



Segmentation of lung lobes and lesions in CT scans for severity classification of covid-19

Member:

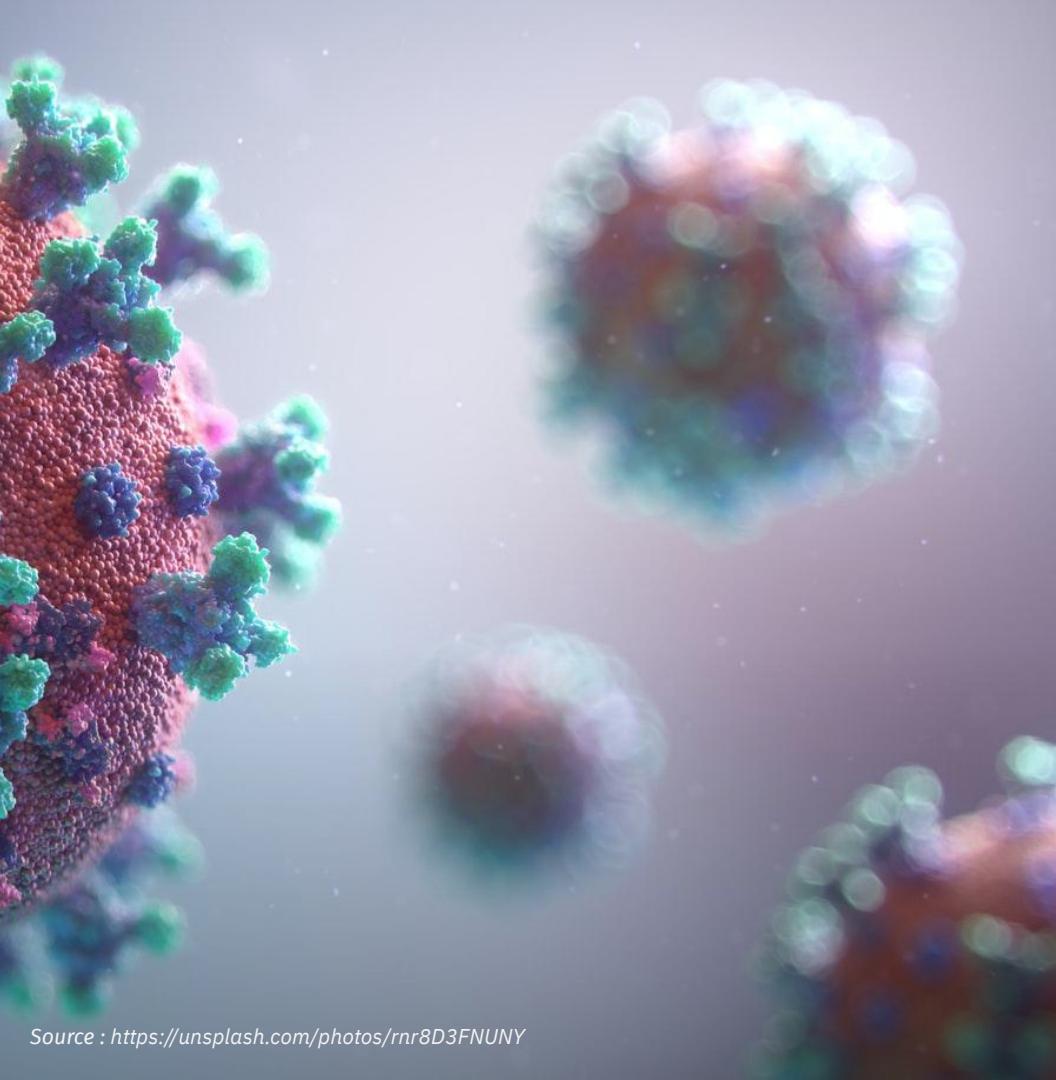
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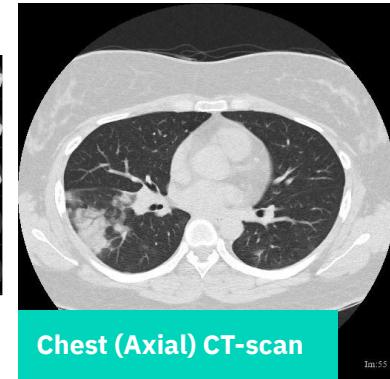
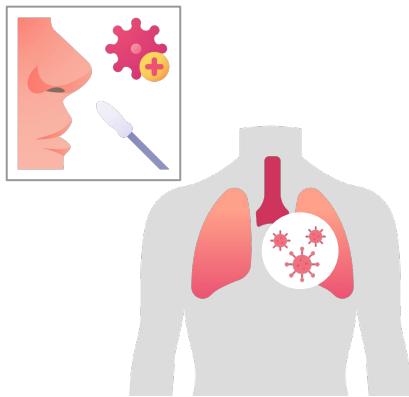
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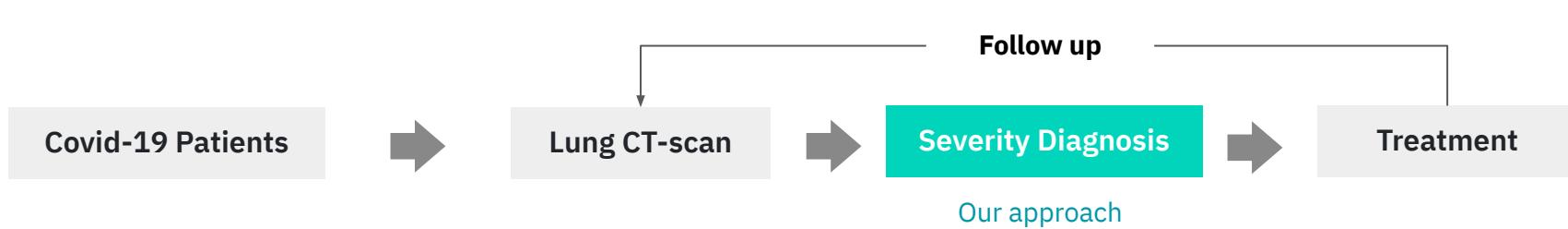
Outline

- Introduction
- Data Preparation
- Models
- Test1 Result
- Percentage of Infection & TSS
- Test2 Result
- Discussion
- Conclusion

Introduction



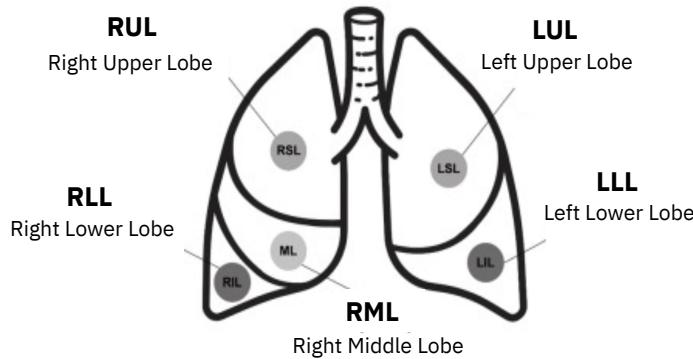
Chest (Axial) CT-scan



Total Severity Score (TSS)

Range from 0 to 25

- Total Severity Score (TSS) is the Sum of Individual Lobar score.

