Deep Learning

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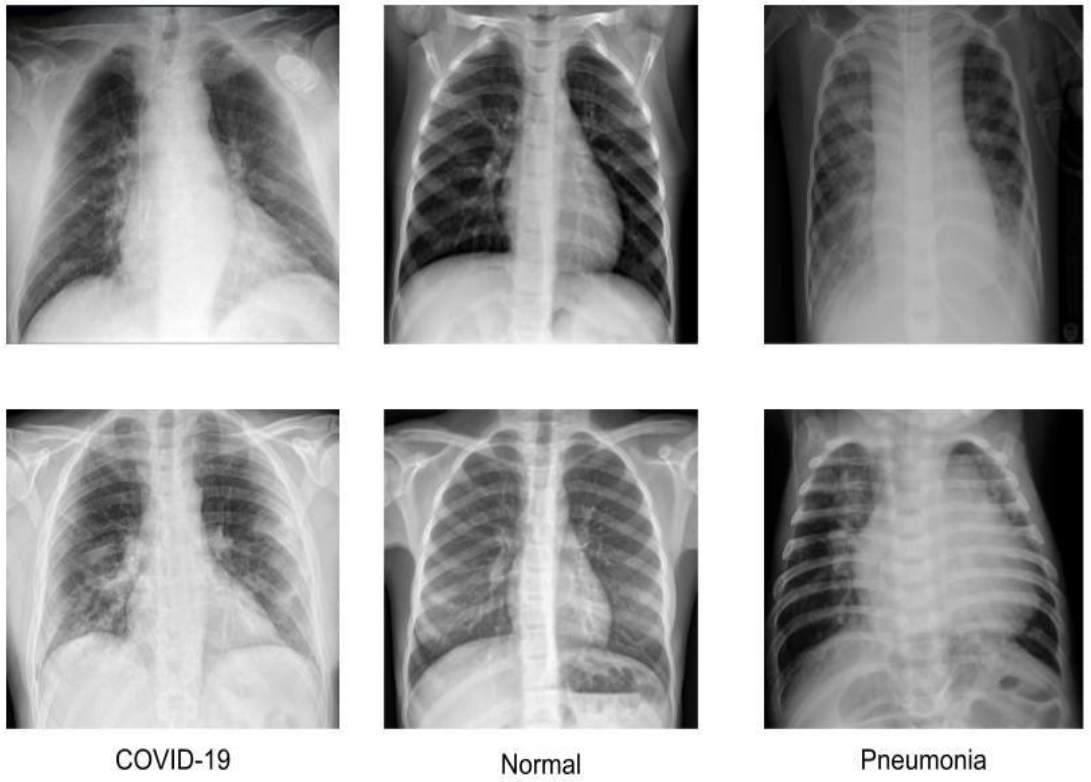
Overview

Chest X-ray images could facilitate greatly in mass COVID-19 screening.

In this study, we build deep learning models to detect COVID-19 positive cases using chest X-ray image.

We leverage DNN models such as DenseNet, ResNet, VGG to build automated COVID-19 screening.

Early results (based on deep features) show performance improvement and further possibilities.



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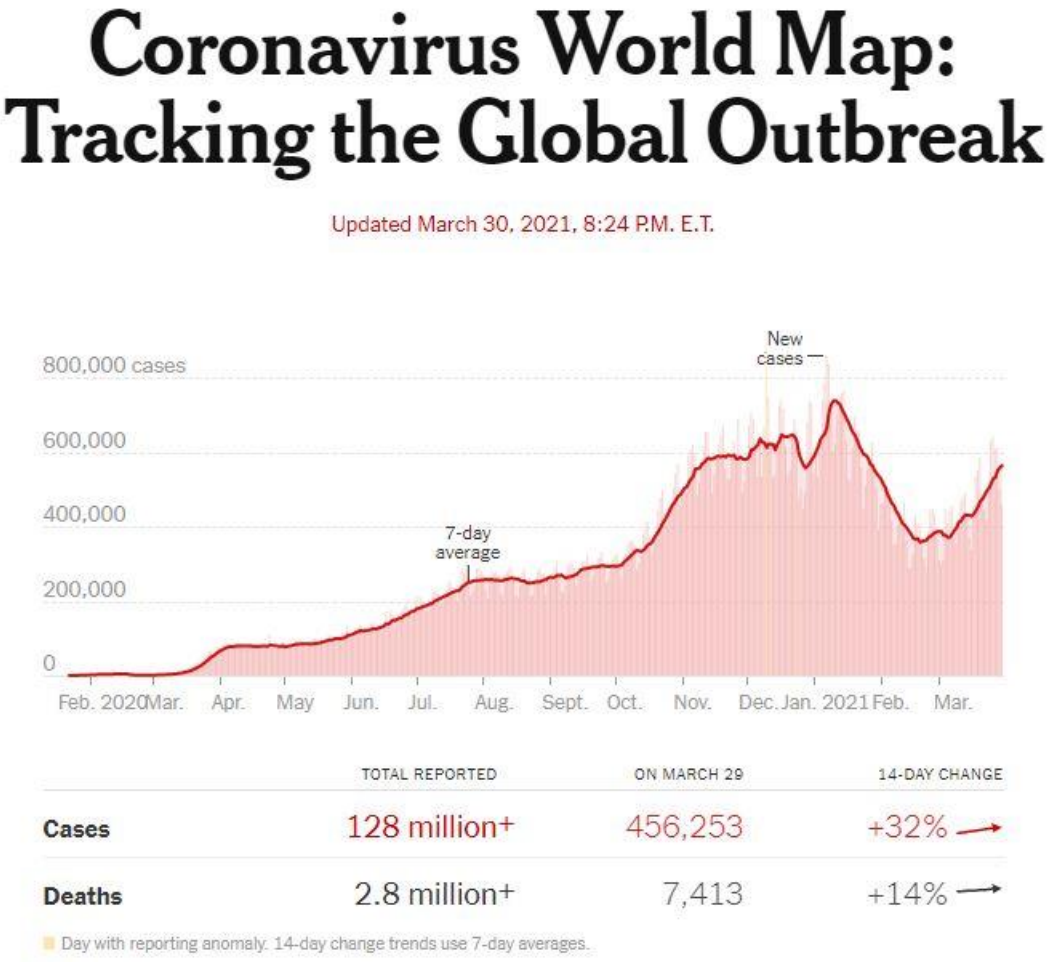
Motivation

