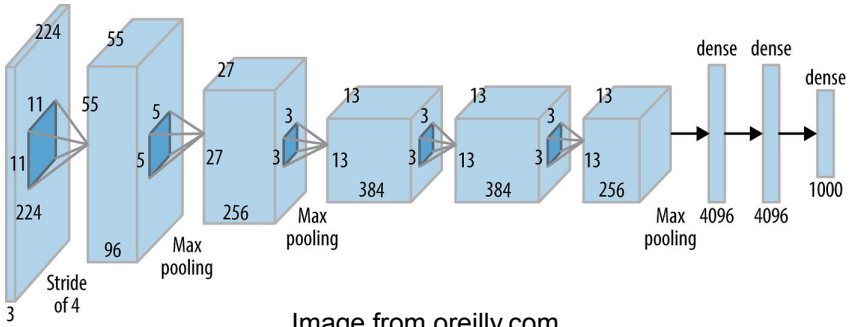


Image from oreilly.com

AlexNet Model

- Learning rate = 1e-5
- Batch size = 15

Accuracy	Precision	Recall
77.75%	79.85%	74.23%

Future Directions

Improvements

- Increase size training set and implement augmentation
- Adjust image size
  - 320 x 320, 512 x 512, 1024 x 1024
- Add additional fully connected layer to AlexNet

Future Projects

- Apply AlexNet to other conditions diagnosed through medical imaging
  - Pneumonia, TB
- Determine bounding boxes around heart and thorax to calculate the cardiothoracic ratio

Thank you!

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Project report: https://github.com/bjnugent/cardiomegaly/tree/main/reports/final_report.pdf