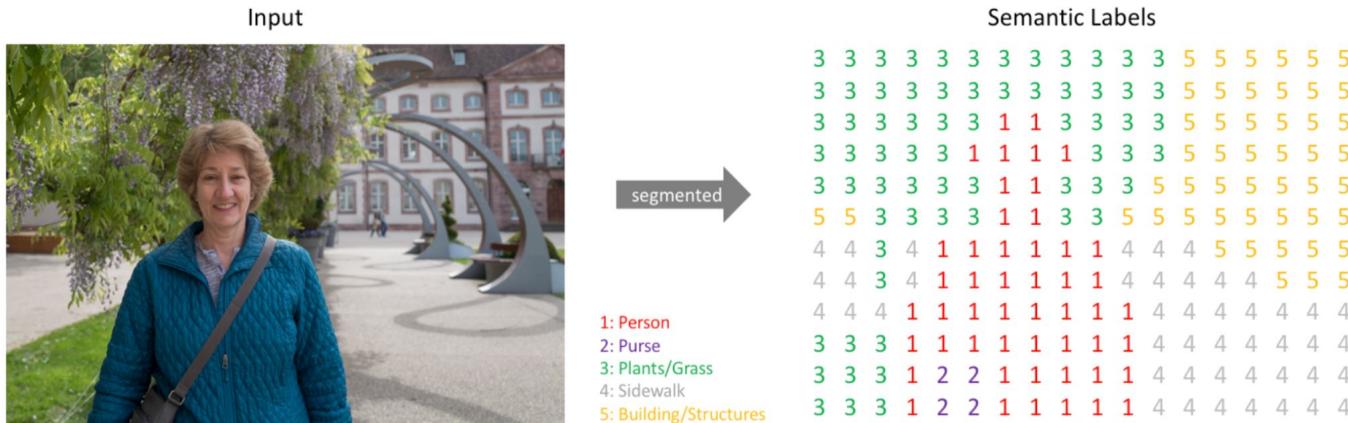


Percentage of Infection: PI	CT-Score
0%	0
<= 5 %	1
6% - 25%	2
26% - 50%	3
51% - 75%	4
> 75%	5

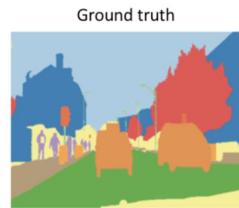
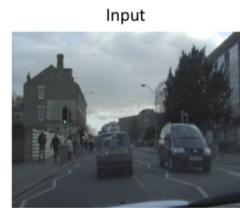
Score	Severity Type
<= 7	Mild
8-17	Moderate
>= 18	Severe

Semantic Segmentation

Deep Learning Technology



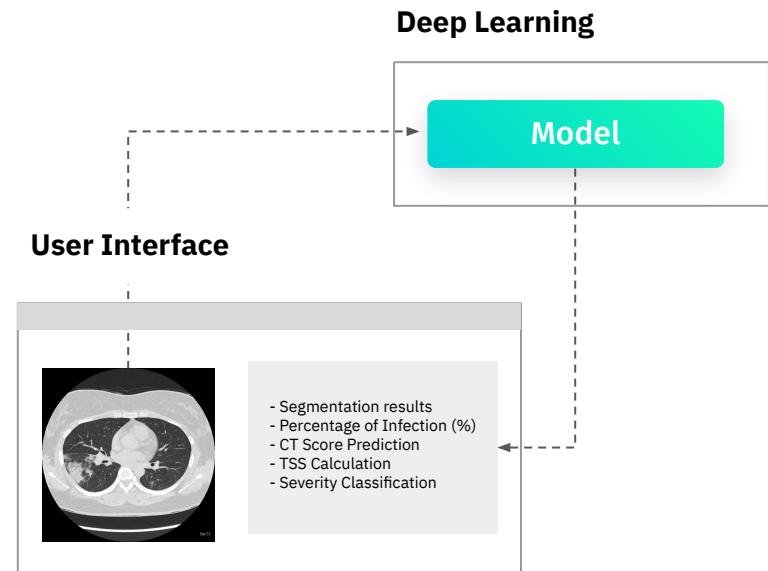
Autonomous driving



Source : <https://www.jeremyjordan.me/semantic-segmentation/>

Objectives

- To Apply Deep Learning Technology to Segment Lung Lobes and Lesions for Severity Classification of COVID-19 CT scans.
- To Create User Interface that Assist the Medical Personnel with Accurately and Detecting Lung Lesions.



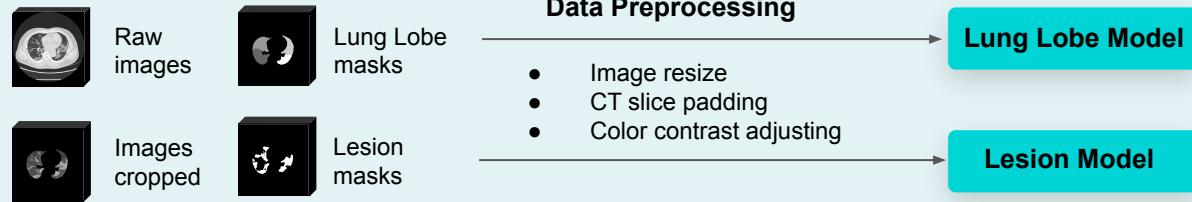
Workflow

TRAINING

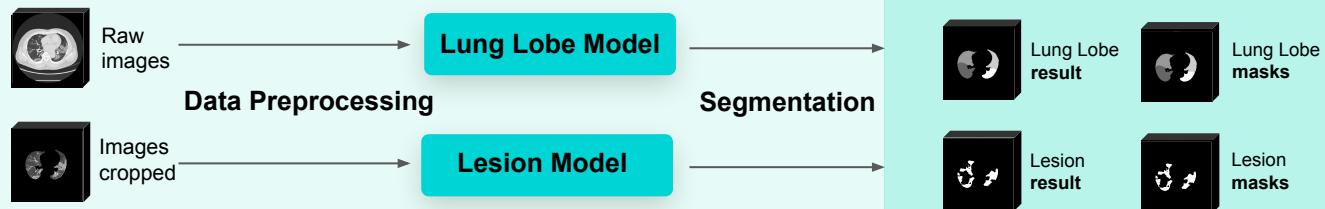
TESTING

IMPLEMENTATION

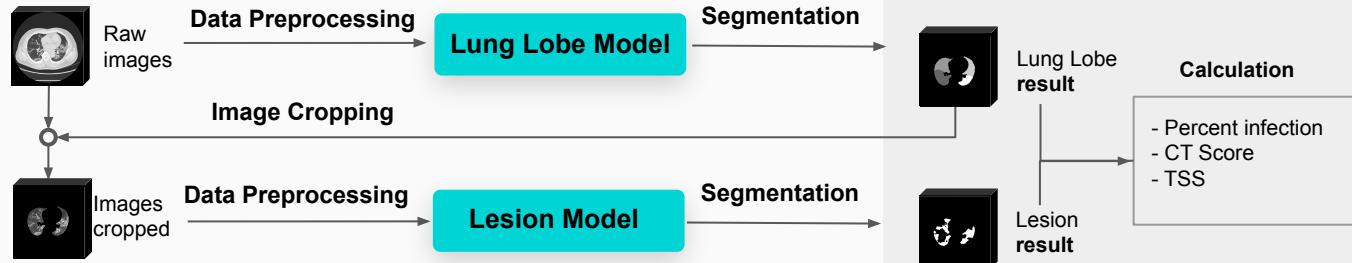
Training set



Test set 1

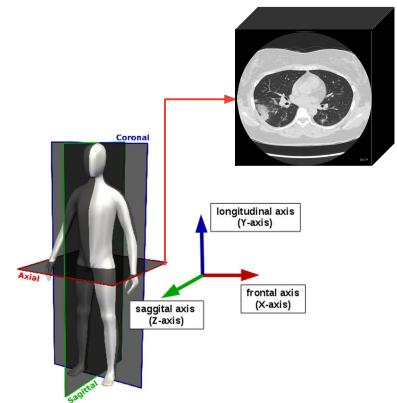


Test set 2



Dataset

1 Patients = CT-scan (Axial)



Dataset	Covid-19 Patients		
	No Lesion	Lesion	Total
Train set	8	24	32
Test Set 1	2	6	8
Test Set 2	15	47	62

- For Model Training
- Model **DSC** Testing
- **TSS** Testing

Totals Patients: 100 cases

*same 2 severe cases

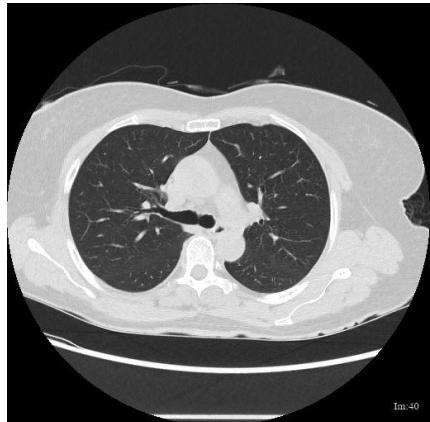
Test Set 2			
No Lesion	Mild	Moderate	Severe
15	15	26	6