- Since December 2019, the infection rate of COVID-19 cases has been very high.
- In such infectious disease, early detection tools would help largely to mitigate the spread and save lives.
- Current COVID-19 screening are expensive and time-consuming.
- Chest X-ray imaging is available and accessible in many clinical sites as it is considered standard equipment in most healthcare systems.



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What is Deep Learning?

Deep Learning is an artificial intelligence function that imitates the working of the human brain in processing data and creating patterns for use in decision making.

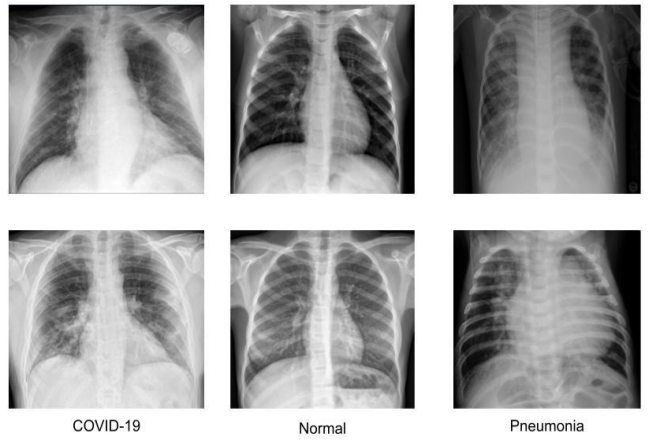
Deep Learning transformed internet business like web search and advertising.

Deep Learning is enabling brand new products and businesses.

What is Deep Learning?

- Use of Deep Learning:

  Medicine (reading X-ray images)
  Self driving car
  Agriculture
  And many more…



Neural Network

- Deep learning refers to training neural networks sometimes very large neural networks.
- A Neural Network is a technology built to simulate the activity of the human brain. Specifically, pattern recognition and the passage of input through various layers of simulated neural connections.
- Inspired by human mind
- Neurons are activated by some input
- Massively used for problems of classification and regression
- Archived amazing results in the field
- The idea was developed in 1960s but has been popular after 2010s.

