Development of a Convolutional-Neural-Network for the Classification of Covid-19 X-Ray Images

by

Nguyen Peter Phan Dinh

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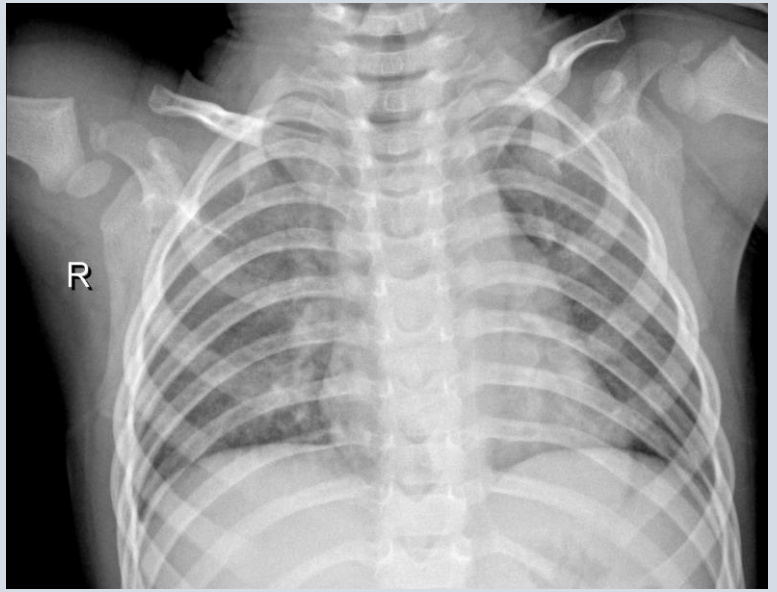
Motivation and Goal

Negative

[1]

Positive



[2]

Motivation

- Intepretation of X-rays can be time consuming and error-prone.
- Speed up the process and increase the accuracy of the detection to improve the diagnosis of COVID-19.

Goal

- Developing a Convolutional Neural Network (CNN) to classify X-rays for the determination of COVID-19 cases.

Dataset

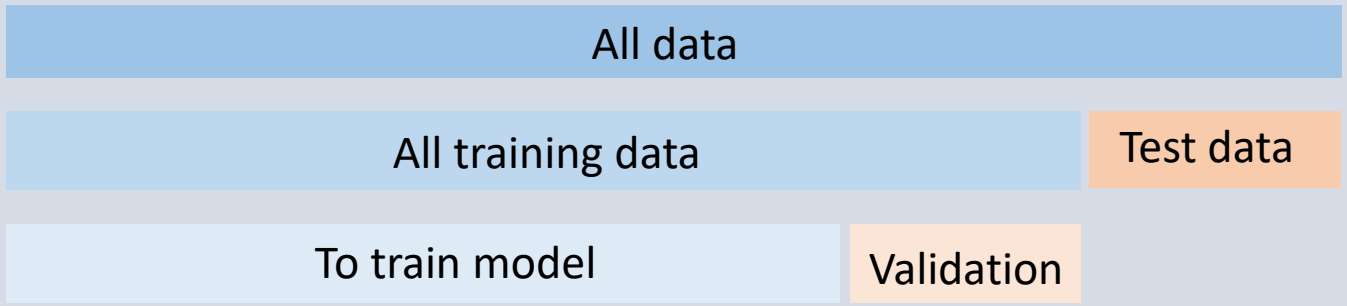
Datesets of X-ray images

- Covid-19-negative (normal): https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia [1]
- Covid-19-positive: https://github.com/ieee8023/covid-chestxray-dataset [2]

Data filtering

- Dataset in github contains X-ray images of several infections (COVID-19, Streptococcus, Influenza,etc.).
  - ➢ Filter data for only COVID-19 X-rays.
- Dataset contains x-rays with different views (PA = Posteroanterior and AP= Anteroposterior).
  - ➢ Filter data for only PA-view.
- To avoid the development of a bias in the model, the ratio of positve/negative data is set to 1.

Dataset workflow



196 samples of positive data + 196 samples of negative data = 392 samples of data.