DSC: Dice Similarity Coefficient

Dataset

Raw data

Axial

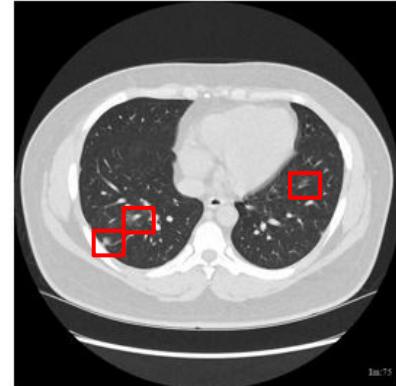


512 pixels

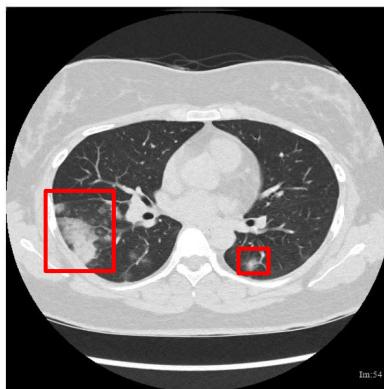
512 pixels



Normal



Mild



Moderate

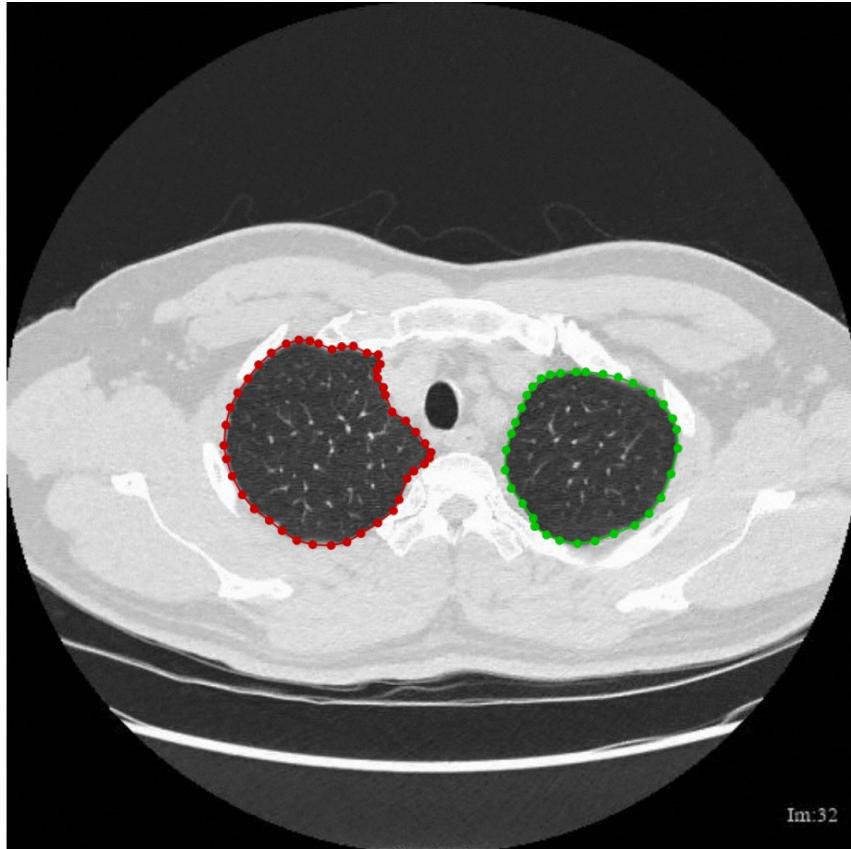
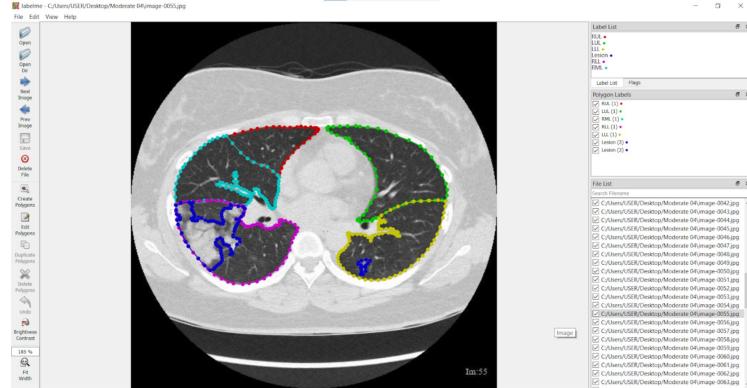


