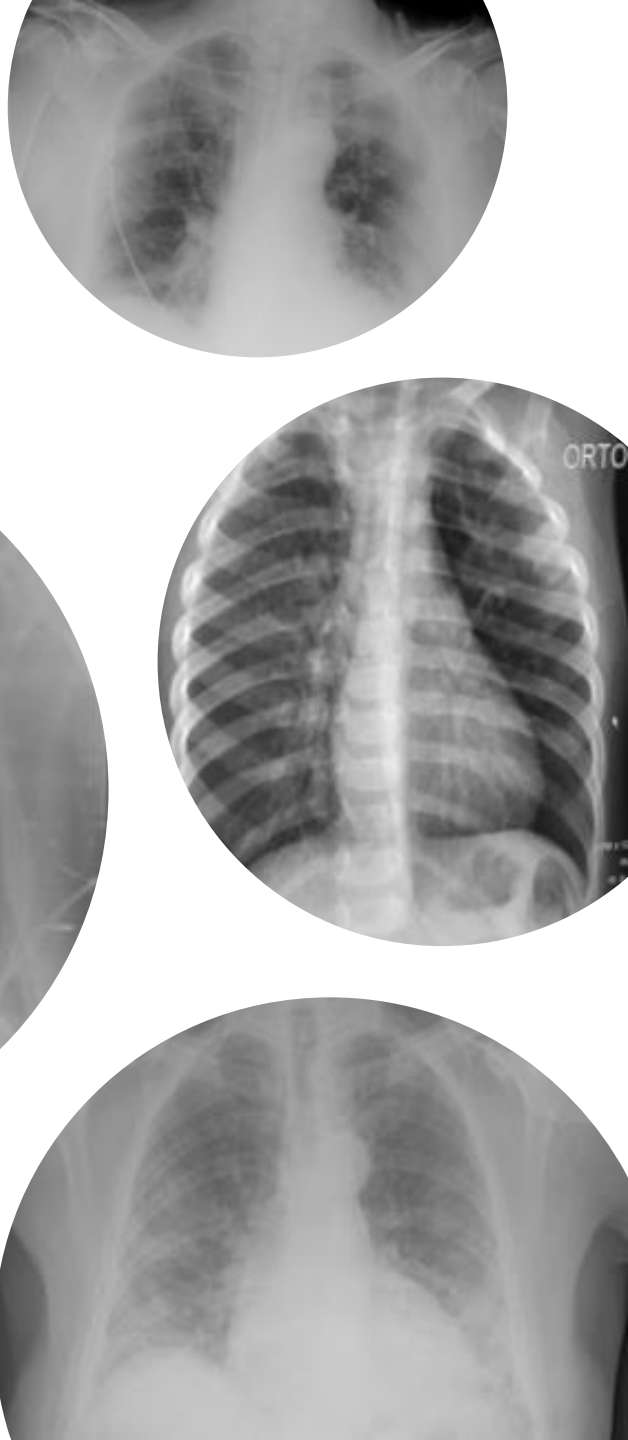
Imaging's Potential to Assist in COVID-19 Crisis

- CSIC 5011 / MATH 5473 Project 2 -

Yingshu CHEN[1], Wing Hei SUM[2], Ho Pan IP[3], Zipeng WU[4]

