Using Neural Networks to Diagnose COVID-19 from CT Scans

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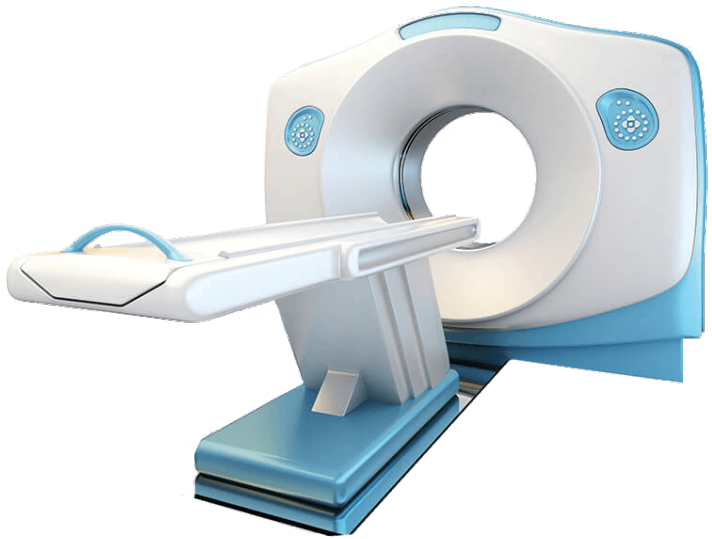
Background

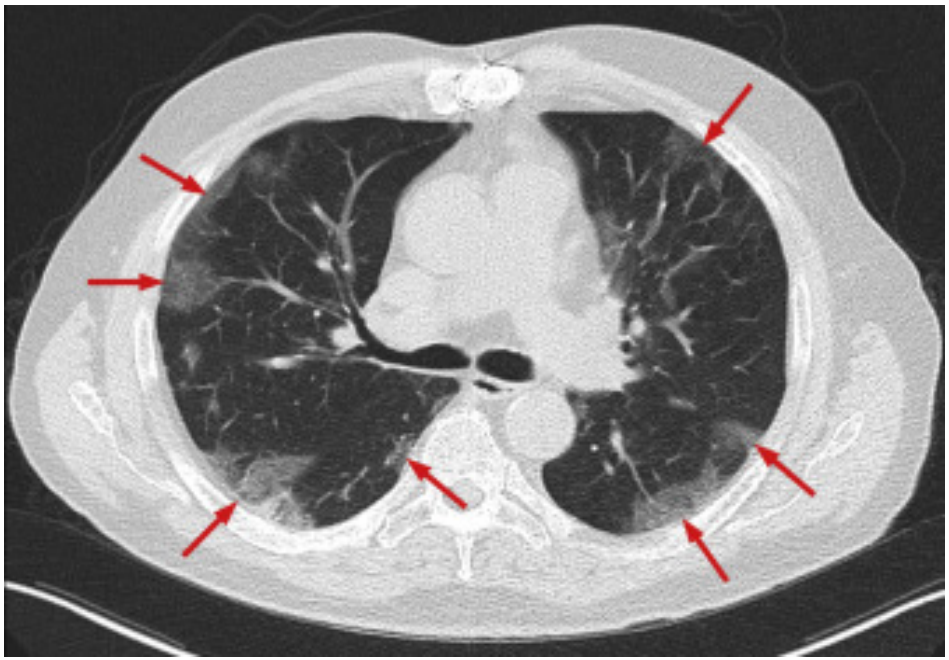
- Computer vision has many potential applications like diagnosing patients from medical imaging
- Which neural network might better diagnose COVID-19 from CT scans: A convolutional neural network (CNN) or a residual network (ResNet)?
- How large do CT scans need to be for a network to perform well?



A CT scanner [1]

About COVID-19 CT Scans

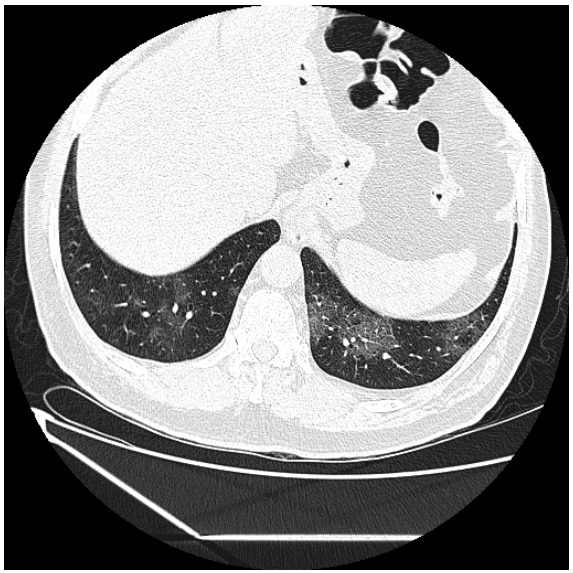
- The most common difference is ground-glass opacity [2]
- This is the grey between what's seen in a normal lung scan and a heavily diseased lung scan [3]
- A heavily diseased lung scan is white from a lung filled with pus or fluid [3]



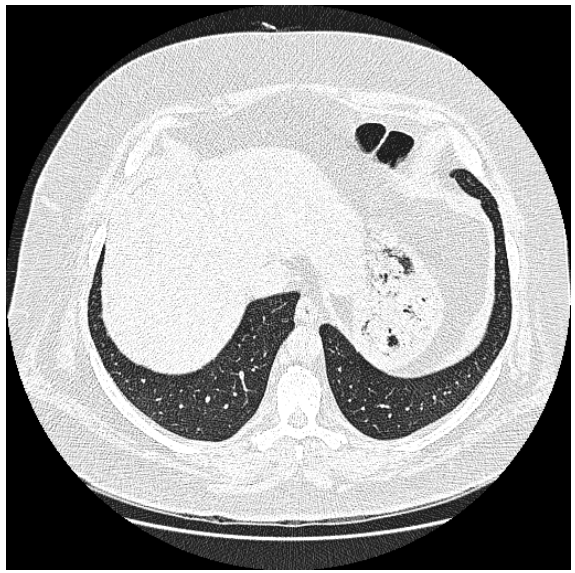
Ground-glass opacities found in a scan of someone with COVID-19 [2]

About the Data Set [4]

- One folder contains 7,495 CT scans of patients with COVID-19
- The other folder contains 944 CT scans of patients without COVID-19
- The folders are the only labels
- Each scan is 512 x 512 pixels with 3 slices