Neural Network

- Where can neural networks be applied

Computer Vision

Object Recognition

Self-driving cars

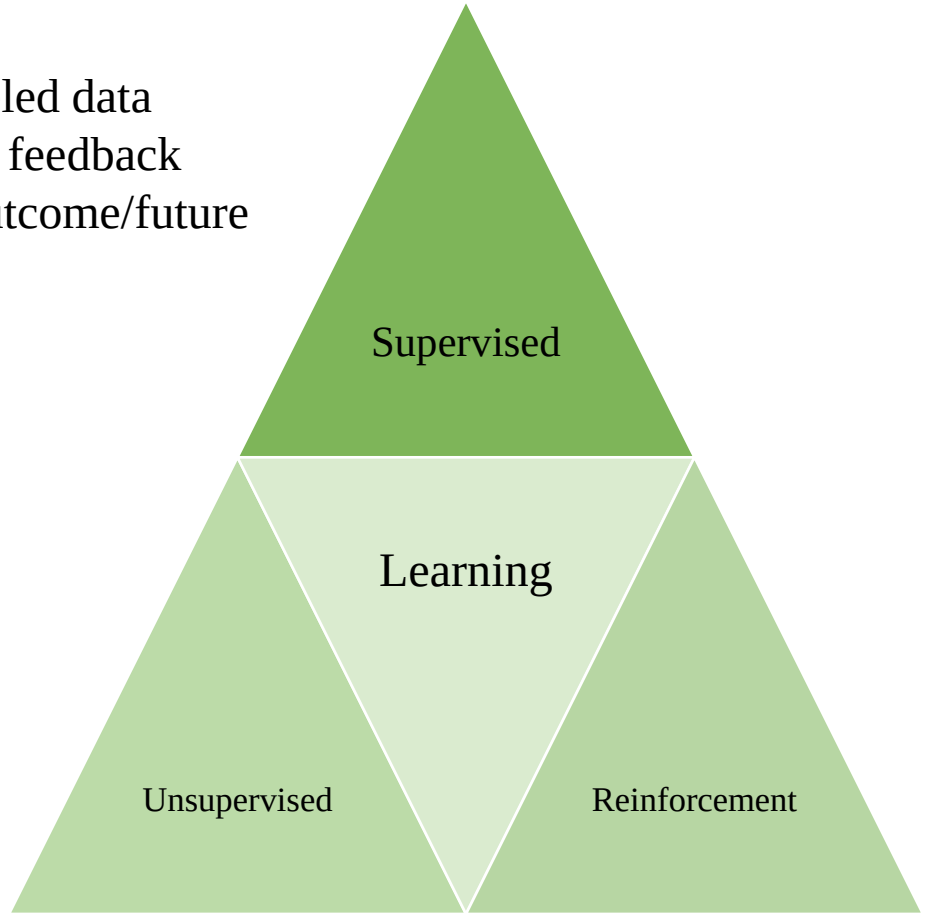
Price Prediction

Image Processing

Speech Recognition

Learnings

- Labeled data
- Direct feedback
- Predict outcome/future



- No labels
- No feedback
- Find hidden structure

- Decision process
- Reward system
- Learn series of actions

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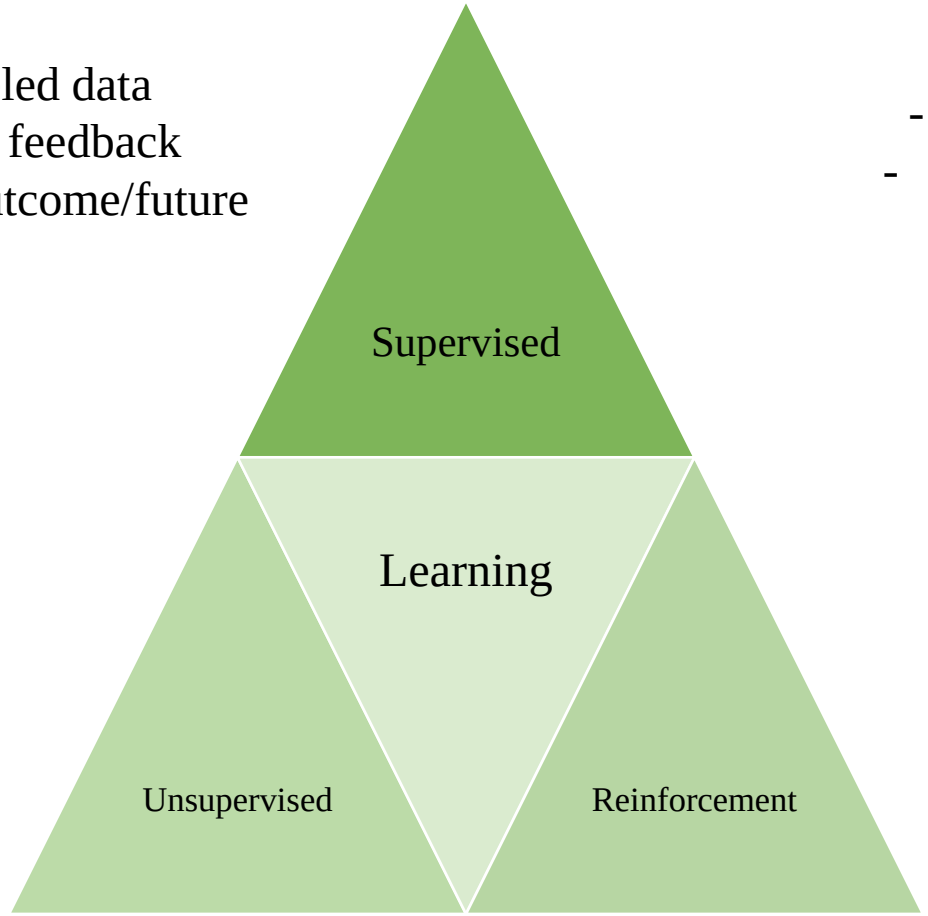
Supervised Learning

- Labeled data
- Direct feedback
- Predict outcome/future



- Regression
- Classification

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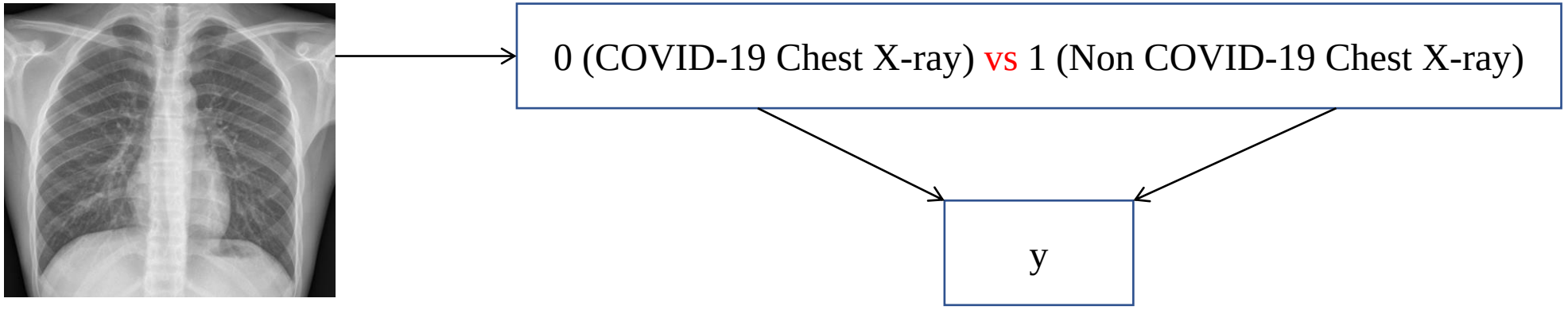
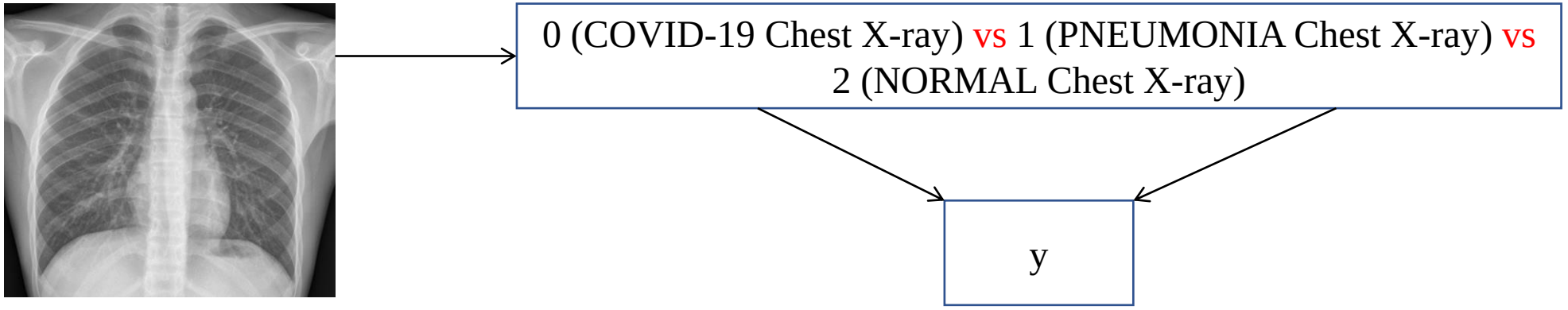
Binary Classification