Severe

Image Annotation



labelme

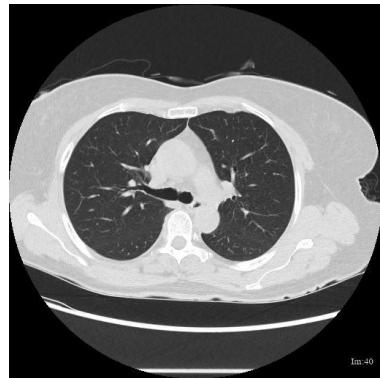


Data Preparation

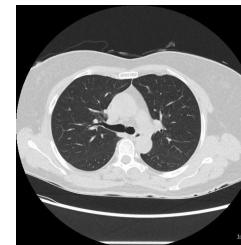
Image size

Number of CT slice

Image color adjustment



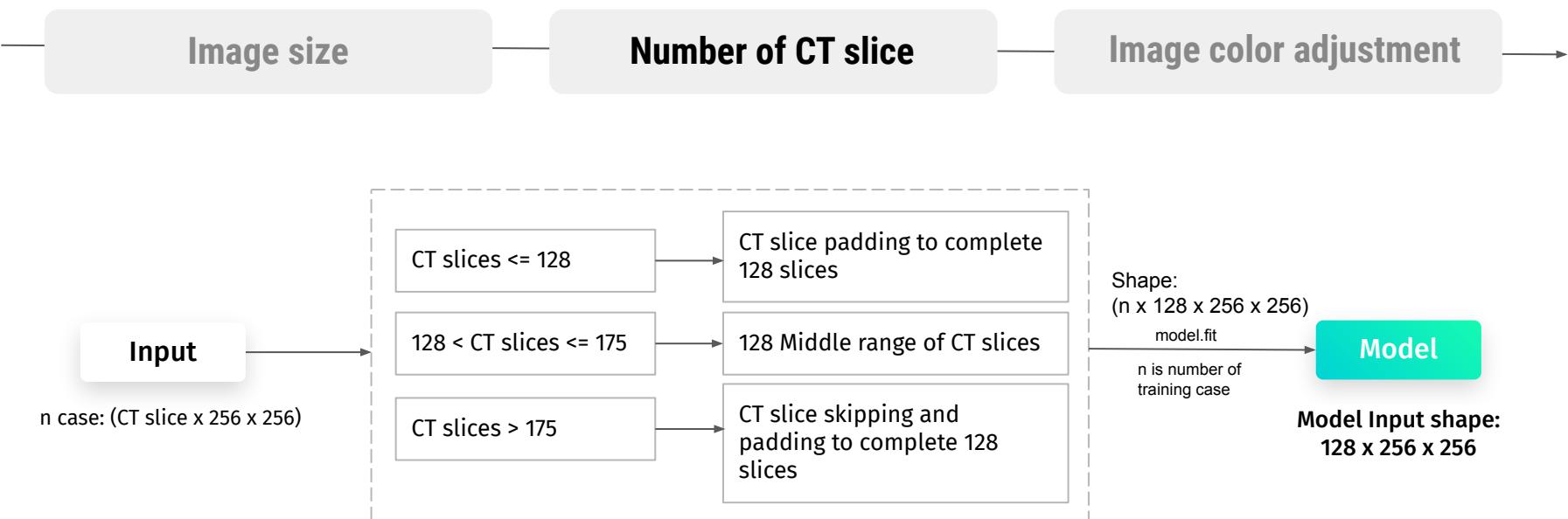
512 pixels



256
pixels

256 pixels

Data Preparation



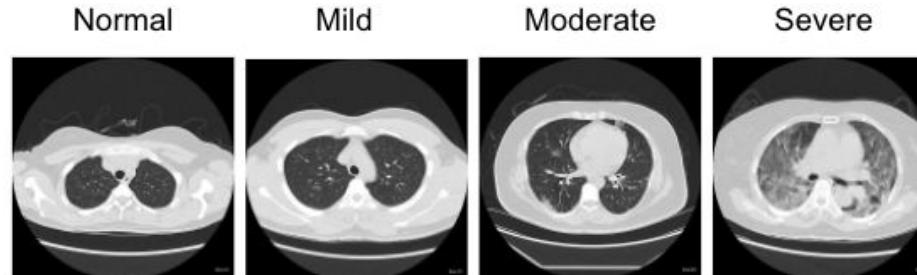
Data Preparation

Image size

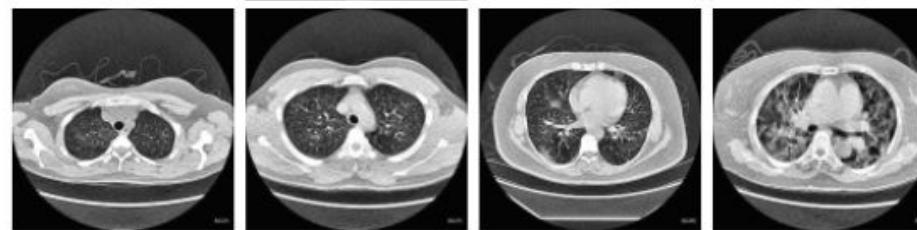
Number of CT slice

Image color adjustment

Raw Image

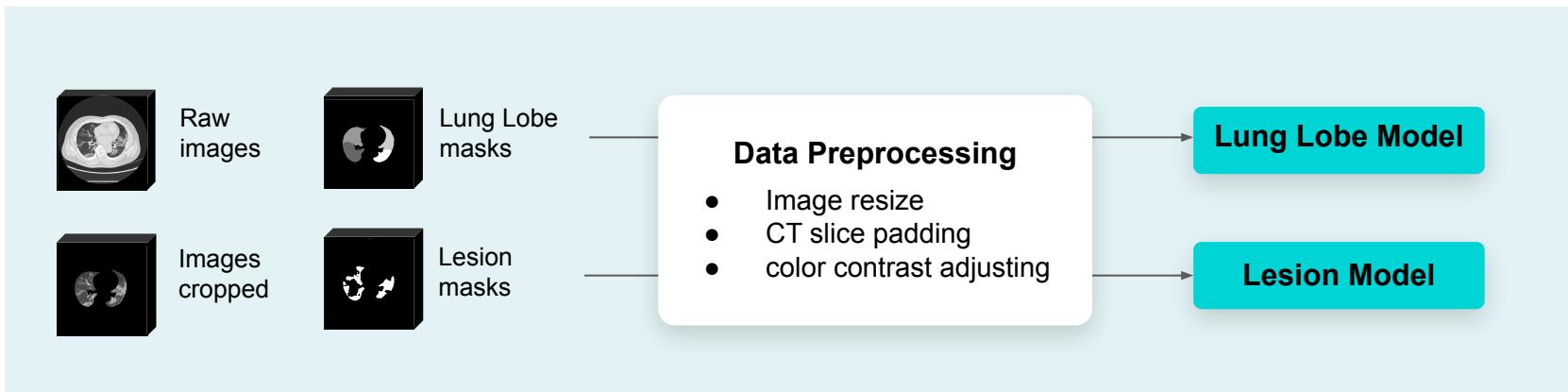


CLAHE



Model

Model Training

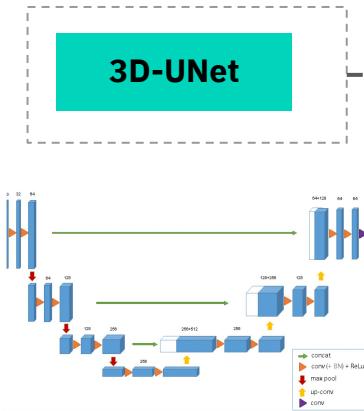


Server Specification

- (Intel(R) Xeon(R) Gold 6126 CPU @ 2.60GHz
- NVIDIA Tesla V100 SXM2 GPU
- 40 GB RAM

Model

Structure



Pretrained Models Backbone

DenseNet Structure

DenseNet 121

DenseNet 169

DenseNet 201

ResNet Structure

ResNet 18

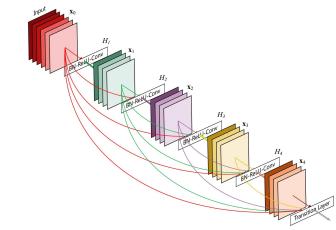
ResNet 32

ResNet 50

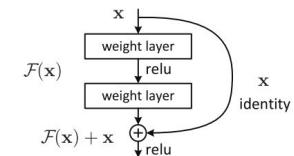
ResNet 101

ResNet 152

DenseNet



ResNet



Hyperparameter Tuning

Loss Function

Loss function	IoU	DSC
Dice loss	87.05%	92.65%
Focal loss	82.32%	89.54%
Focal loss + Dice loss	87.14%	92.73%

Regularizer

Regularizer	IoU	DSC
L1	87.71%	93.06%
L2	87.88%	93.20%

Regularizer	Value	IoU	DSC
L2	0.1	88.44%	93.38%
L2	0.01	88.73%	93.59%

Dropout

Lung lobe model		
Dropout rate	IoU	DSC
0.2	89.52%	92.18%
0.3	89.37%	92.04%
0.4	87.54%	90.40%

Lesion model		
Dropout rate	IoU	DSC
0.2	76.88%	81.68%
0.3	74.71%	79.68%
0.4	79.35%	84.03%
0.5	74.78%	79.34%

Model Parameter Setting

Lung Lobe Model

Training Parameters	Value
Activation Function	Softmax
Loss Function	Focal loss + Dice loss
Optimizer	Adam
Learning Rate	0.0001
Dropout Rate	0.2
Regularizer	L2 = 0.01
Batch Size	1
Max Epochs	200
Epochs Patience	20

Lesion Model

Training Parameters	Value
Activation Function	Sigmoid
Loss Function	Focal loss + Dice loss
Optimizer	Adam
Learning Rate	0.0001
Dropout Rate	0.4
Regularizer	L2 = 0.01
Batch Size	1
Max Epochs	200
Epochs Patience	50