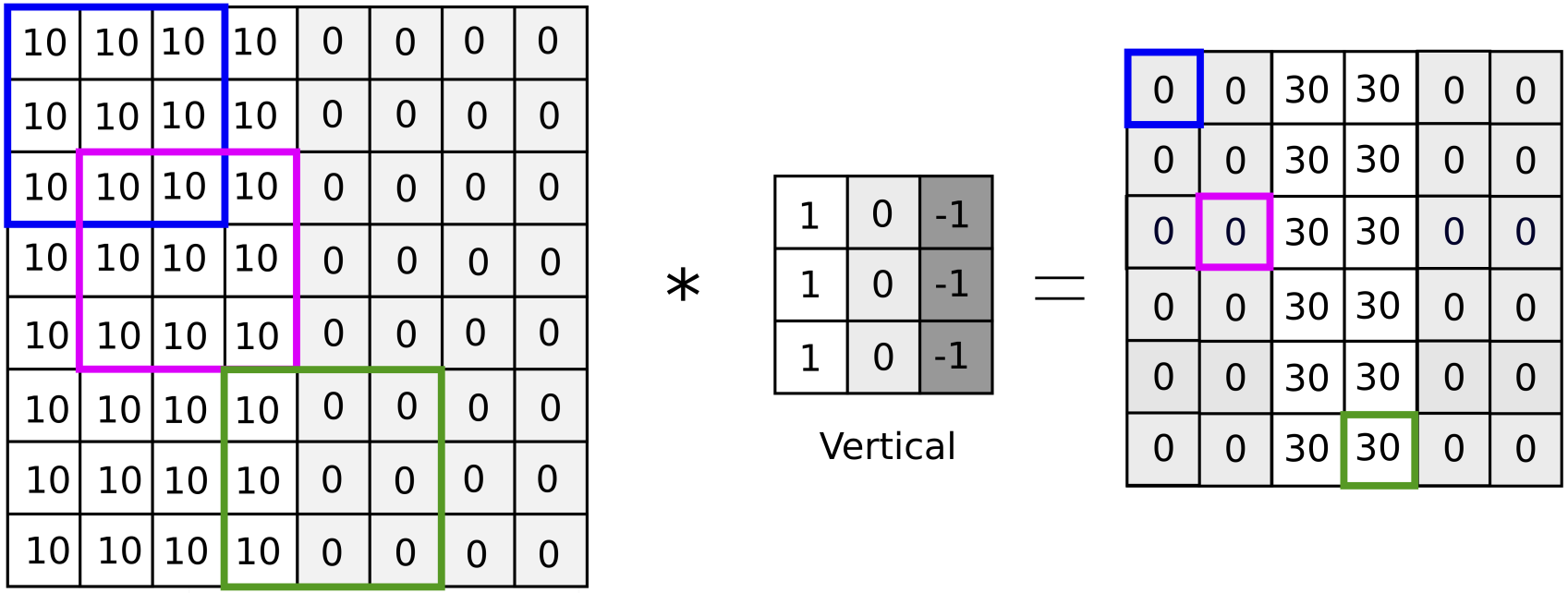
Positive



Negative

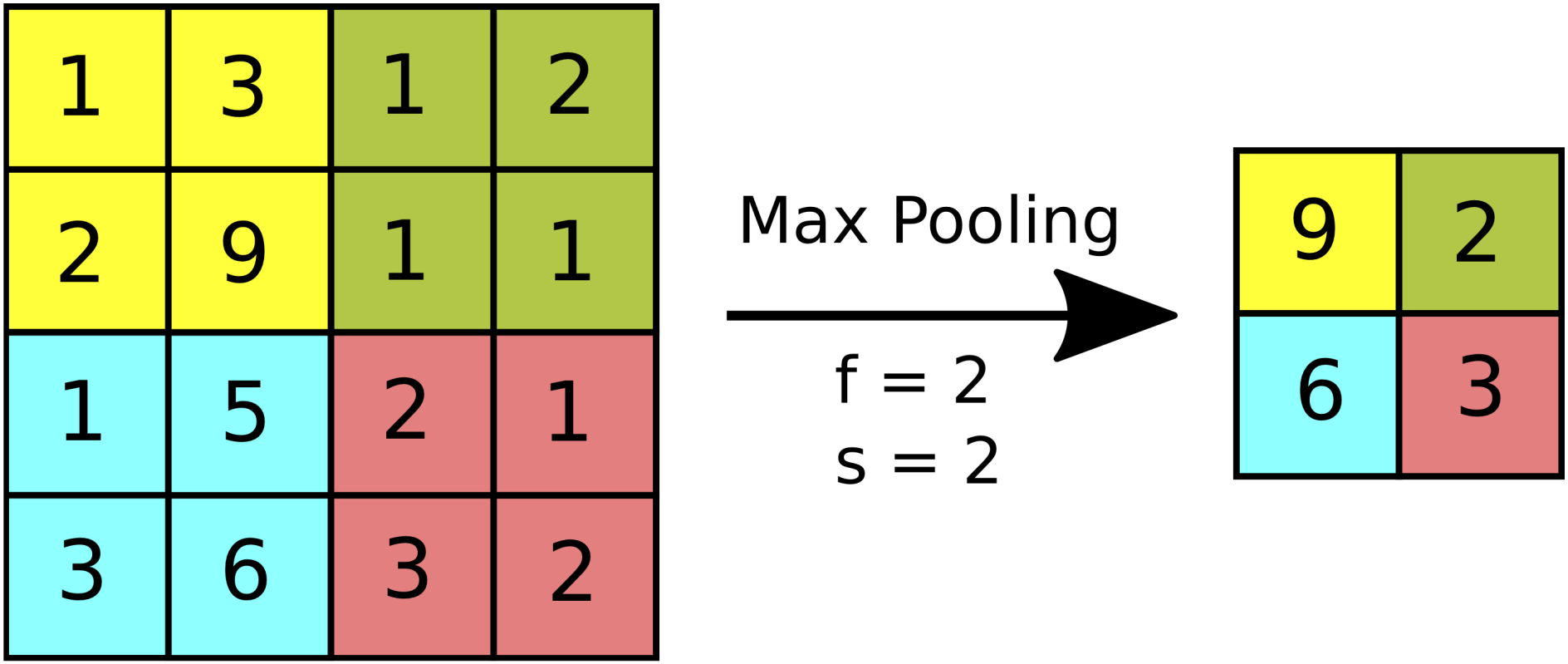
Positive and negative CT scans from the data set [4]