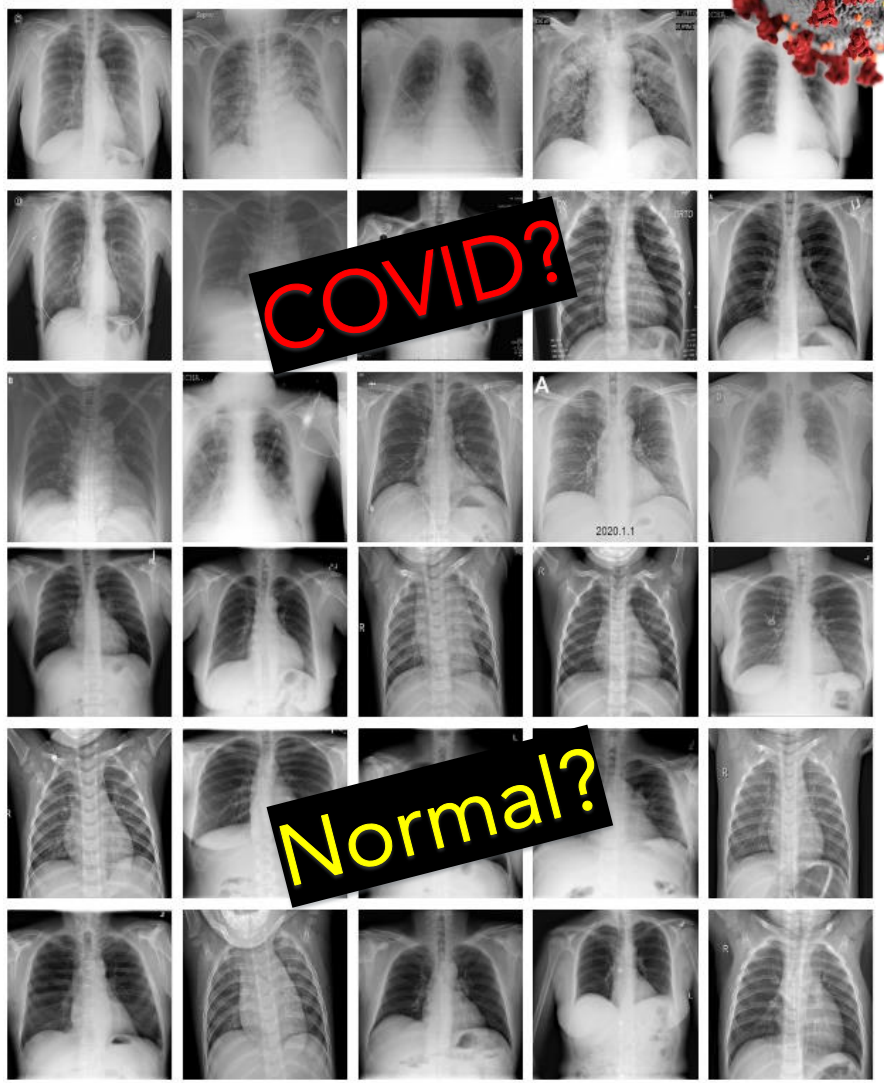
Department of Computer Science and Engineering[1], Industrial Engineering and Decision Analytics[2], Mathematics[3], Physics[4]



Motivation

- Severe COVID-19 pandemic
  - How to detect COVID without detection kit?
  - How to speed up detection?

- Chest X-ray Image Classification!
  - Issue: lack sufficient data
- Data augmentation via synthesis!



Outline

- Data and observation
- Data augmentation using generative model
- Data distribution
- Classification results

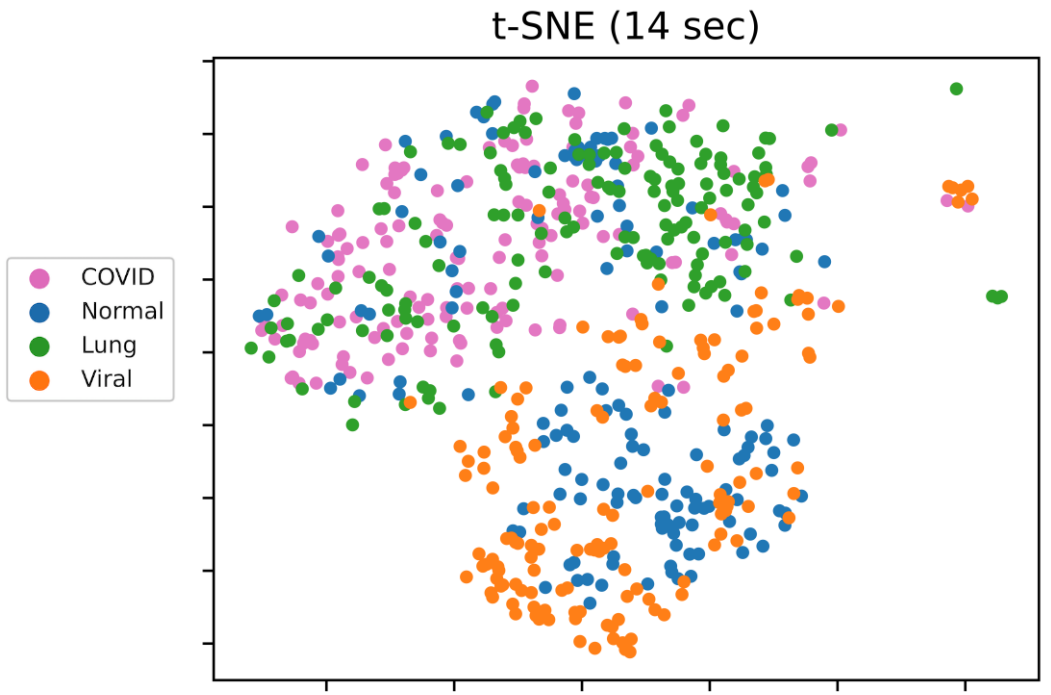
Data Observation

- Data* Statistics
  - Small original dataset
  - 20k images
  - Viral PNA only 1k
- Real Data visualization
  - Normal is sparse
  - Normal and Viral are close
  - COVID and Lung are close