Lung Lobe Model Result

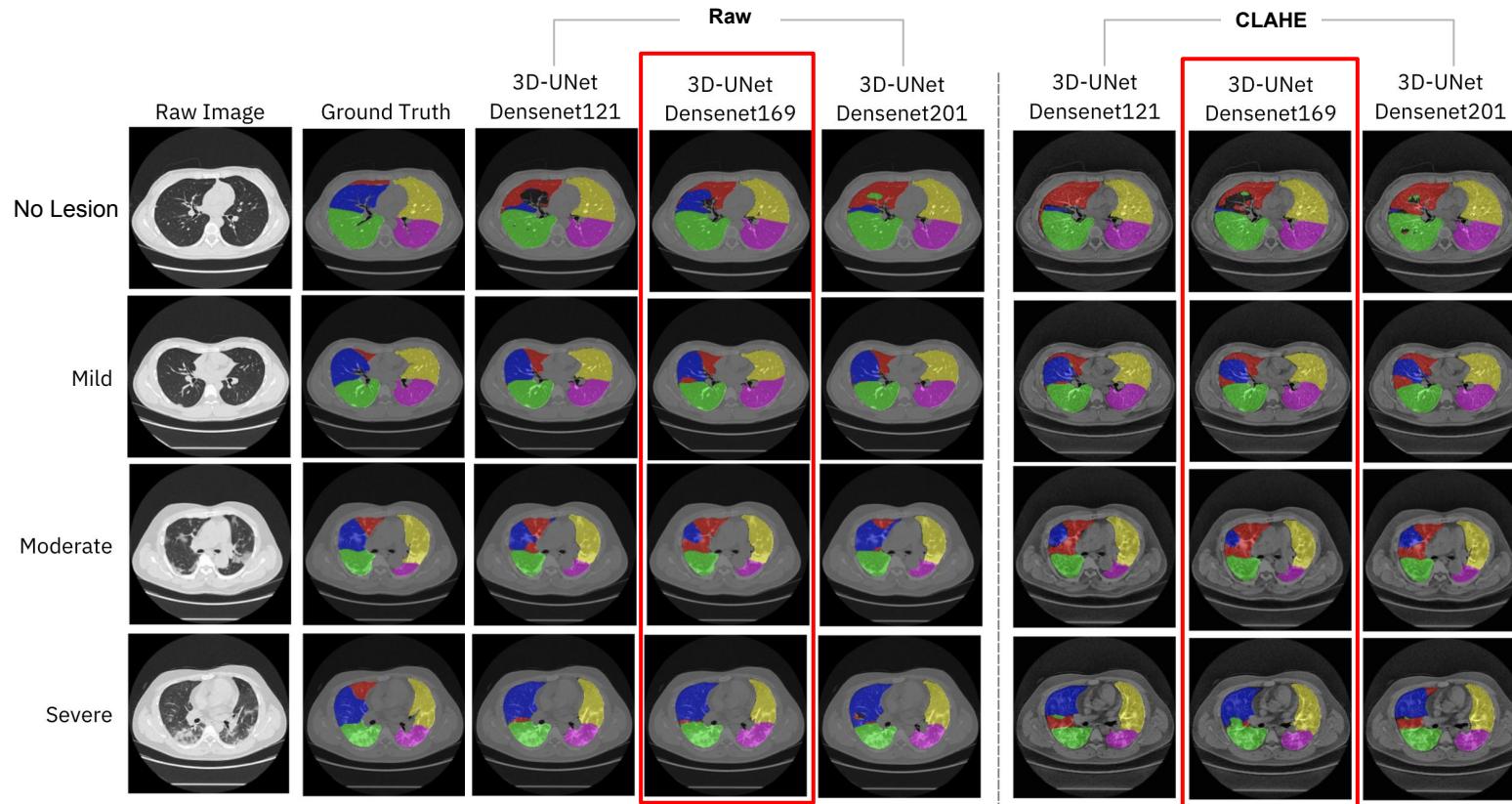
With Test set 1

Model	Backbone	Color	IoU	DSC	Accuracy	Precision	Sensitivity	Specificity
3D-Unet	DenseNet121	Raw	89.36%	91.85%	98.46%	94.00%	94.67%	98.48%
3D-Unet	DenseNet169	Raw	90.44%	92.89%	98.49%	94.18%	95.52%	98.49%
3D-Unet	DenseNet201	Raw	89.58%	92.11%	98.47%	94.15%	94.77%	98.50%
3D-Unet	ResNet18	Raw	88.24%	90.88%	98.43%	93.55%	94.11%	98.48%
3D-Unet	ResNet34	Raw	88.53%	91.11%	98.45%	93.82%	93.94%	98.50%
3D-Unet	ResNet50	Raw	88.70%	91.44%	98.45%	93.80%	94.18%	98.49%
3D-Unet	ResNet101	Raw	87.92%	90.68%	98.45%	93.89%	93.23%	98.50%
3D-Unet	ResNet152	Raw	88.30%	91.01%	98.45%	93.69%	93.83%	98.50%

Model	Backbone	Color	IoU	DSC	Accuracy	Precision	Sensitivity	Specificity
3D-Unet	DenseNet121	CLAHE	87.49%	90.25%	98.45%	93.02%	93.62%	98.51%
3D-Unet	DenseNet169	CLAHE	88.75%	91.50%	98.46%	94.58%	93.50%	98.51%
3D-Unet	DenseNet201	CLAHE	87.48%	90.29%	98.44%	93.40%	93.24%	98.50%
3D-Unet	ResNet18	CLAHE	86.34%	89.37%	98.41%	93.14%	92.42%	98.51%
3D-Unet	ResNet34	CLAHE	86.61%	89.54%	98.42%	92.78%	92.92%	98.49%
3D-Unet	ResNet50	CLAHE	86.52%	89.62%	98.43%	93.27%	92.37%	98.51%
3D-Unet	ResNet101	CLAHE	86.20%	89.07%	98.43%	90.55%	94.76%	98.47%
3D-Unet	ResNet152	CLAHE	83.17%	86.03%	98.45%	88.72%	93.55%	98.50%

Lung Lobe Model Result

Model	Backbone	Color	IoU	DSC	Accuracy	Precision	Sensitivity	Specificity
3D-Unet	DenseNet169	Raw	90.44%	92.89%	98.49%	94.18%	95.52%	98.49%
3D-Unet	DenseNet169	CLAHE	88.75%	91.50%	98.46%	94.58%	93.50%	98.51%