CNNs: The Convolutional Filter



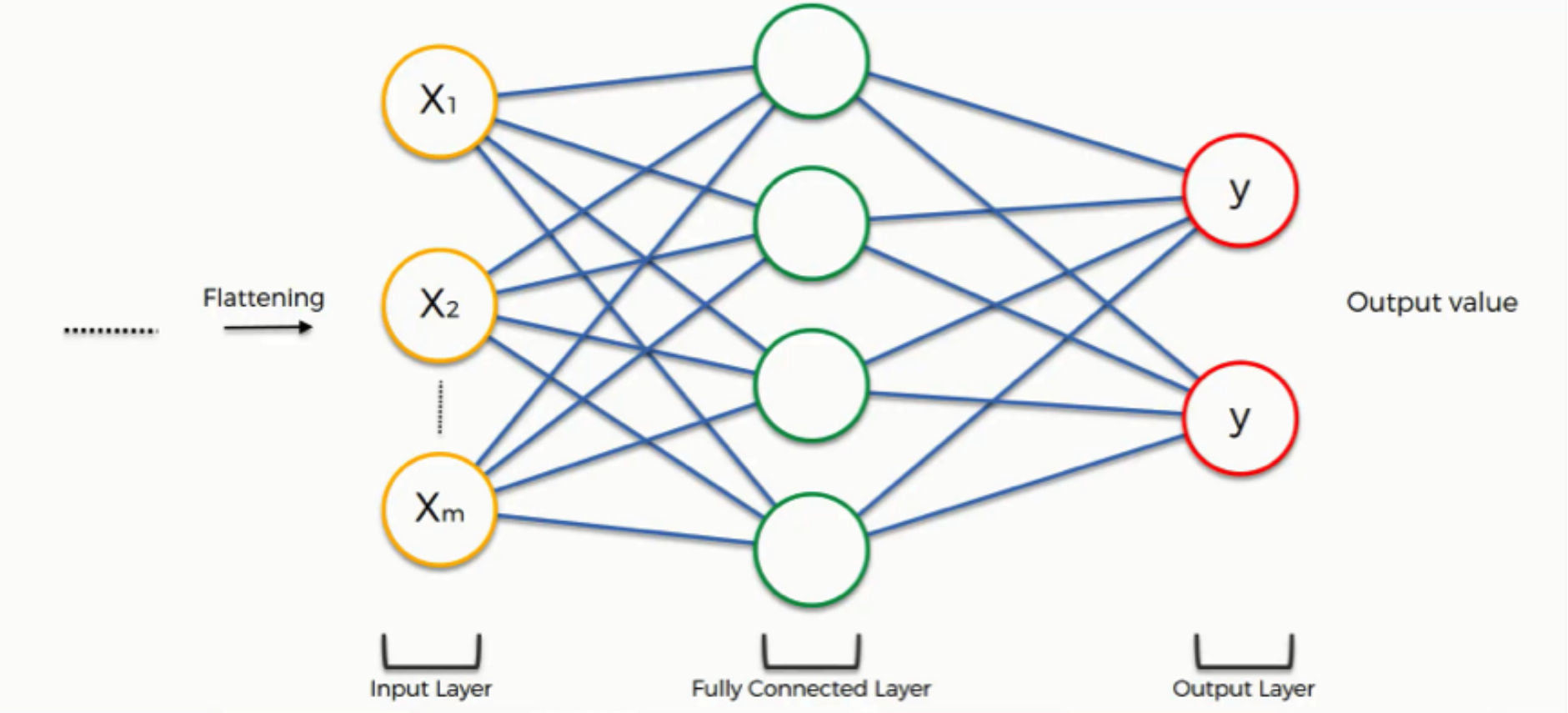
The input on the left is run through a convolutional filter in the middle for detecting vertical edges, giving the output on the right [5]

CNNs: The Max Pooling Filter



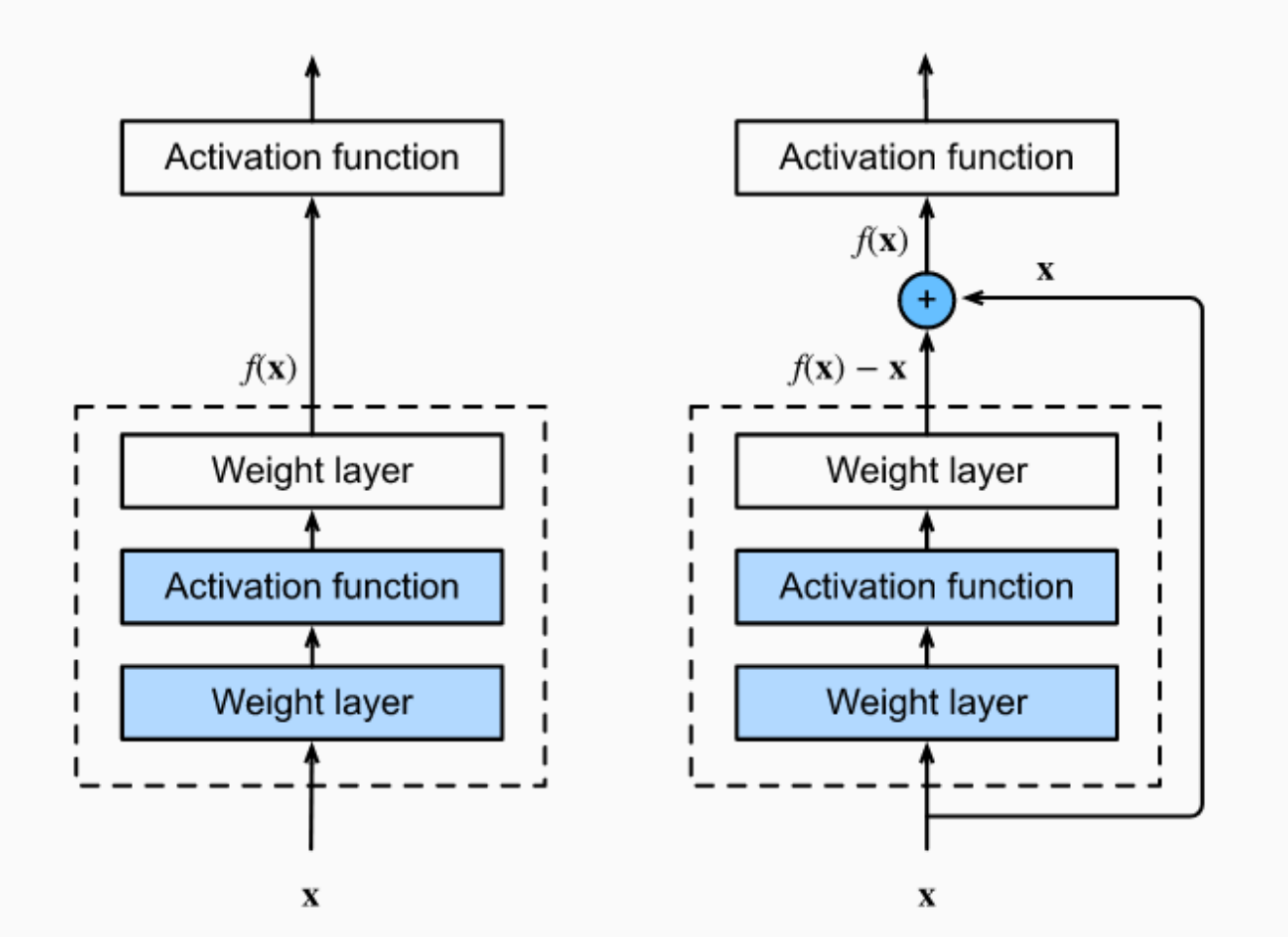
The input on the left is run through a max pooling filter, giving the output on the right. The filter has length 2 with a stride of 2. [5]