- In binary classification our goal is to learn a classifier that can input an image represented by its feature vector X and predict whether the corresponding label y is 1 or 0.



Multi-Class Classification

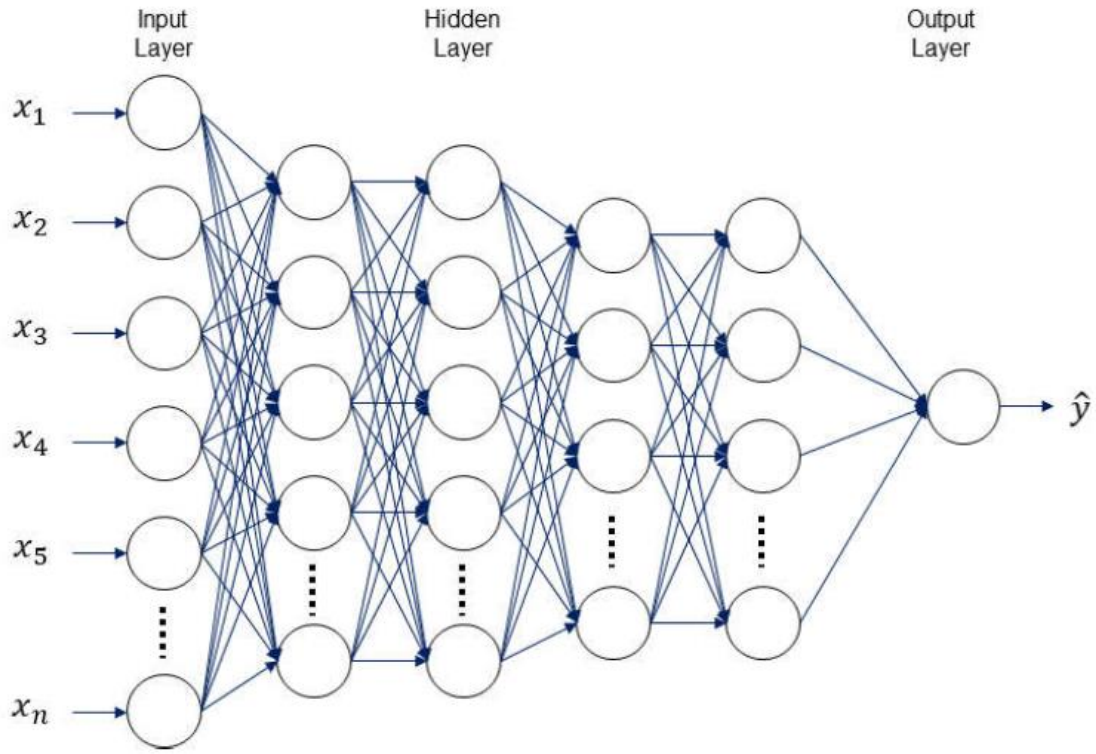
- In multi-class classification, machine can predict 0 or more non-exclusive class labels.



Deep Neural Network (DNN)

-$x_1, x_2, \ldots, x_n$ represent the input data with n attributes

-$\hat{y}$ represents the value predicted through the DNN.