Table 1: Data Statistics

Class	Normal	COVID-19	Lung Opacity[a]	Viral Pneumonia[b]
Train	9,942	3,366	5,762	1,095
Test	250	250	250	250
Total	10,192	3,616	6,012	1,345
Blended Train	9,942	7,000	5,762	7,000

[a,b] Non-COVID lung infection.

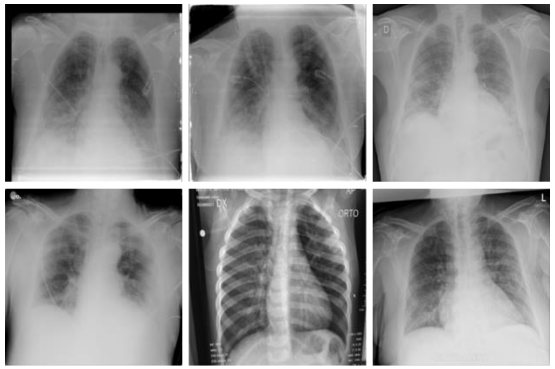


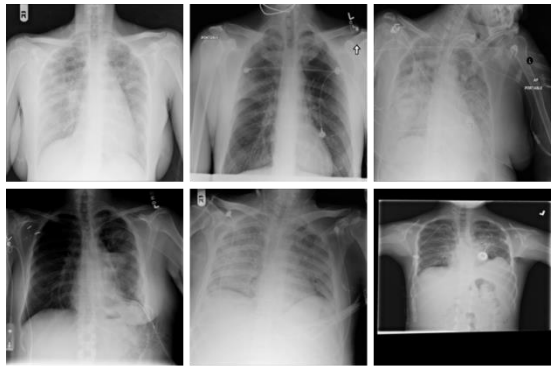
*Data source: https://www.kaggle.com/tawsifurrahman/covid19-radiography-database

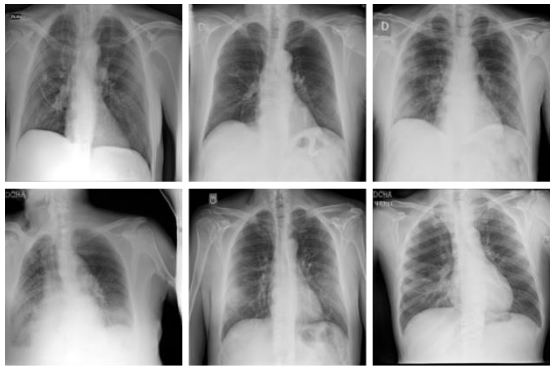
Data Augmentation

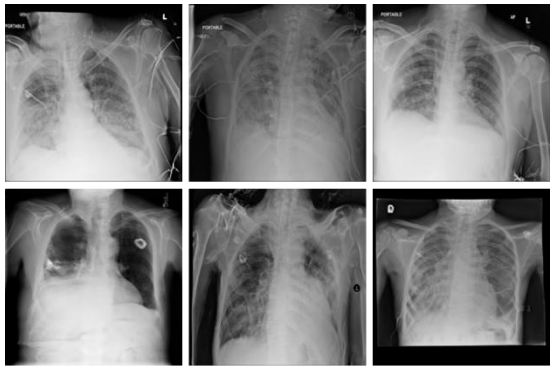
- Generative Model - SOTA conditional GAN
  - *stylegan2-ada* model with limited data (thousand scale)
  - Photorealistic synthesis
  - Unconditional vs Conditional GAN