CNNs: The Fully Connected Layer



A fully connected layer in a CNN [6]

ResNet Structure



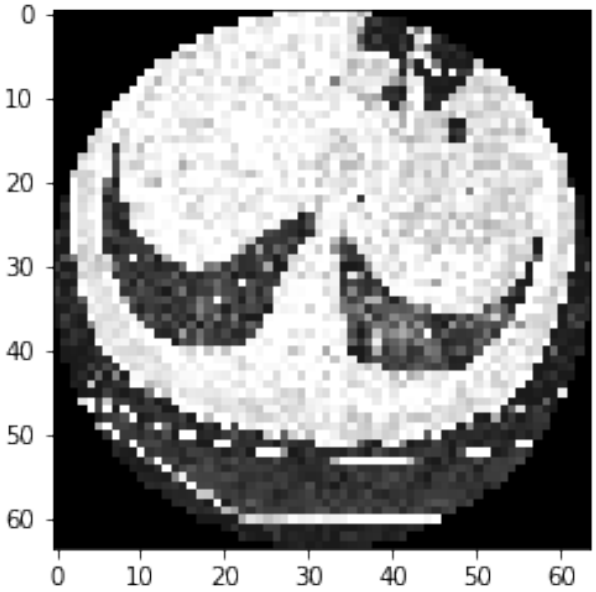
A block from a standard neural network on the left and a block from a ResNet on the right [7]

Coding Process

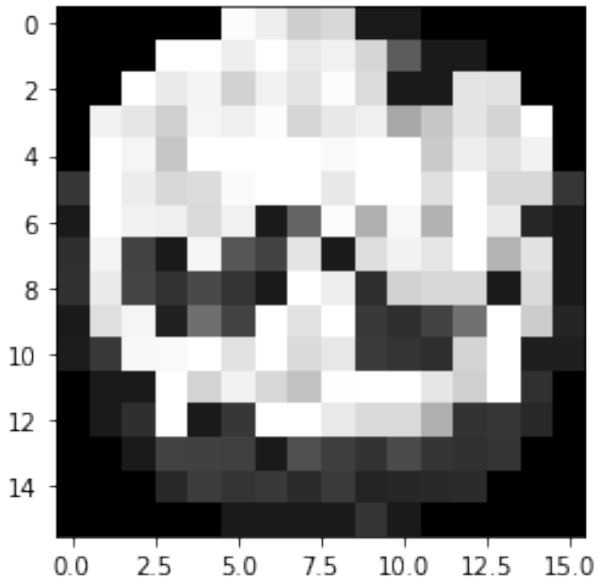
- All coding was done in Python using Jupyter Notebook, with neural networks using the tensorflow and keras libraries
- The CT scans were imported as 64 x 64 images with 3 slices and converted into arrays
- Labels were created and the data was shuffled into train and test sets
- A CNN with roughly 15 layers was implemented
- The CNN used convolutional, max pooling, average pooling, and fully connected layers
- The ResNet had the same structure as the CNN + a skip connection

Finding Limits to the Neural Networks

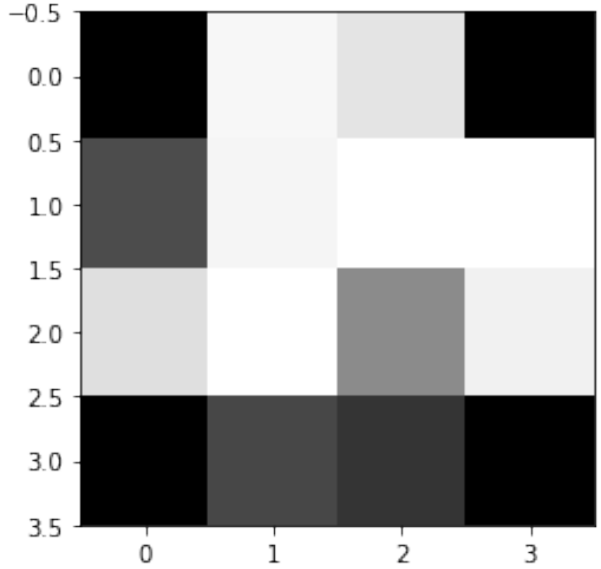
- After obtaining initial results, the next direction was to try the networks on different image sizes