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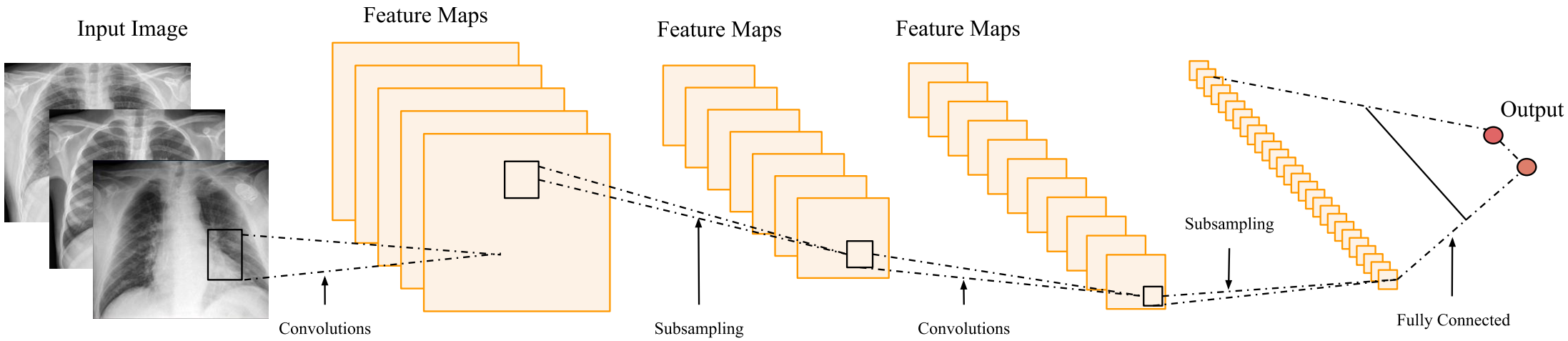
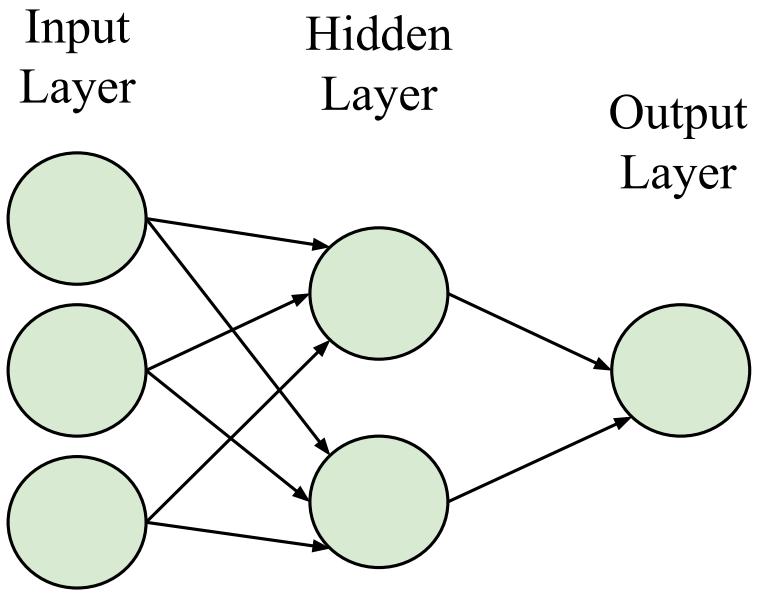
Feature Extraction Using CNN



CNN is also a kind of DNN which use convolutional layers

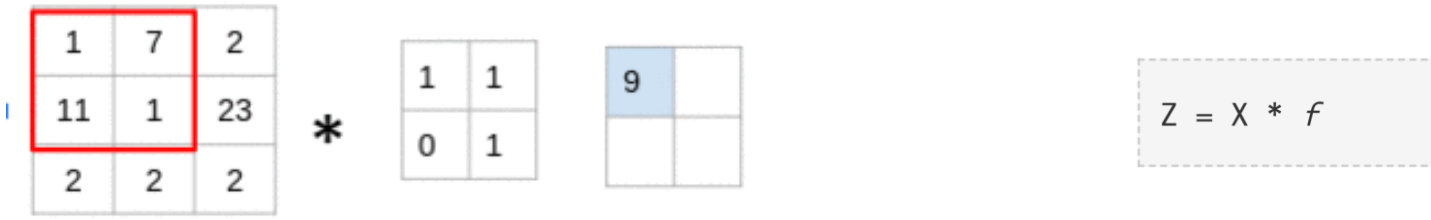
Layers in CNN

- This is a 2-layer neural network with 1 hidden layer.
- Here, 3 input neurons, 2 neurons in its hidden layer and 1 output neuron
- We have used the following layers-
  - Convolution layer
  - Fully Connected Layer
  - Dropout Layer
  - Pooling Layer



Convolutional Layer

Consider that we have an image of size 3 x 3 and a filter of size 2 x 2



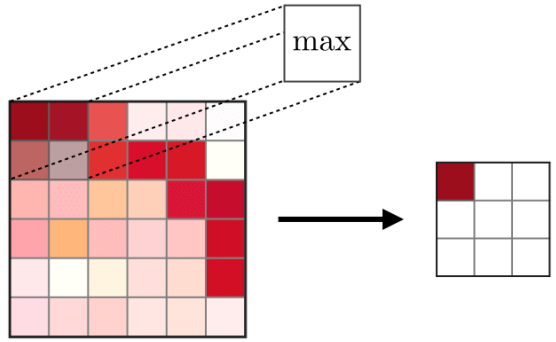
$$Z = X * f$$

```
(1x1 + 7x1 + 11x0 + 1x1) = 9
(7x1 + 2x1 + 1x0 + 23x1) = 32
(11x1 + 1x1 + 2x0 + 2x1) = 14
(1x1 + 23x1 + 2x0 + 2x1) = 26
```

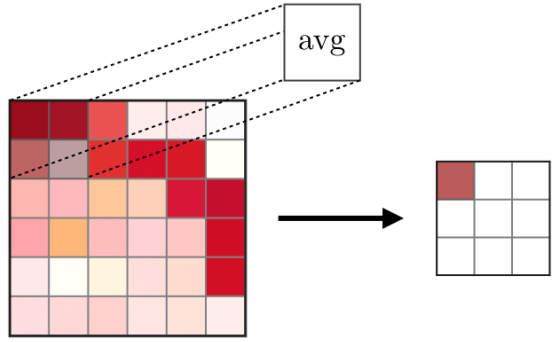
Pooling Layers

- Reduce dimensions of the feature maps.
- Reduce number of parameters to learn the network.
- makes the model robust
- Types of pooling layers-
  - Max pooling
  - Average pooling