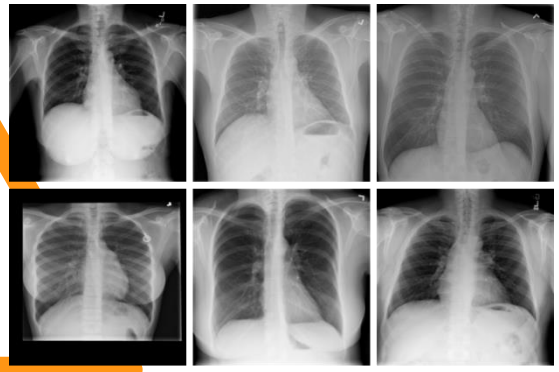
Data Augmentation
- Photorealism of Synthesis

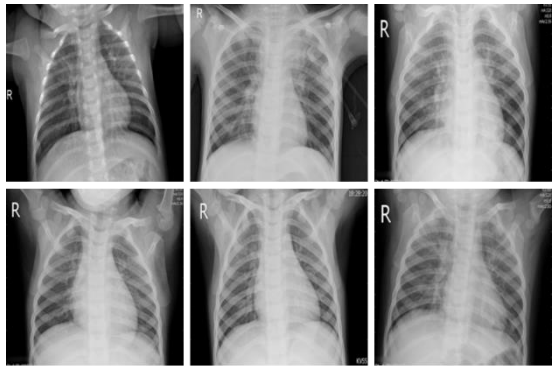

Real COVID-19 CXRs

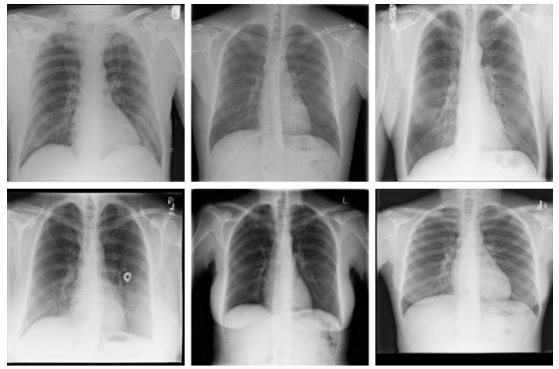

Real Lung Opacity CXRs

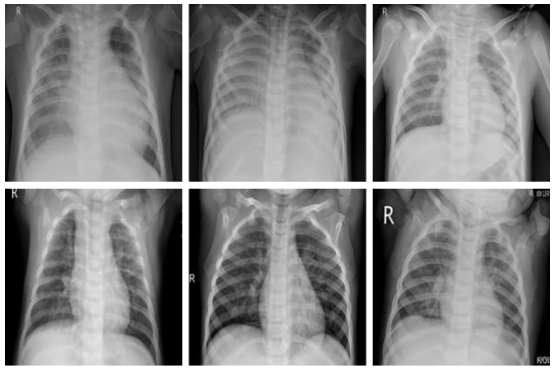

Synthetic COVID-19 CXRs


Synthetic Lung Opacity CXRs


Real Normal CXRs


Real Viral PNA CXRs


Synthetic Normal CXRs


Synthetic Viral PNA CXRs

Data Augmentation

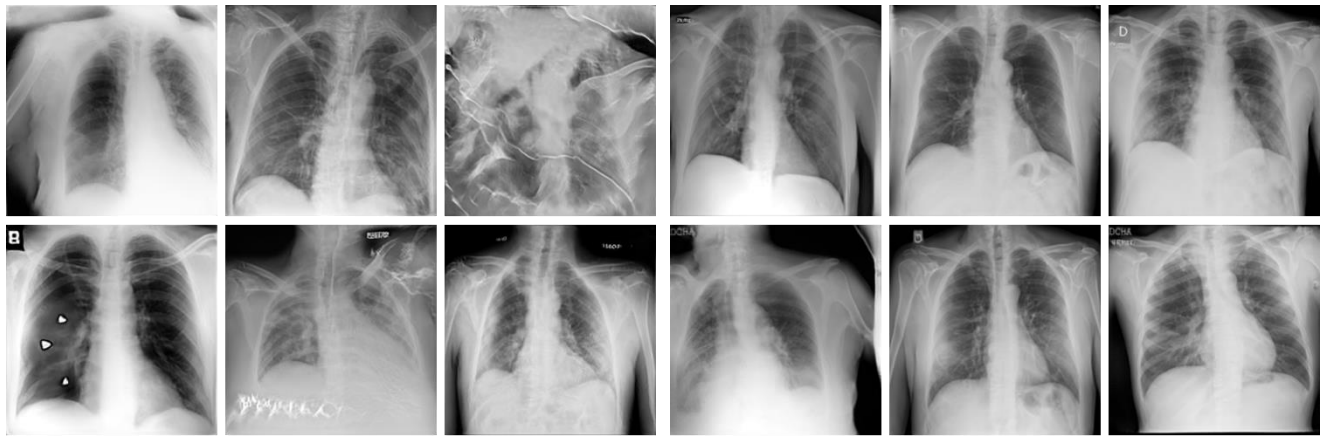
- Generative Model
  - SOTA conditional GAN
    - *stylegan2-ada* model with limited data (thousand scale)
    - Photorealistic synthesis
    - Unconditional vs Conditional GAN
    - Expected to assist in data augmentation