64 x 64



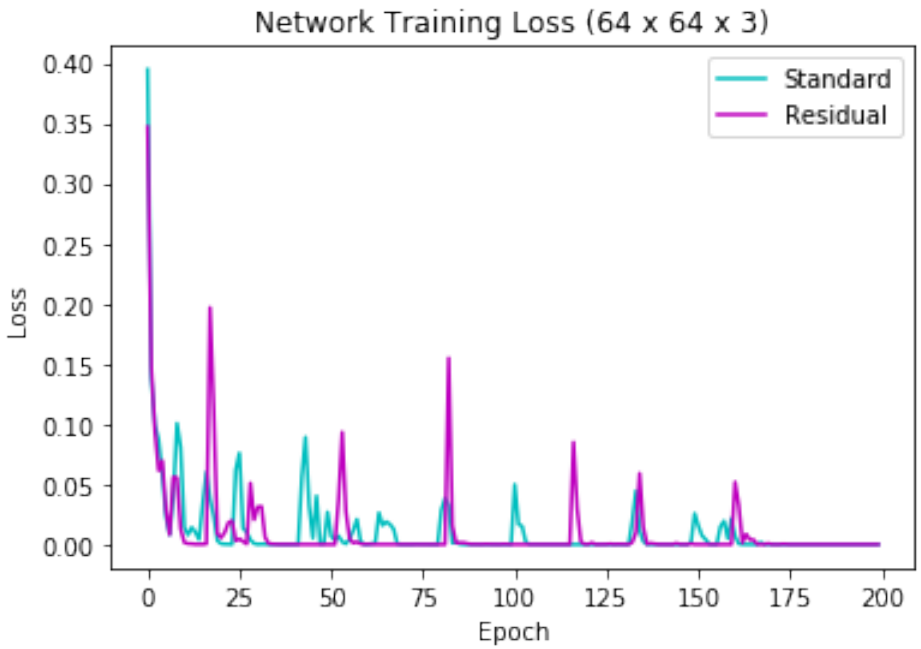
16 x 16



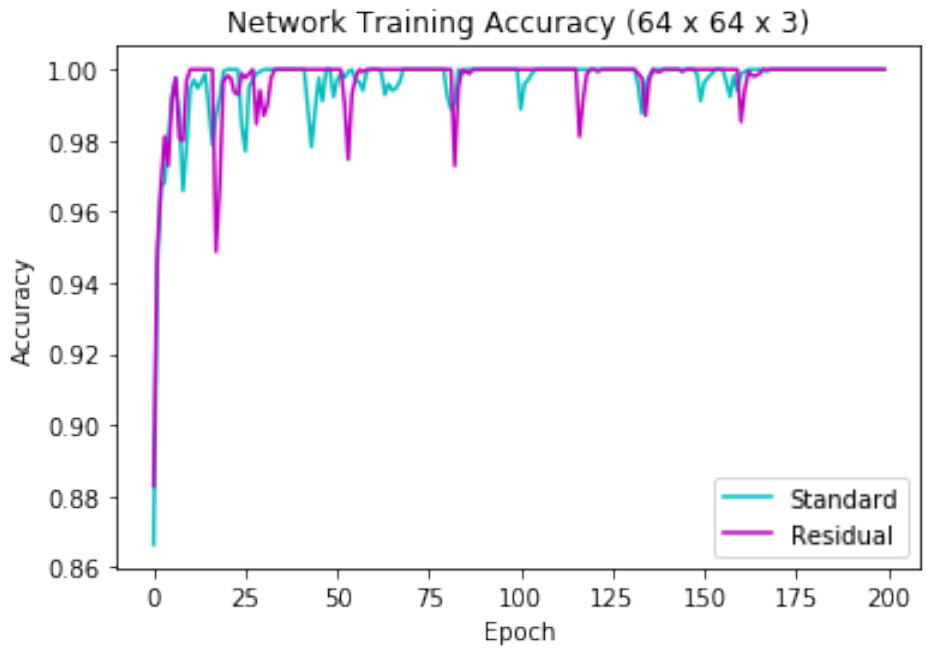
4 x 4

Training Results (64 x 64)

CNN and ResNet appeared to perform similarly during training



Training Loss

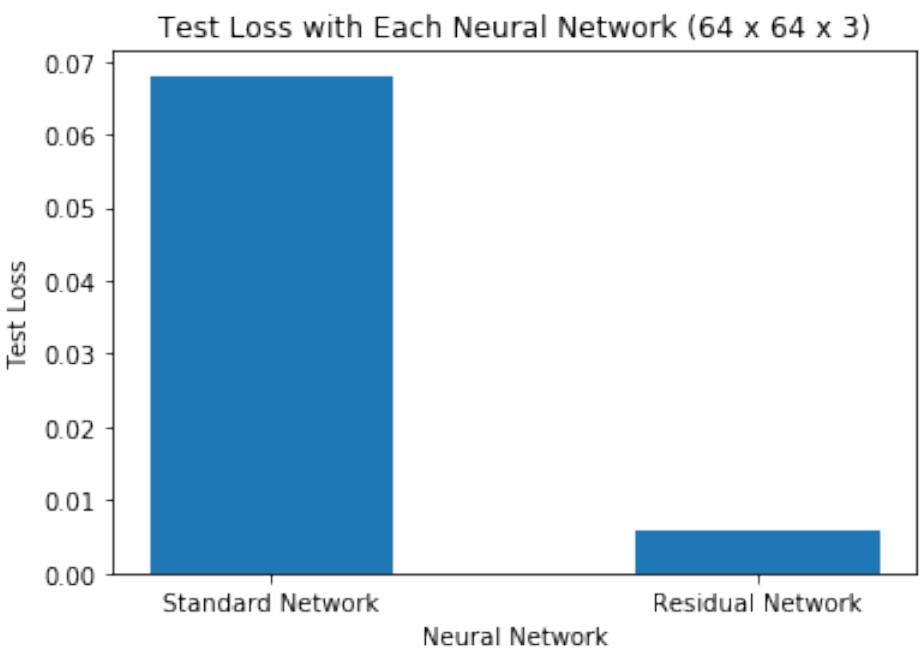


Training Accuracy

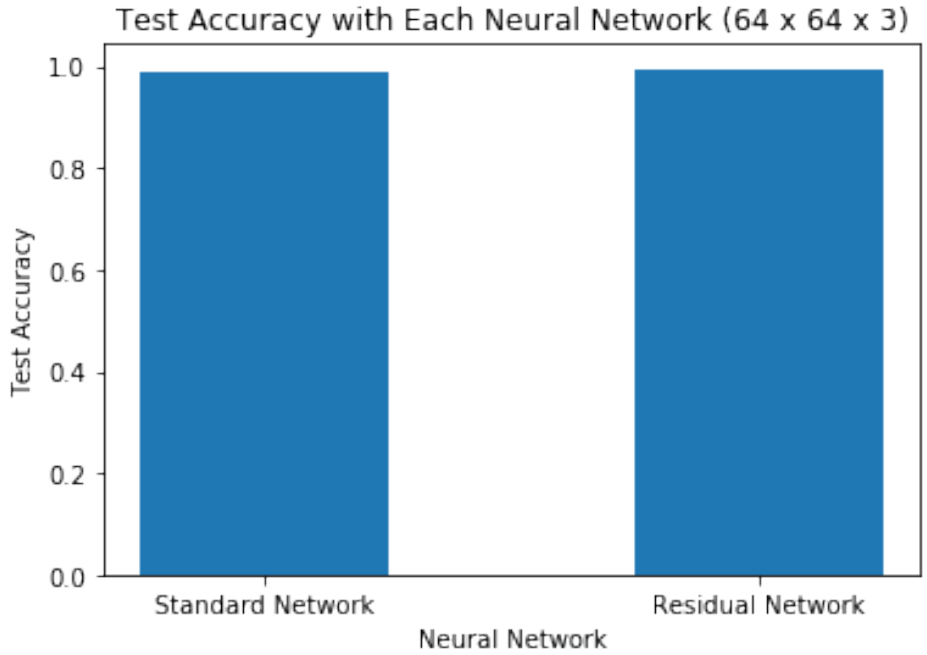
Training loss (left) and accuracy (right) using CNN (teal) and ResNet (purple)

Test Results (64 x 64)