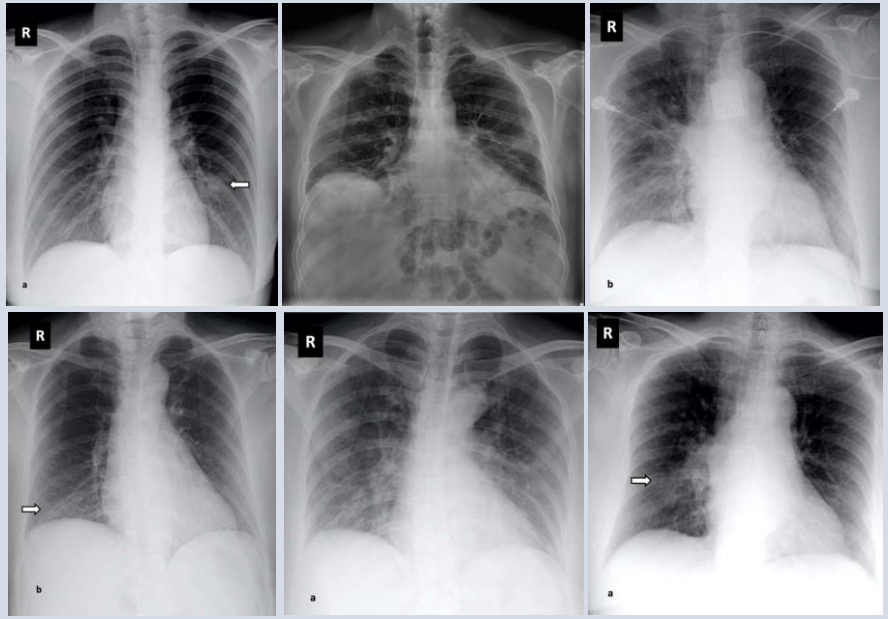
70% as training data and 30% as test data.

15% of all training data as validation data.