Model Result

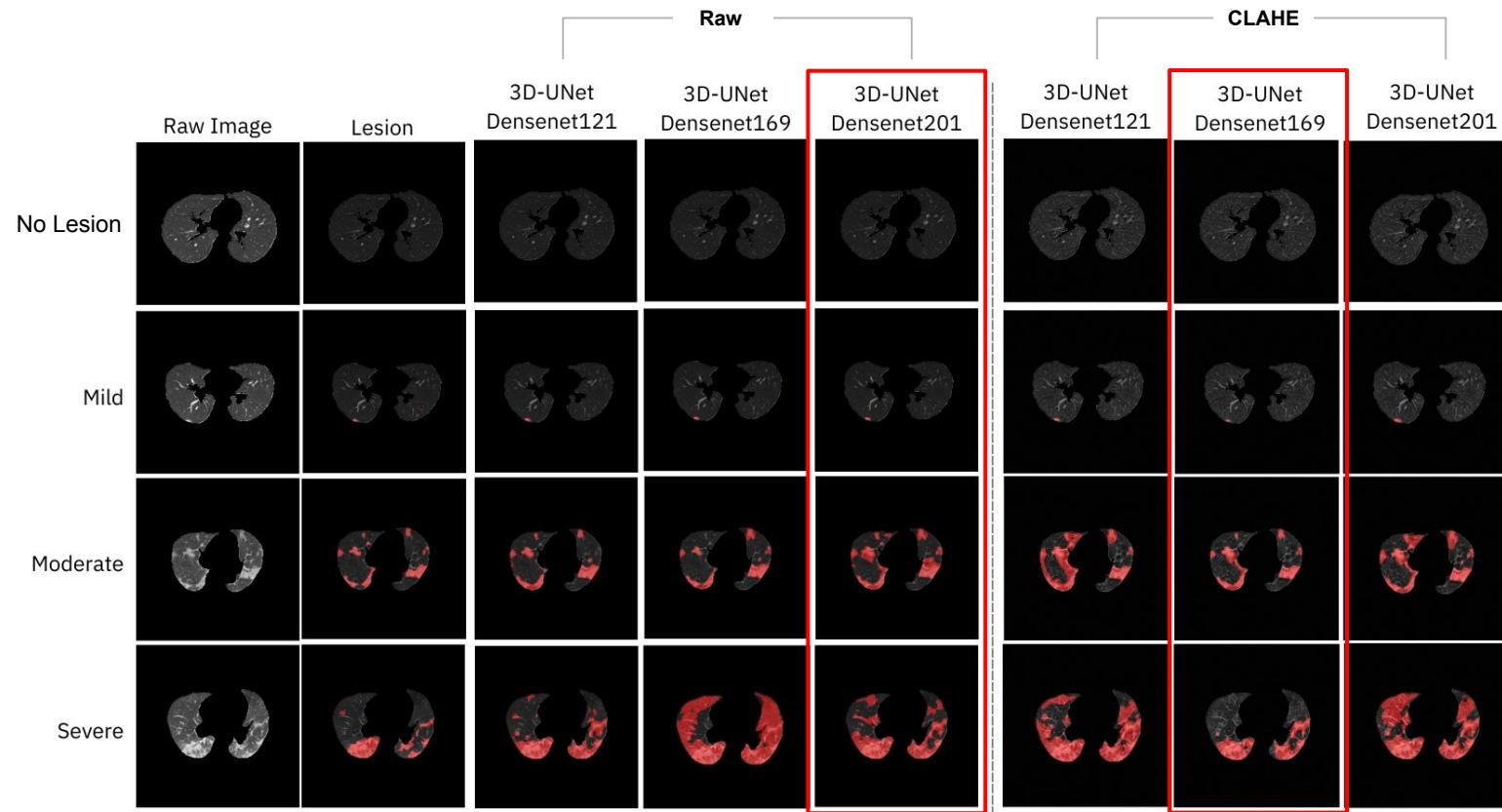
With Test set 1

Model	Backbone	Color	IoU	DSC	Accuracy	Precision	Sensitivity	Specificity
3D-Unet	DenseNet121	Raw	72.74%	78.22%	98.73%	78.49%	93.37%	98.75%
3D-Unet	DenseNet169	Raw	76.07%	81.23%	98.73%	78.49%	93.37%	98.75%
3D-Unet	DenseNet201	Raw	79.35%	84.03%	98.81%	84.52%	92.02%	98.85%
3D-Unet	ResNet18	Raw	73.99%	78.49%	98.41%	77.72%	93.52%	98.42%
3D-Unet	ResNet34	Raw	72.34%	76.92%	98.57%	75.55%	94.33%	98.56%
3D-Unet	ResNet50	Raw	75.89%	80.52%	98.51%	79.13%	94.24%	98.48%
3D-Unet	ResNet101	Raw	72.02%	76.29%	98.34%	76.30%	92.87%	98.33%
3D-Unet	ResNet152	Raw	67.84%	72.46%	98.62%	71.59%	93.51%	98.64%

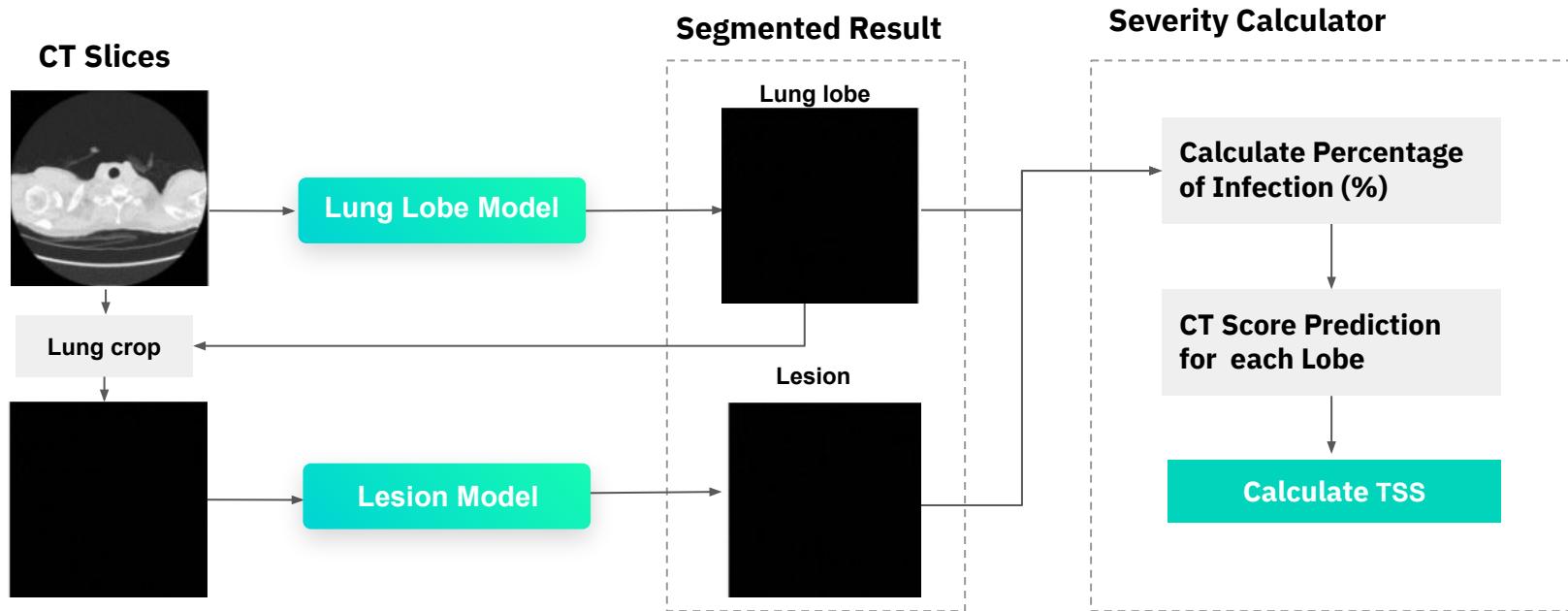
Model	Backbone	Color	IoU	DSC	Accuracy	Precision	Sensitivity	Specificity
3D-Unet	DenseNet121	CLAHE	66.72%	71.44%	95.16%	98.86%	86.70%	89.07%
3D-Unet	DenseNet169	CLAHE	79.61%	84.22%	98.86%	86.70%	89.07%	98.91%
3D-Unet	DenseNet201	CLAHE	73.01%	77.75%	98.48%	76.64%	93.91%	98.49%
3D-Unet	ResNet18	CLAHE	64.32%	68.67%	98.08%	67.83%	93.72%	98.05%
3D-Unet	ResNet34	CLAHE	68.63%	73.26%	98.35%	72.06%	94.37%	98.33%
3D-Unet	ResNet50	CLAHE	68.41%	73.24%	98.19%	71.80%	93.91%	98.13%
3D-Unet	ResNet101	CLAHE	78.59%	83.45%	98.95%	85.57%	89.23%	99.05%
3D-Unet	ResNet152	CLAHE	76.57%	81.05%	98.69%	82.61%	90.38%	98.72%

Lesion Model Result

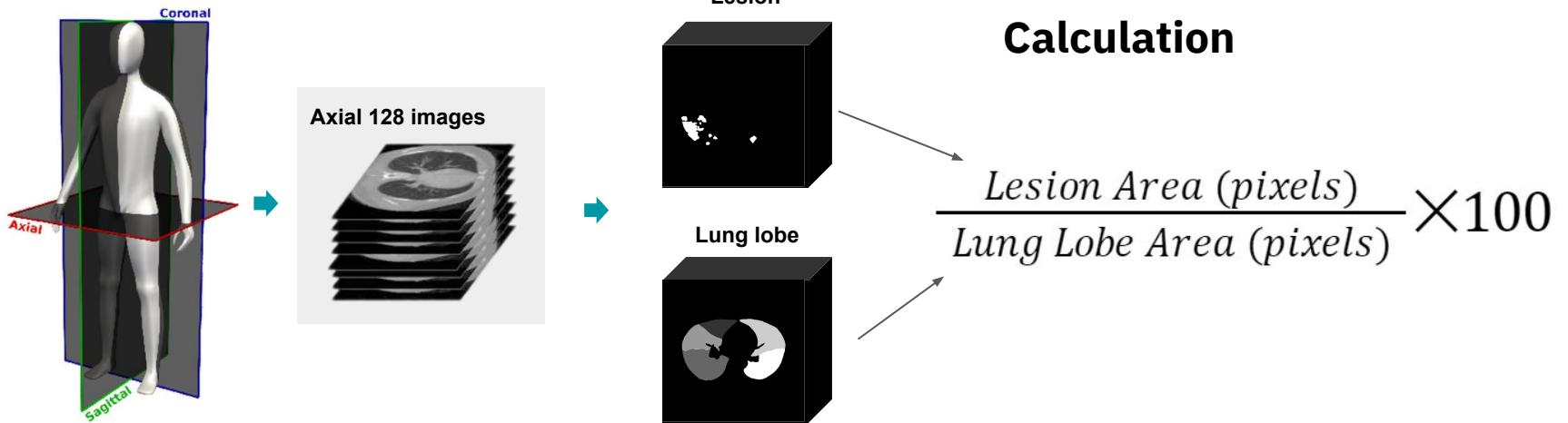
Model	Backbone	Color	IoU	DSC	Accuracy	Precision	Sensitivity	Specificity
3D-Unet	DenseNet201	Raw	79.35%	84.03%	98.81%	84.52%	92.02%	98.85%
3D-Unet	DenseNet169	CLAHE	79.61%	84.22%	98.86%	86.70%	89.07%	98.91%



Model Implementation



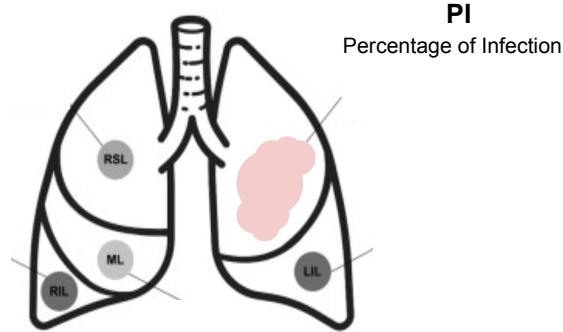
Percentage of Infection Calculation



Total Severity Score (TSS)

Range from 0 to 25

- Total Severity Score (TSS) is the Sum of Individual Lobar score.