• Preserves detected features
• Most commonly used

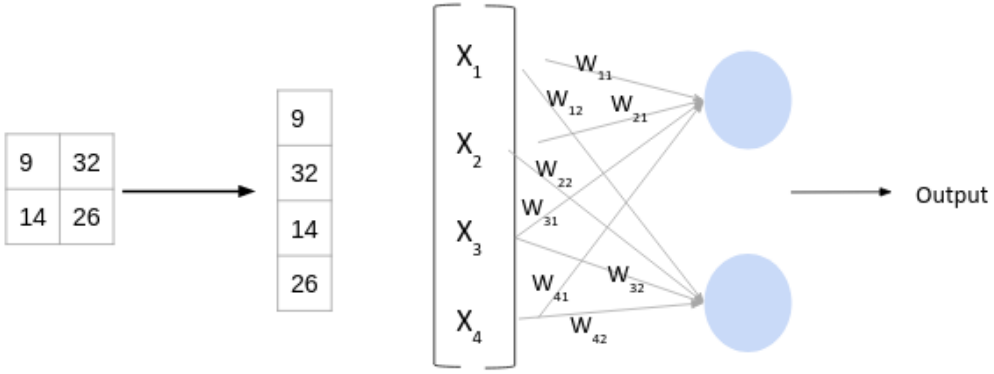


• Down samples feature map



Fully Connected Layer

- The features are sent to the fully connected layer that generates the final results.
- The fully connected layer in a CNN is nothing but the traditional neural network.



$$Z = W^T . X + b$$

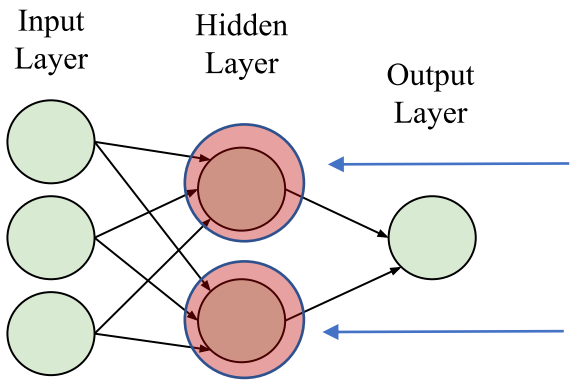
$$Z = \begin{bmatrix} W_{11} & W_{21} & W_{31} & W_{41} \\ W_{12} & W_{22} & W_{32} & W_{42} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

$$Z_{2x2} = \begin{bmatrix} W_{11}X_1 + W_{21}X_2 + W_{31}X_3 + W_{41}X_4 \\ W_{12}X_1 + W_{22}X_2 + W_{32}X_3 + W_{42}X_4 \end{bmatrix}$$

Activation Function

Some common activation functions are:

1. Sigmoid function
2. Hyperbolic tangent function (tanh)
3. Rectified linear unit
4. Softmax function

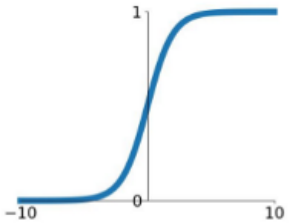


Apply activation

Apply activation

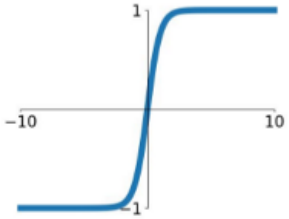
Sigmoid

$$\sigma(x) = \frac{1}{1+e^{-x}}$$



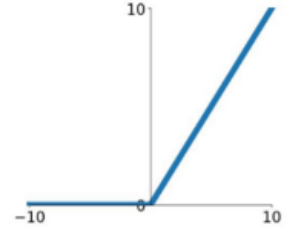
tanh

$$\tanh(x)$$



ReLU

$$\max(0, x)$$



Softmax

$$\sigma(\mathbf{z})_i = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}} \text{ for } i = 1, \ldots, K \text{ and } \mathbf{z} = (z_1, \ldots, z_K) \in \mathbb{R}^K$$

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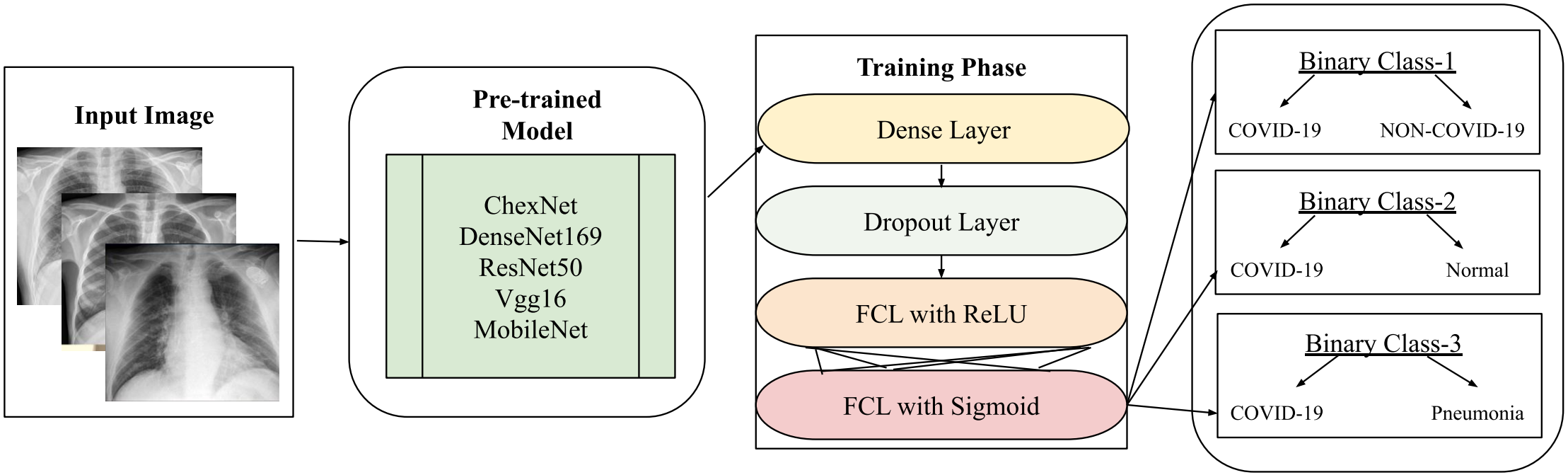
Modeling