The CNN had higher loss than the ResNet, but accuracy was nearly equal



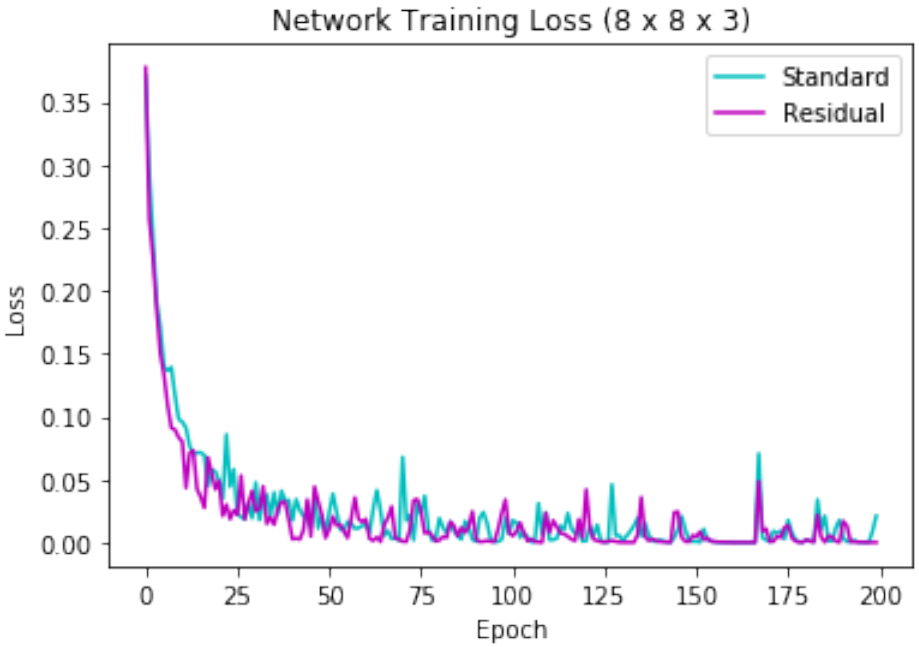
Test Loss



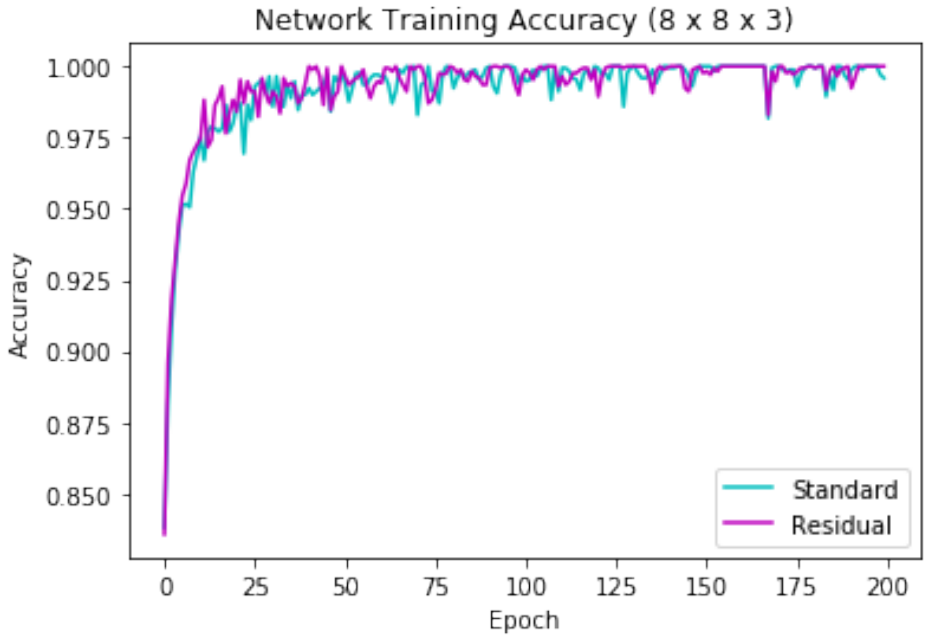
Test Accuracy

Training Results (8 x 8)

There is more variety in results between each epoch, but the loss and accuracy still trend towards 0 and 1



Training Loss

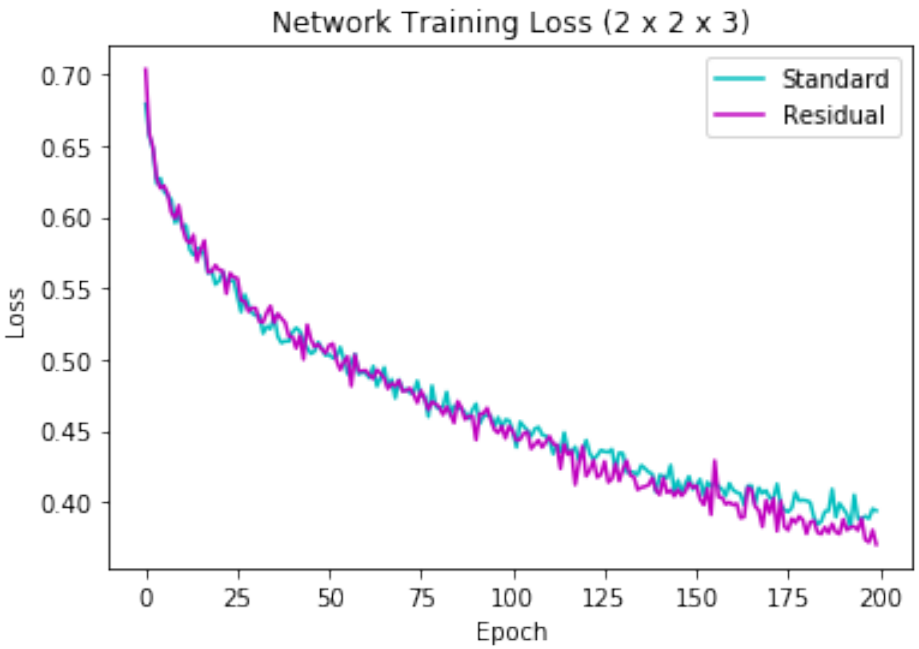


Training Accuracy

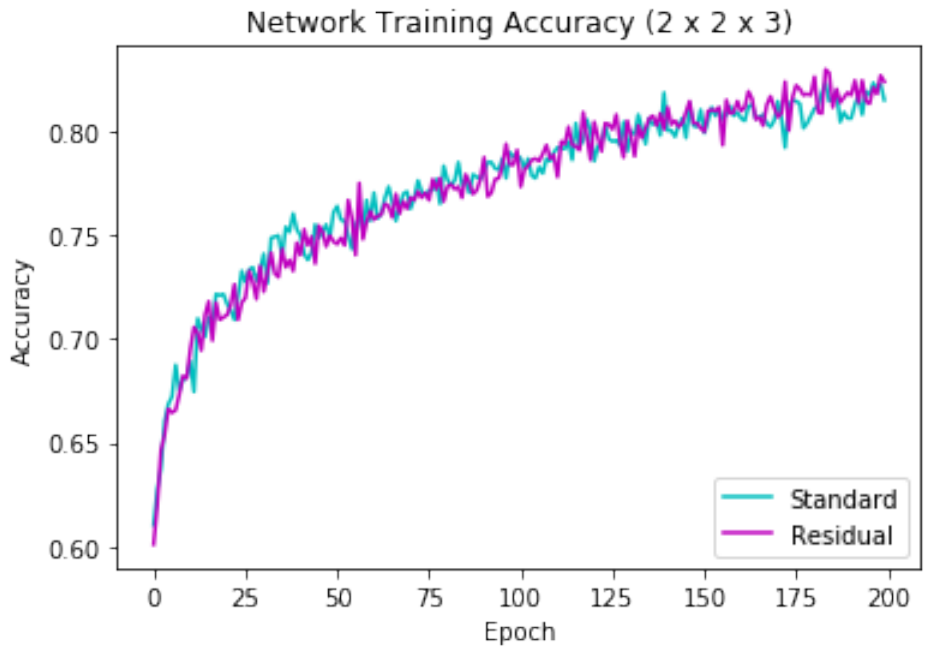
Training loss (left) and accuracy (right) using CNN (teal) and ResNet (purple)