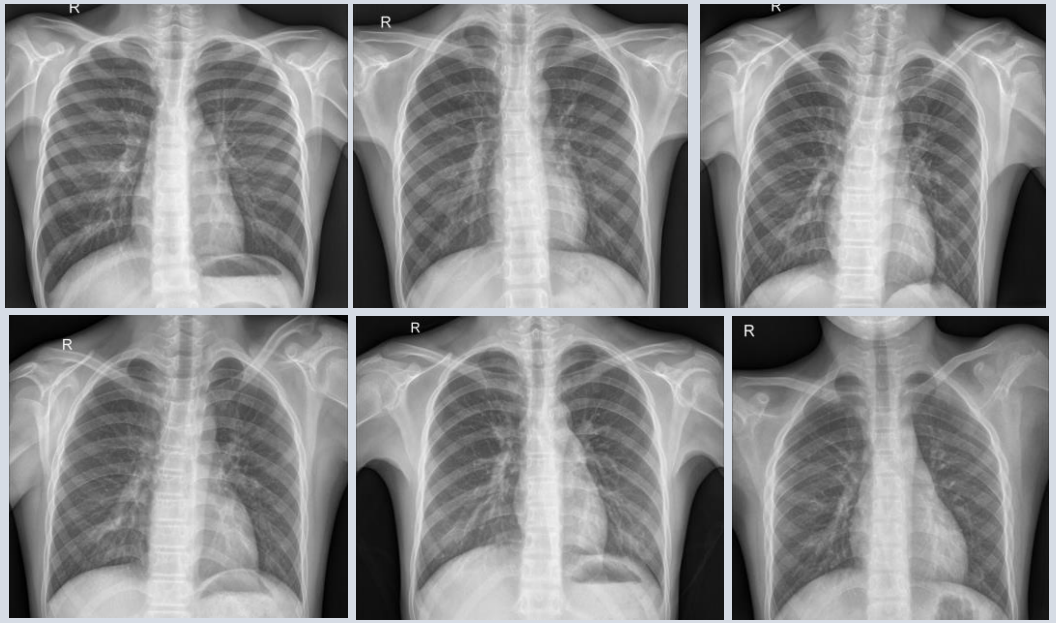
Dataset

A sample from the dataset

COVID-19-positive X-rays



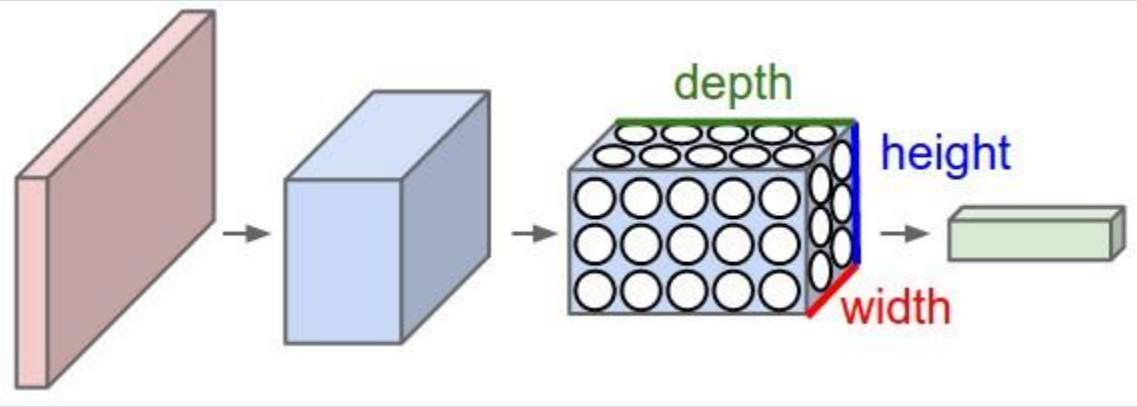
COVID-19-negative X-rays



Next step: train a CNN to learn the patterns (features) of the COVID-19-positve X-rays.

CNN-Model Development

Convolutional Neural Network



[3]

- CNN model is defined by using the Python-library **Keras** [4].
- Model parameters such as filters, kernel size, dropout rate, etc. are set.
- 15% of the training data is used for validation and updating the hyperparameters during the training process.
- ReLu is used as the activation function throughout the CNN.
- In total, 5,631,169 parameters are trained.

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 222, 222, 32)	896
max_pooling2d (MaxPooling2D)	(None, 111, 111, 32)	0
dropout (Dropout)	(None, 111, 111, 32)	0
conv2d_1 (Conv2D)	(None, 109, 109, 64)	18496
max_pooling2d_1 (MaxPooling2	(None, 54, 54, 64)	0
dropout_1 (Dropout)	(None, 54, 54, 64)	0
conv2d_2 (Conv2D)	(None, 52, 52, 128)	73856
max_pooling2d_2 (MaxPooling2	(None, 26, 26, 128)	0
dropout_2 (Dropout)	(None, 26, 26, 128)	0
flatten (Flatten)	(None, 86528)	0
dense (Dense)	(None, 64)	5537856
dropout_3 (Dropout)	(None, 64)	0
dense_1 (Dense)	(None, 1)	65

Total params: 5,631,169
Trainable params: 5,631,169
Non-trainable params: 0

CNN-Model Development

The developed model is applied on the test data and the result is illustrated in a confusion matrix.

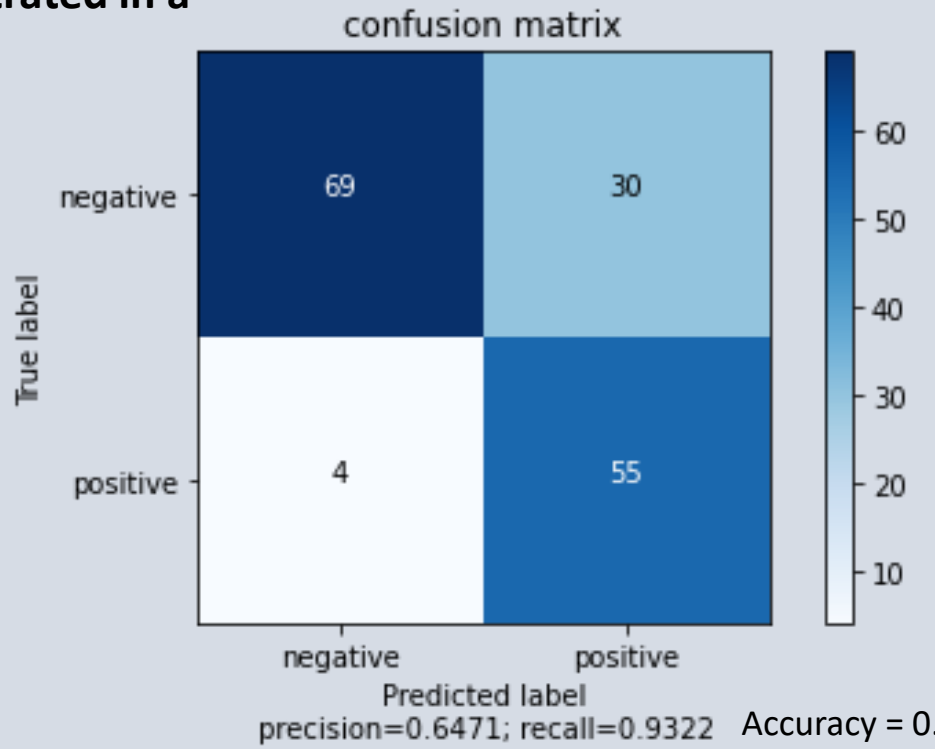
- In this classification task, accuracy is not a suitable measure.
  - Example: For 100 x-rays (with 10 COVID-19-positive cases), the model always predicts negative.→ accuracy=90% but it fails to predict the positive cases.
- Instead, the measures precision and recall are used [5].