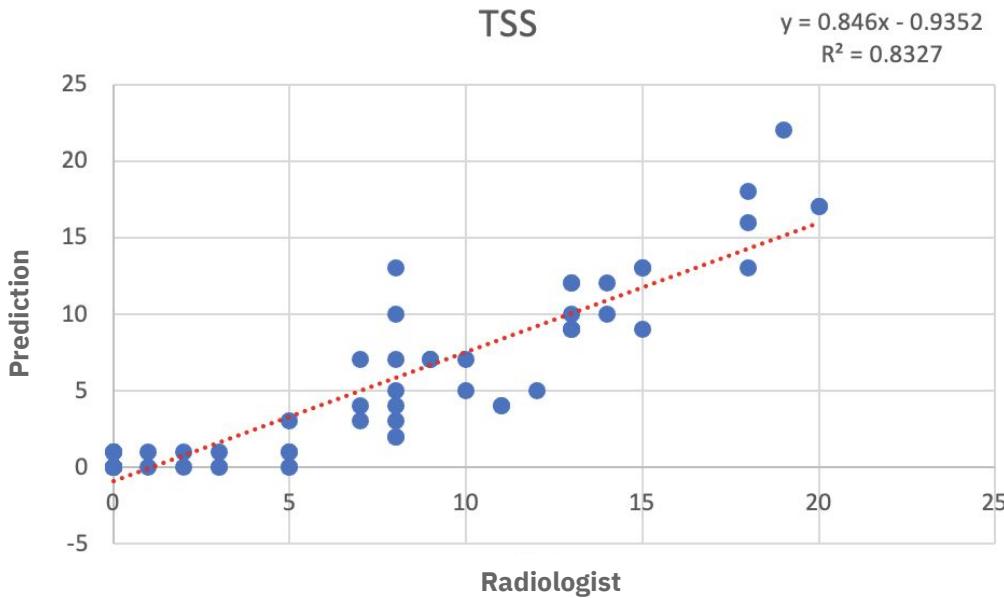
Percentage of Infection: PI	CT-Score
0%	0
<= 5 %	1
6% - 25%	2
26% - 50%	3
51% - 75%	4
> 75%	5

Score	Severity Type
<= 7	Mild
8-17	Moderate
>= 18	Severe

TSS R-Square

Test set 2

Regression Statistics	
Correlation Coefficient	0.9125
R square	0.8327
Observations	62
p-value	< 0.001



User Interface



Hospital Number



CT-scans Image



The screenshot shows a Streamlit application window titled "COVID-19 Severity Calculator (CSC)". On the left, there is a sidebar labeled "INFORMATION" containing a "See more Description" button and two input fields: "Hospital Number" and "Choose CT scan File". Below these are buttons for "Predict" and "Save", and a message "Please Choose the CT-Scan Files". On the right, a large teal-bordered area is labeled "Show result". At the bottom of the window, it says "Made with Streamlit".

INFORMATION

Please Fill the Hospital Number

Hospital Number

Choose CT scan File

Drag and drop files here
Limit 200MB per file • JPG

Browse files

Predict Save

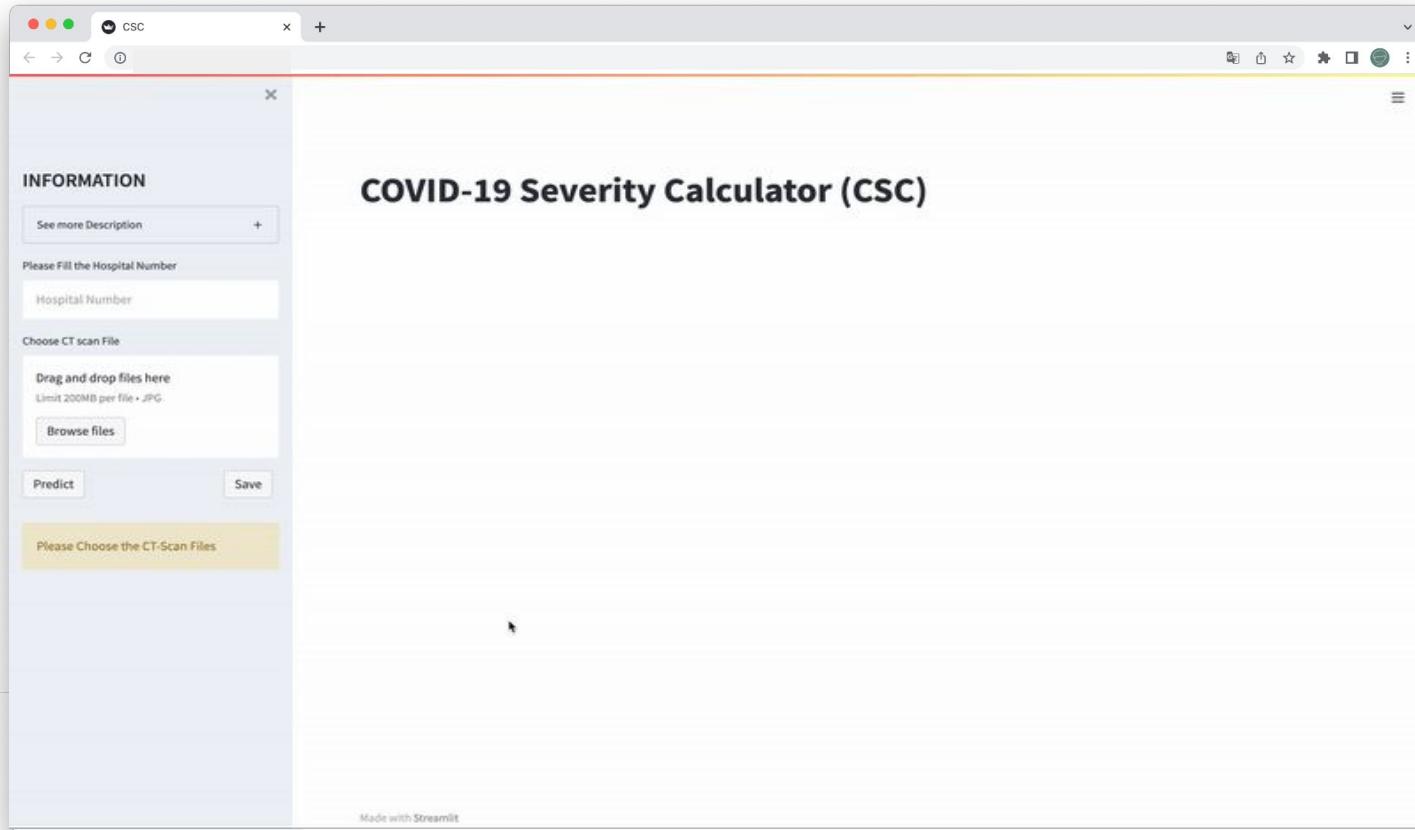
Please Choose the CT-Scan Files

COVID-19 Severity Calculator (CSC)

Show result

Made with Streamlit

User Interface



User Interface

COVID-19 Severity Calculator (CSC)