Training Results (2 x 2)

The loss is much higher on the and the accuracy is much lower



Training Loss

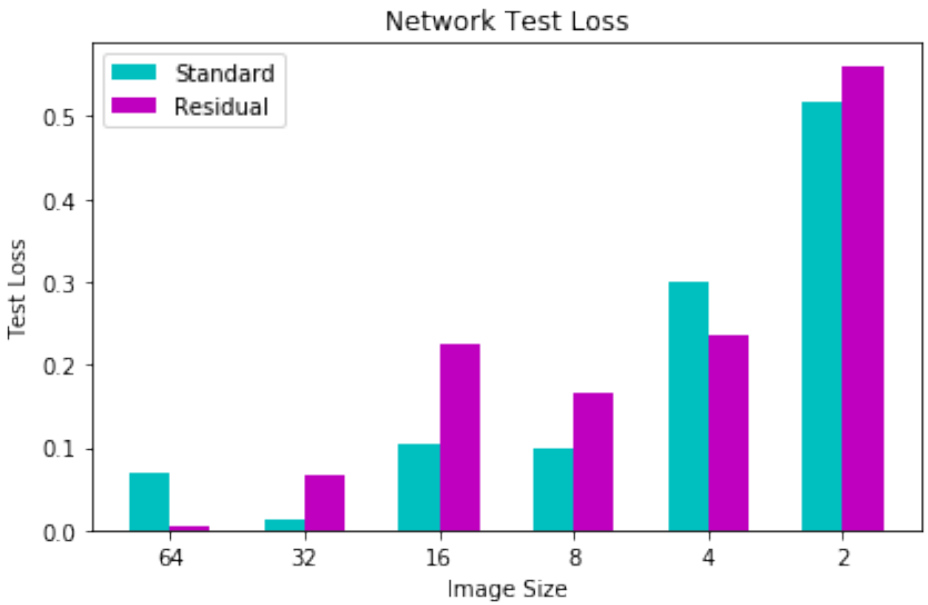


Training Accuracy

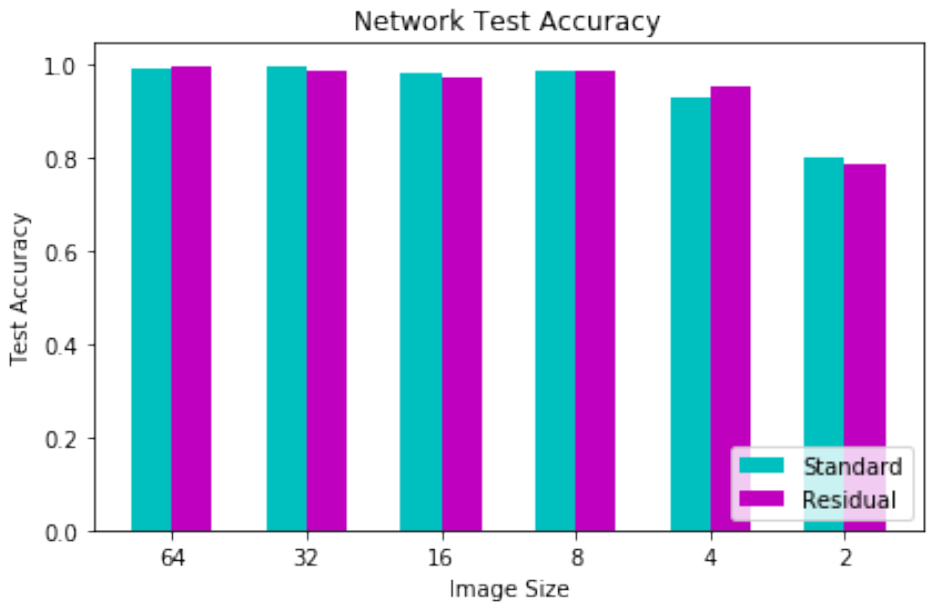
Training loss (left) and accuracy (right) using CNN (teal) and ResNet (purple)

All Test Results Visualized

The test results after training each network with 200 epochs



Test Loss



Test Accuracy

Test loss (left) and accuracy (right) using CNN (teal) and ResNet (purple)

All Test Results in Detail

The test results after training the CNN model (S) and the ResNet model (R) with 200 epochs

Image Size	Loss (S)	Accuracy (S)	Loss (R)	Accuracy (R)
64 x 64	0.068	0.989	0.006	0.995
32 x 32	0.012	**0.995**	0.066	**0.984**
16 x 16	0.105	**0.979**	0.224	**0.968**
8 x 8	0.099	**0.984**	0.166	**0.984**
4 x 4	0.301	0.926	0.235	0.952
2 x 2	0.516	0.799	0.561	0.783

Conclusions

- The CNNs and ResNets both appeared effective at making the correct diagnosis
- If the networks had many more layers, there might have been a more visible difference between the results
- Both types of networks were surprisingly robust as image size decreased
- A health care provider using CT scans to diagnose COVID-19 could use scans as small as 8 x 8 in size for 0.98 accuracy instead of 512 x 512
- Scanning for these smaller images could expose patients and health care workers to less radiation while also saving space in patient databases

References I

Special thanks to Dr. Pineda

Thanks for listening! Any questions?

References:

[1] South Carolina Diagnostic Imaging (ND). Computed tomography (CT scan). https://www.scdiag.com/services/ct/.

[2] Adams, H. J.A., Kwee T. C., Yakar D., Hope M. D., Kwee R. M. (2020). Chest CT imaging signature of coronavirus disease 2019 infection: In pursuit of the scientific evidence. *Chest, 158*(5), 1885-1895. https://doi.org/10.1016/j.chest.2020.06.025.

[3] Fiore, K. (2020). Hazy on ground-glass opacities? Here's what they are. https://www.medpagetoday.com/pulmonology/generalpulmonary/86751.