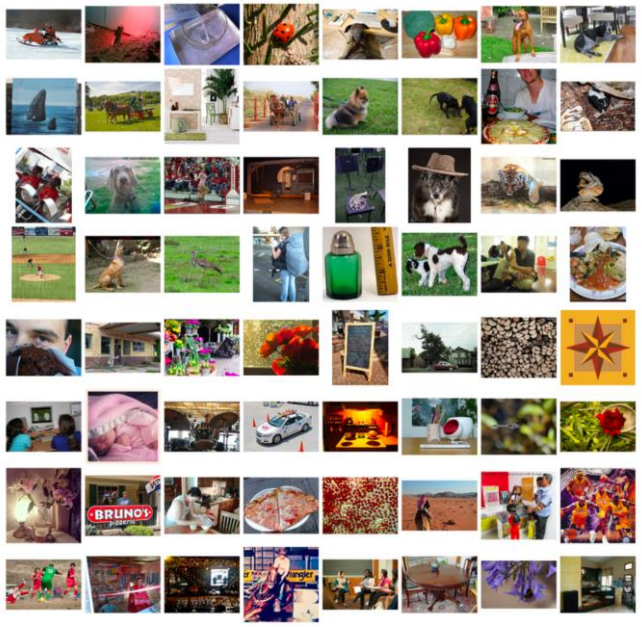
Model architecture for the prediction of COVID-19, NON-COVID-19, Normal and Pneumonia patients

What is a Pretrained Model

- **Transfer Learning:** Transfer learning generally refers to a process where a model trained on one problem is used in some way on a second related problem.
- This is desirable for a number of reasons, not least:
  - **Useful Learned Features**: The models have learned how to detect generic features from photographs, given that they were trained on more than 1,000,000 images for 1,000 categories.
  - **State-of-the-Art Performance**: The models achieved state of the art performance and remain effective on the specific image recognition task for which they were developed.
  - **Easily Accessible**: The model weights are provided as free downloadable files and many libraries provide convenient APIs to download and use the models directly.

What is a Pretrained Model: DenseNet

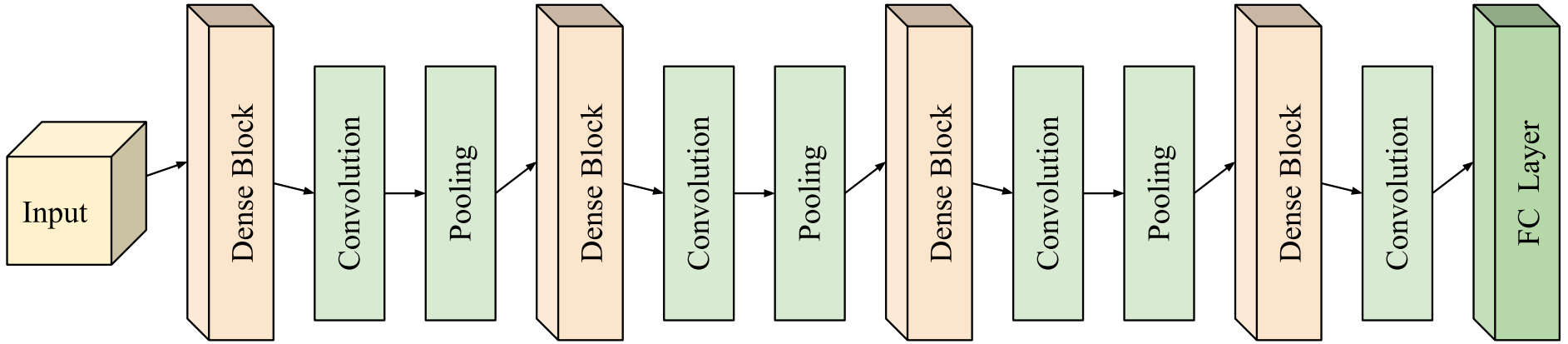
DenseNet is a network architecture where each layer is directly connected to every other layer in a feed-forward fashion (within each *dense block*).