Table 3: Unconditional vs. Conditional Generative Model

Model*	Unconditional				Conditional			
	Normal	COVID-19	Lung Opacity	Viral PNA	Normal	COVID-19	Lung Opacity	Viral PNA
FID↓	18.28	33.48	28.74	28.25	**16.39**	**25.24**	**24.22**	**26.85**

*Four unconditional models and one conditional model with 4 labels

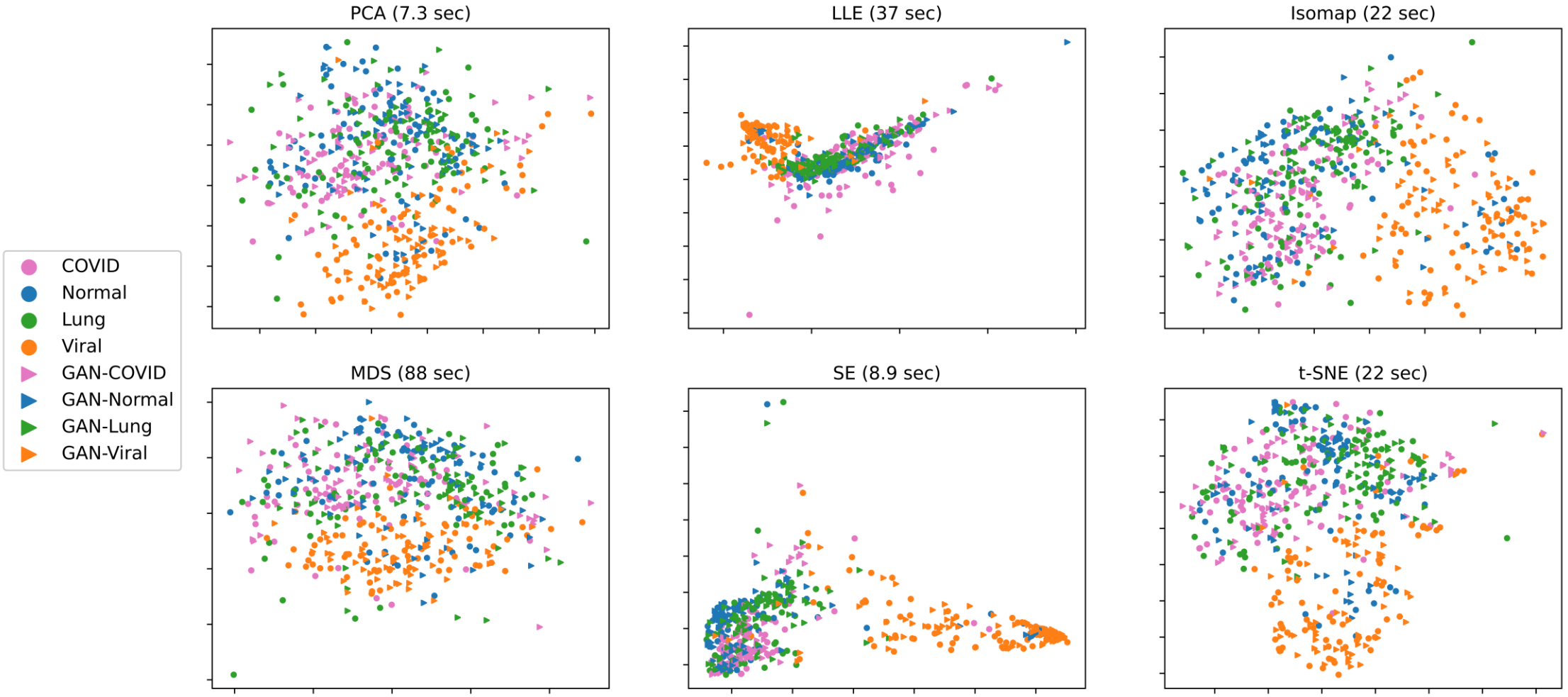
Lower FID means closer to real data distribution