References II

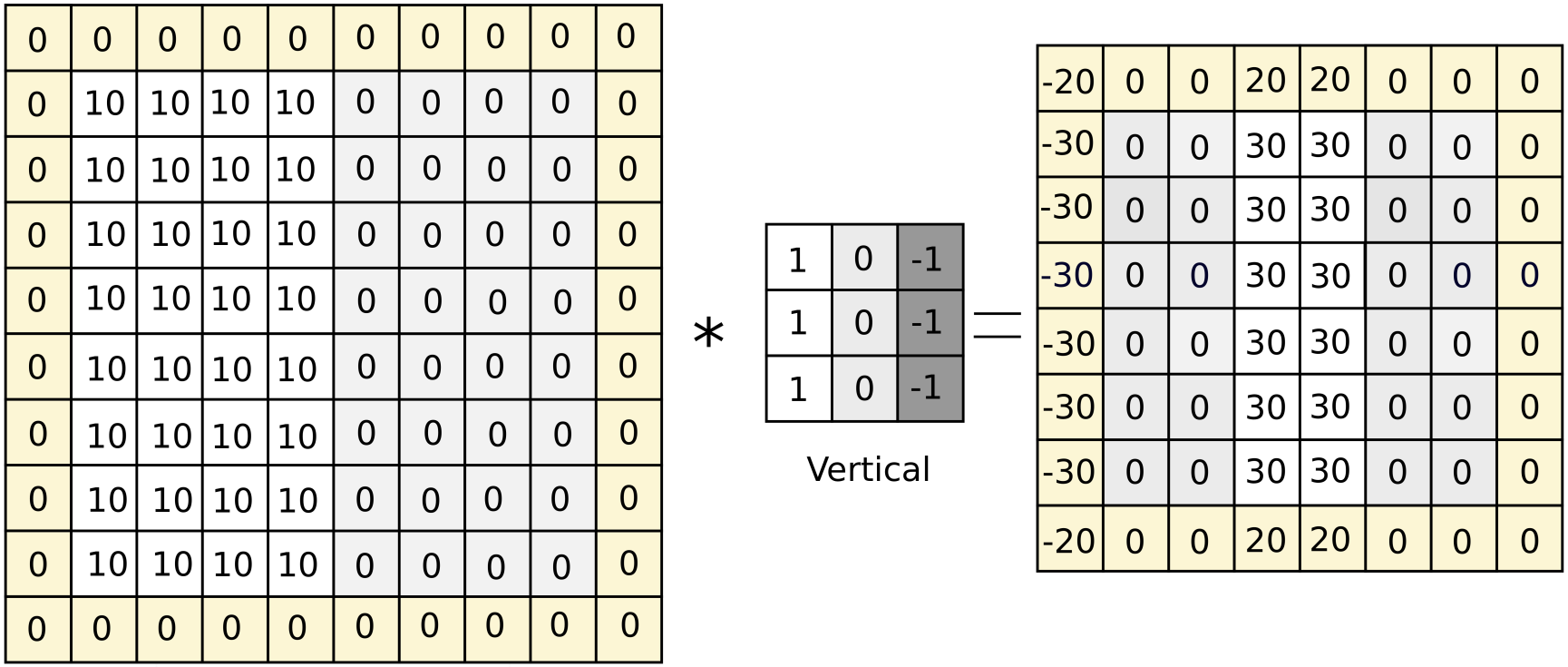
[4] Aria M., Ghaderzadeh M., Asadi F., Jafari R. (2021) COVID-19 Lung CT Scans: A large dataset of lung CT scans for COVID-19 (SARS-CoV-2) detection. Kaggle. DOI: 10.34740/kaggle/dsv/1875670.

[5] Reynolds A. (2019). Convolutional neural networks (CNNs). https://anhreynolds.com/blogs/cnn.html.

[6] SuperDataScience Team (2018). Convolutional neural networks (CNN): Step 4 - full connection. https://www.superdatascience.com/blogs/convolutional-neural-networks-cnn-step-4-full-connection.

[7] Dive Into Deep Learning (ND). 7.6. Residual networks (ResNet). https://d2l.ai/chapter_convolutional-modern/resnet.html#fig-residual-block.

Bonus Slide: CNNs - Zero Padding

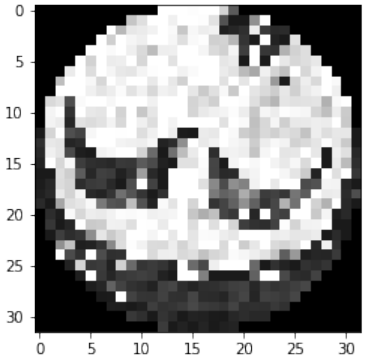


The input on the left with one layer of padding is run through a convolutional filter in the middle for detecting vertical edges, giving the output on the right. The output has the same surface dimension as the input when excluding the input's padding. [5]

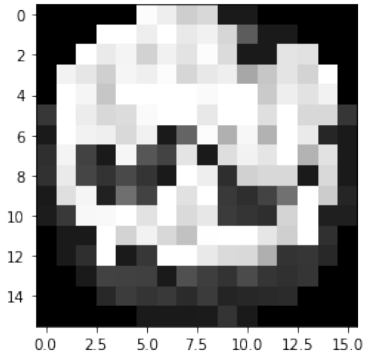
Bonus Slide: CNNs - Cost and Backpropagation

- Everything discussed about the CNN process has been forward propagation
- After an iteration of forward propagation, the cost is calculated
- Cost is attempting to measure the difference between the model's predicted labels and the actual labels
- Cost is used to initialize backpropagation, which is a series of derivations starting at the deepest layer of the network and ending at the outermost layer of the network
- The resulting derivatives are used to update the network's parameters for the next iteration of forward propagation

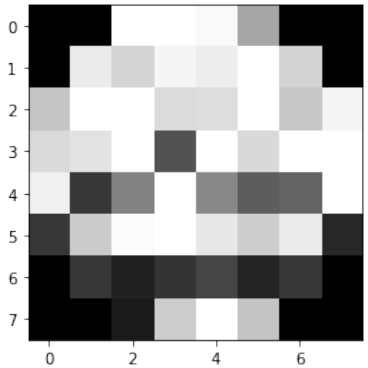
Bonus Slide: The Effects of Image Size



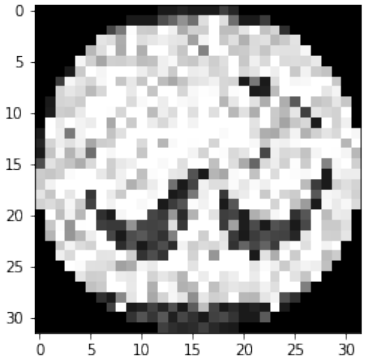
Positive 32 x 32



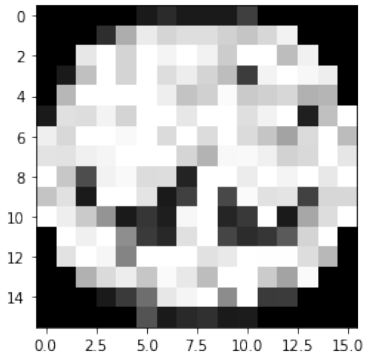
Positive 16 x 16



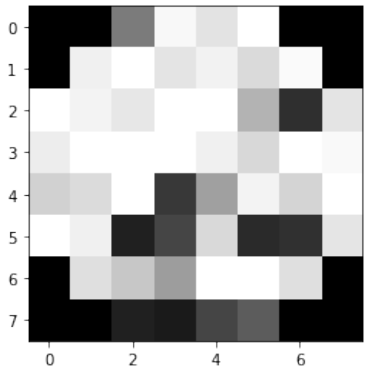
Positive 8 x 8



Negative 32 x 32



Negative 16 x 16



Negative 8 x 8