- DenseNet with weights are available in Keras:
  - **DenseNet121**
  - **DenseNet169**
  - **DenseNet201**

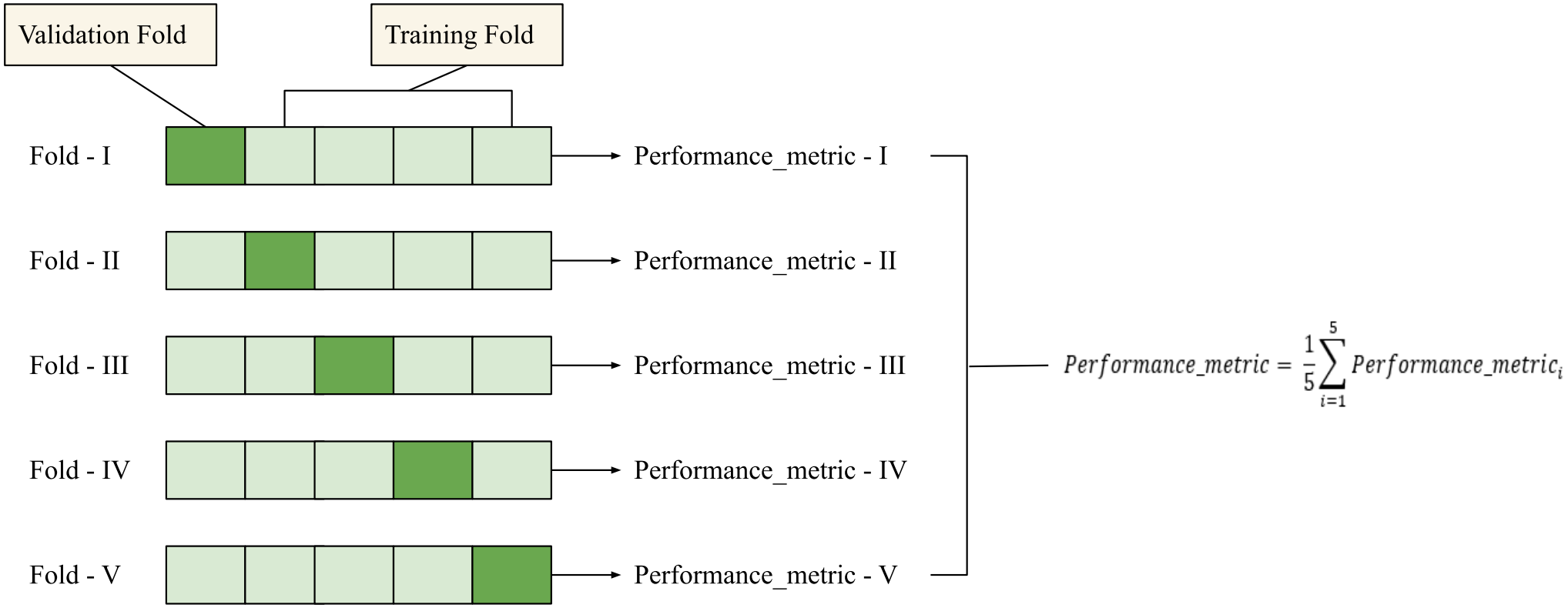
- ChexNet, is a 121-layer convolutional neural network that inputs a chest X-ray image and outputs the probability of pneumonia.

Architecture of DenseNet



Model architecture Dense Convolutional Network (DenseNet121)

Training



- Schematic representation of cross validation
- We are using k-fold cross validation to make model more robust.

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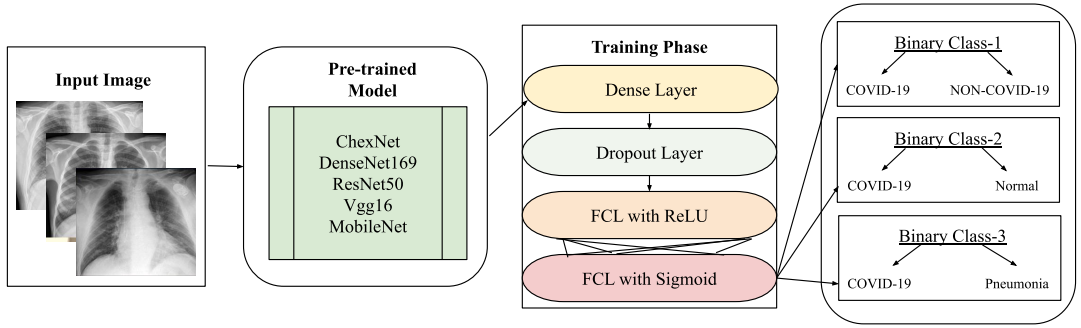
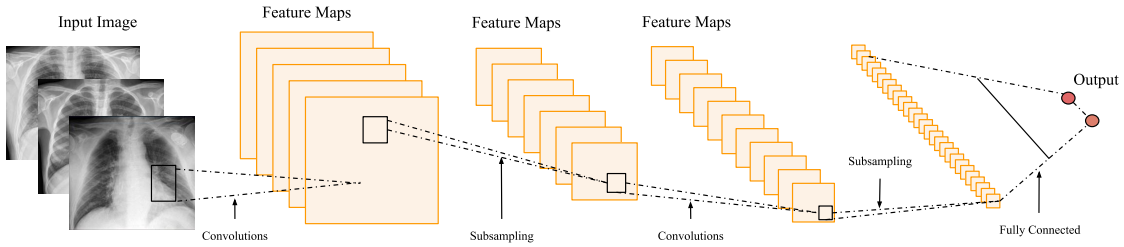
Evaluation

- To evaluate the model, we have used following performance metrics
  - Accuracy = (TP+TN)/(TP+FP+FN+TN)
  - Precision = TP/(TP+FP)
  - Recall = TP/(TP+FN)
  - F1 Score = 2*(Recall * Precision) / (Recall + Precision)

Conclusion





Deep Learning uses layers of algorithm to process data, understand and visually recognize data like chest x-ray image.

Information is passed through each layer, with the output of the previous layer providing input for the next layer.

Feature extraction uses a procedure to automatically construct meaningful “features” of the data for purposes of training, learning, and understanding.

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Thank you.