$$precision = \frac{TP}{TP + FP}$$

$$recall = \frac{TP}{TP + FN}$$

TP = True positives
FP = False positives
FN = False negatives

Equations to compute the model performance



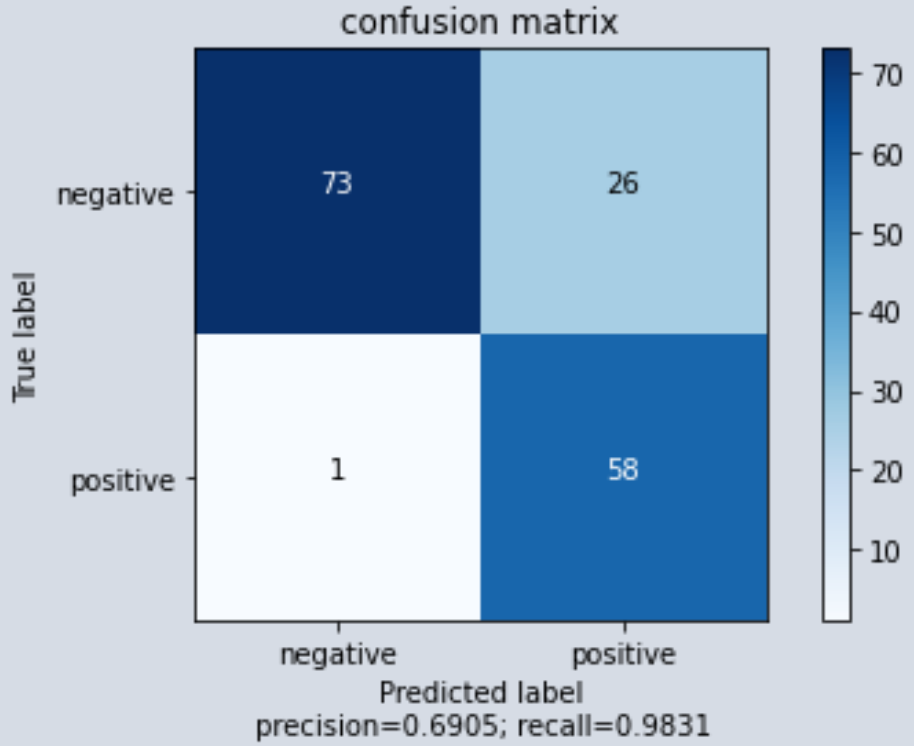
Accuracy = 0.785

- With current model, out of 100 COVID-19-positive cases, 7 cases will be missed.
- For medical applications not acceptable.
- Next step: Improving model's precision and recall by tuning the hyperparameters.

CNN-Model Development

Improve the model performance by tuning the Hyperparameters

- Using the Python-library **Keras Tuner**, different combinations of hyperparameters are tested [6]:
  - filter dense_layer = [64, 128], dropout_rate = [0.2, 0.3, 0.4, 0.5], learning_rate = [0.0001, 0.001, 0.01] .
- In total, 50 different hyperparameter-combinations are tested and the best model is picked from the output.



- Precision is increased from 0.65 to 0.69 and recall is increased from 0.93 to 0.98.
- With improved model, out of 100 COVID-19-positive cases, 2 cases will be missed.
- However, the number of false negatives is still high.

Summary and Outlook

Summary

- A CNN has been developed to classify X-rays in order to detect an infection with COVID-19.
- The CNN is developed using Keras and its hyperparameter are tuned with Keras Tuner.
- Through hyperparameter tuning, the number of false negative identifications is reduced from 7 to 2 per 100 COVID-19-positve samples.
- However, the developed model is not perfect and should serve as a support for the radiologist in classifying COVID-19-patients.

Outlook

- Further optimization of the hyperparameter by widening the search space.
- Usage of more data in the training process.

References

[1] https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia

[2] https://github.com/ieee8023/covid-chestxray-dataset

[3] https://cs231n.github.io/convolutional-networks/

[4] https://keras.io/getting_started/

[5] https://scikit-learn.org/stable/auto_examples/model_selection/plot_precision_recall.html

[6] https://keras-team.github.io/keras-tuner/

More information about the usage of CNN in COVID-19 X-ray classification can be found in the paper:
https://www.medrxiv.org/content/10.1101/2020.08.20.20178913v2.full.pdf

Thank you for your attention!