Unconditional - COVID-19 Conditional - COVID-19

Blended Data Distribution Visualization

- Generative model to some extent reproduce real data distribution



Classification

- Method description
  - Convolutional Neural Network (CNN)
  - Layers: 13
  - Architecture: Conv2D, Dense, Dropout, MaxPooling2D, Flatten
  - Activation functions:

    ReLU and Softmax
  - Early stopping to avoid over-fitting

Table 2: Hyper-parameter settings

Optimizer	Loss	Metrics	Batch Size	Epochs
Adam	sparse_categorical_crossentropy	Accuracy	32	20

- Blended Data

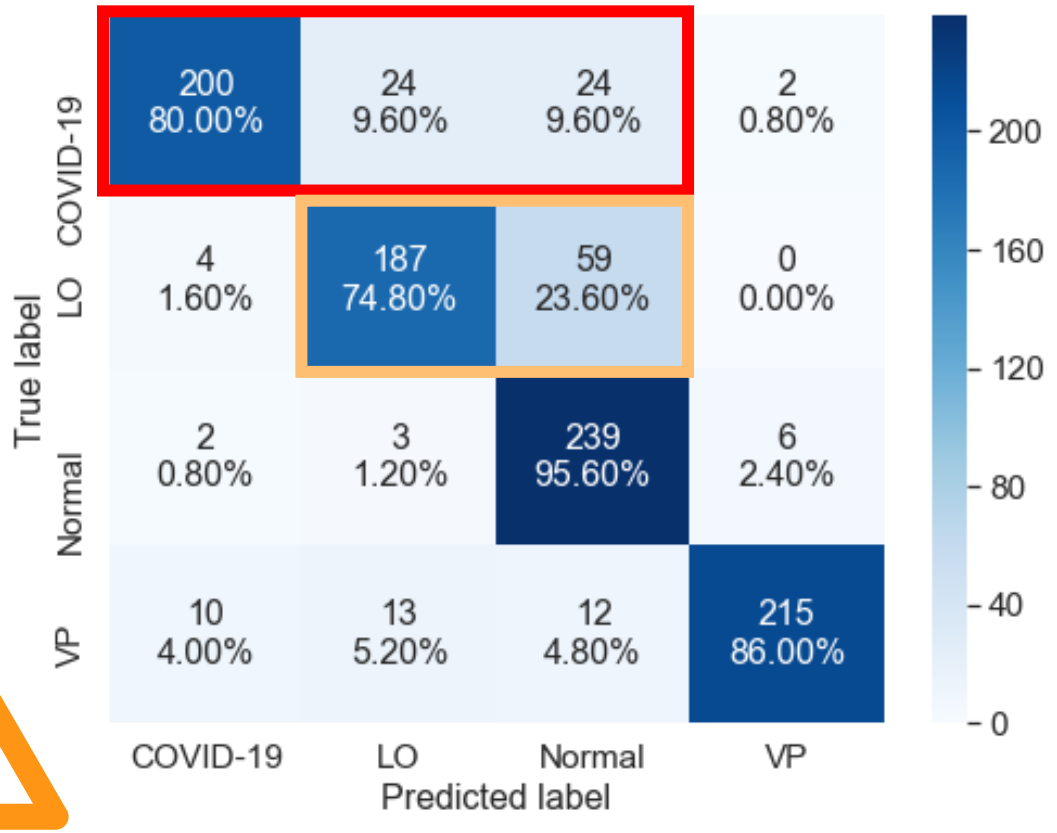
Table 5: Experiments on Data Combination

Data	Validation Acc[a]	Prediction Acc per Class[b]			
		COVID	Lung	Normal	Viral
Real only	86.41%	92.4%	75.2%	82.4%	92.0%
Real + 3,634 COVID synthesis	88.04%	90.4%	**82.4%**	89.2%	95.2%
Real + 1,238 Lung synthesis	86.05%	88.8%	81.2%	88.8%	90.4%
Real + 5,905 Viral synthesis	89.09%	94.4%	80.04%	87.6%	94.8%
Real + 3,634 COVID & 5,905 Viral synthesis	**90.35%**	**95.2%**	80.0%	**91.6%**	96.4%
Real + 3,634 COVID&1,238 Lung&5,905 Viral synthesis	89.35%	94.4%	81.2%	89.2%	**97.2%**

[a,b] Different from Sec.4.1, here we use $\#correct/\#prediction$ in validation set[a] and testing set[b] as accuracy.

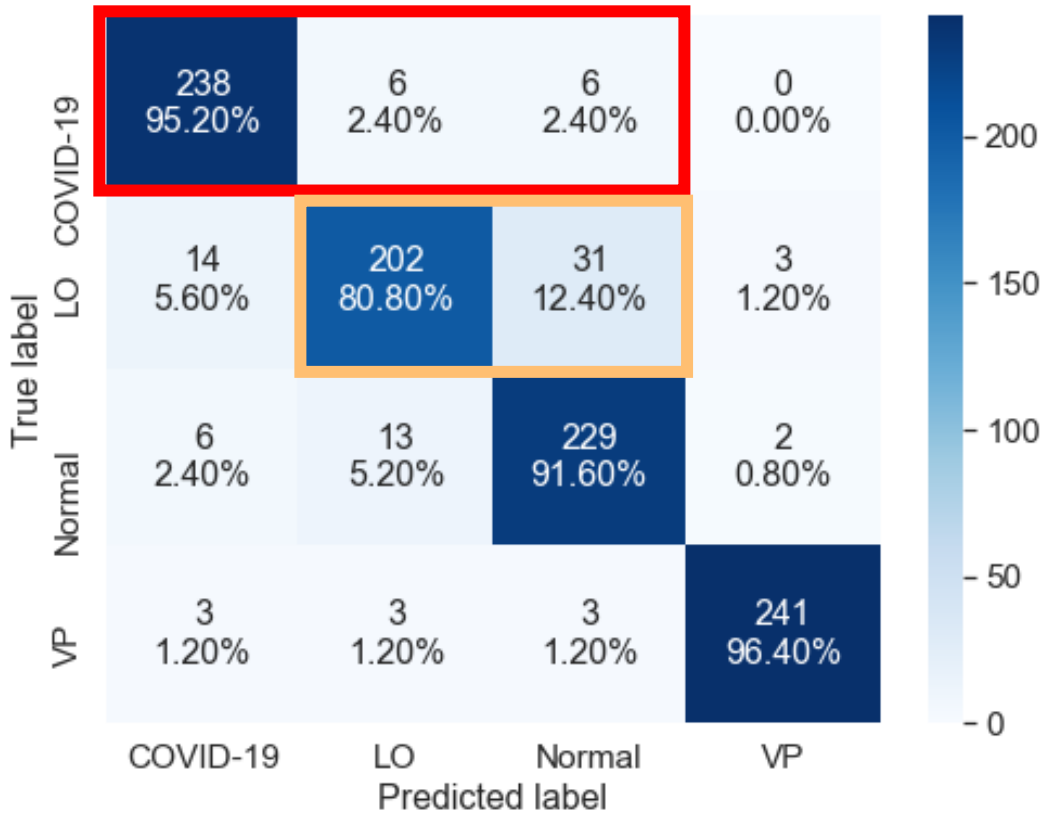
Evaluation on the Classification

Real Data



Overall Accuracy: 84.1%

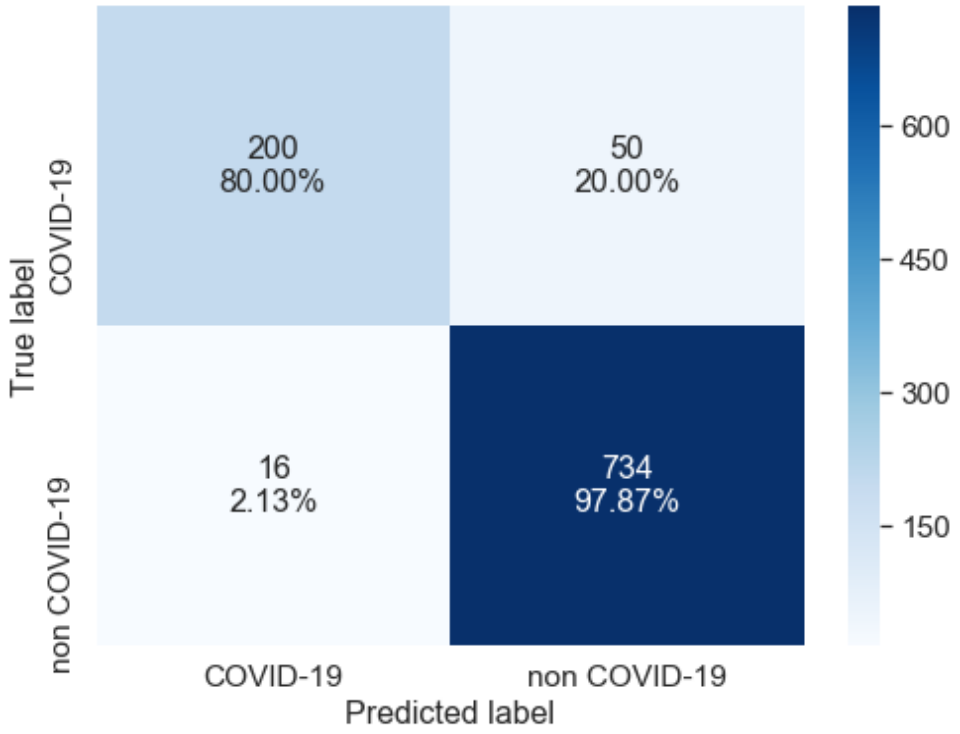
Real Data +
Synthetic Data (COVID-19 & Viral)



Overall Accuracy: 91%

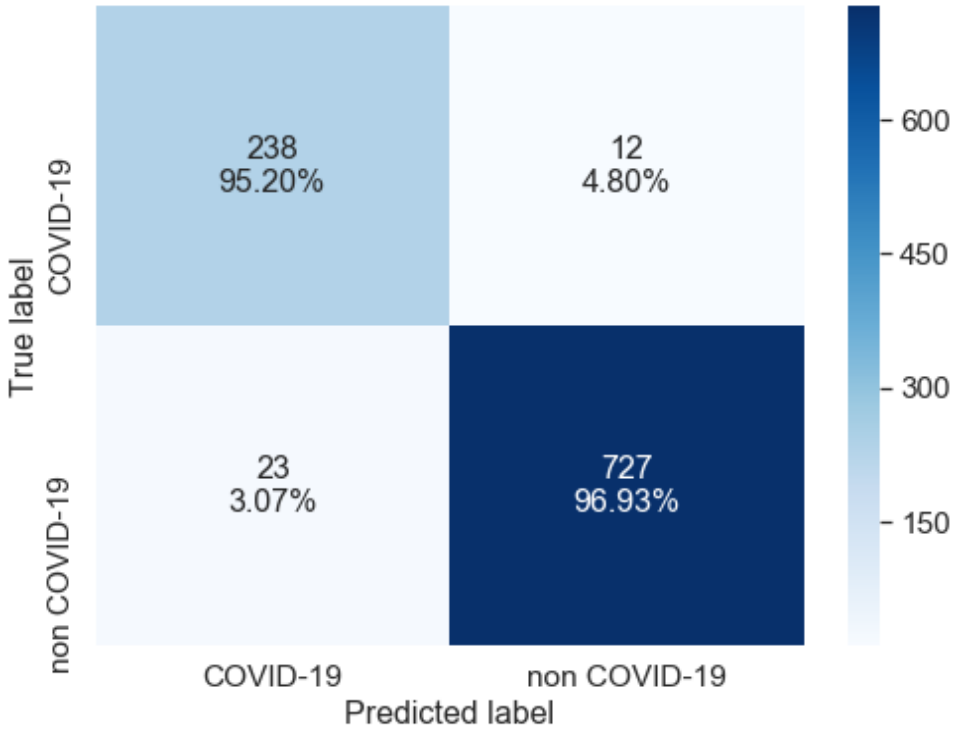
Evaluation on the Classification

Real Data



Accuracy=0.934
Precision=0.936
Recall=0.979
F1 Score=0.957

Real Data +
Synthetic Data (COVID-19 & Viral)



Accuracy=0.965
Precision=0.984
Recall=0.969
F1 Score=0.976

Summary

- Dimensionality reduction methods can work as a visualization and evaluation means to visualize data distribution and get data distribution observation.
- High-quality chest X-ray images synthesis with limited data can be synthesized via a conditional GAN.
- We transfer the COVID-19 CXR detection problem to a 4-class classification problem considering other non-COVID lung infectious CXRs as well.
- We validate the effectiveness of synthetic images for medical data augmentation and visual classification enhancement.
- Qualitatively and quantitatively verify the potential of image generative model to assist in new respiratory infectious disease detection.