1 57 120

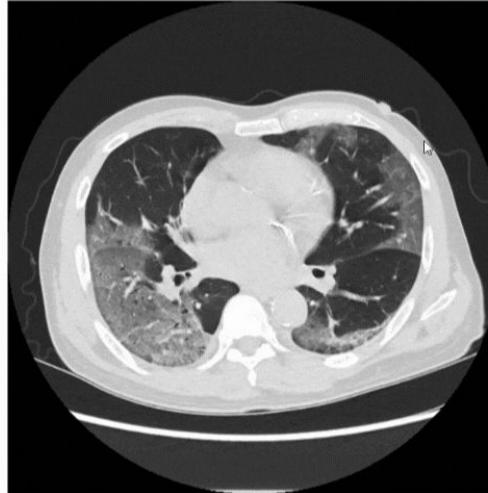
Please Fill the Hospital Number
123456

Choose CT scan File
Drag and drop files here
Limit 200MB per file • JPG
Browse files

image-0120.jpg 35.7KB
image-0119.jpg 33.7KB
image-0118.jpg 35.1KB

Showing page 1 of 40 < >

Predict Save



User Interface



Portable Document Format

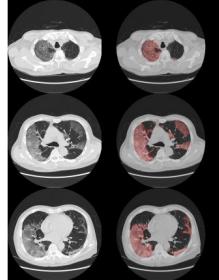
COVID-19 Patient's Information

Date: May-16-2022 Time:15.48.57
Hospital Number (HN): 123456
Total Severity Type(TSS): 18
Severity Type: Severe
Lung Involvement: 50.31%

Percentage of Infection Table

Lobe	Percentage of Infection	Score
Right Upper Lobe (RUL)	88	5
Right Lower Lobe (RLL)	74	4
Right Middle Lobe (RML)	26	3
Left Upper Lobe (LUL)	35	3
Left Lower Lobe (LLL)	29	3

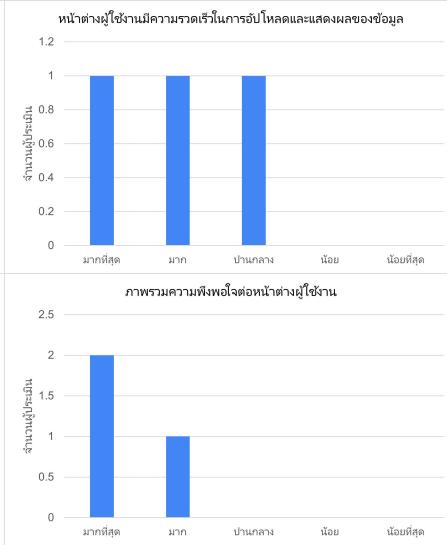
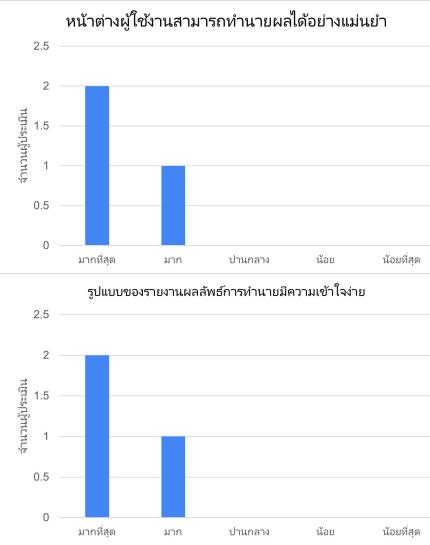
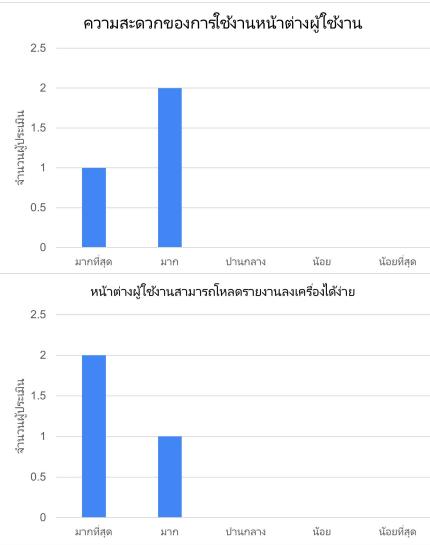
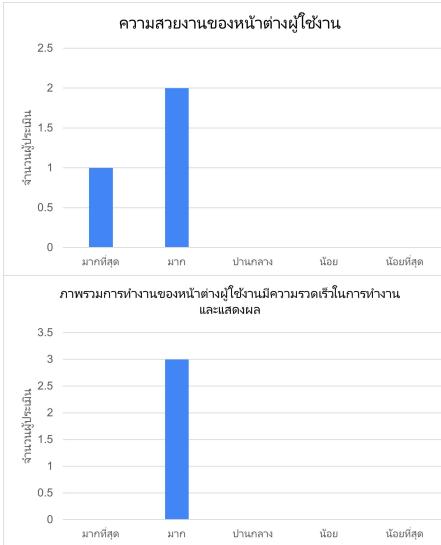
Example Lung Image



Comma-Separated Values

	Right Upper Lobe (RUL)	Right Lower Lobe (RLL)	Right Middle Lobe (RML)	Left Upper Lobe (LUL)	Left Lower Lobe (LLL)
Percentage of Infection	88	74	26	35	29
Score	5	4	3	3	3

Usability Test



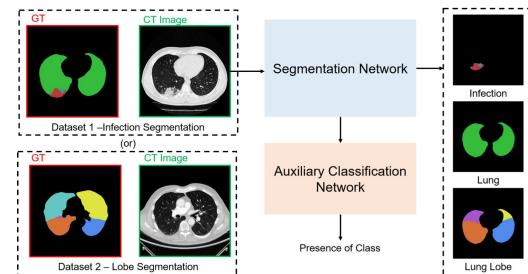
Discussion

Lung Lobe Segmentation Model

Research	Data Volume	Model	Backbone	DSC
Tang et al. 2019	Training: 40 CT Scans Testing: 10 CT Scans (LUNA16), 10 CT Scans (Tianchi)	V-Net	-	91.48% (LUNA16)
				94.17% (Tianchi)
Chen et al. 2020	Training: 40 CT Scans (LUNA16) Testing: 10 CT Scans (LUNA16)	LobeNet (3D-UNet)	-	93.35%
Visvanathan et al. 2021	Set 1: ภาพ Lung CT จำนวน 50 ชุด Set 2: ผู้ป่วย 150 ราย (750 ภาพ) Set 3: ผู้ป่วย 9 ราย (829 ภาพ) Set 4: ผู้ป่วย 50 ราย (200 ภาพ) Set 5: ภาพ Lung CT จำนวน 8 ชุด	CNN	-	85.68%
Our	Training/val: 32 cases (3,752 ภาพ) Testing: 8 cases (1,314 ภาพ)	3D-UNet	DenseNet 169	92.89%

Method	Test set	
	LUNA16	Tianchi
Dice loss	87.07%	88.30%
+ Focal loss	90.94%	92.25%
+ Convex hull	91.48%	94.17%

Method	DSC
LobeNet without GP&FA	87.67
LobeNet without FA	92.44
LobeNet	93.35



Discussion

Lesion Segmentation Model

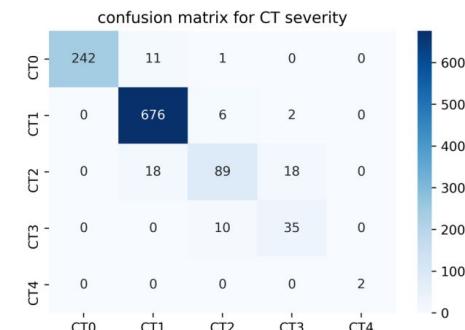
Research	Data Volume	Model	Backbone	DSC
Xiao et al. 2020	888 ชุด โดยมีร้อยละคร่าวม 1,186 รายโรค (Training: 70%, Testing: 20%, Verification: 10%)	3D-Res2UNet	-	95.30%
Qiblawey et al. 2021	Training 15,698 ภาพ Testing 46,411 ภาพ (ผู้ป่วย 856 ราย คุณภาพตัด 254 ราย)	FPN	DenseNet 201	94.13%
Our	Training/val: 32 cases (3,752 ภาพ) Testing: 8 cases (1,314 ภาพ)	3D-UNet	DenseNet 169	84.22%

Xiao et al. 2020

Model	DSC
UNet	81.32
3D-UNet	89.12
3D-UNet+fully CRF	93.25
3D-Res2UNet	95.30

Qiblawey et al. 2021

Model	Backbone	DSC
UNet	DenseNet 201	93.36
FPN	DenseNet 201	94.13

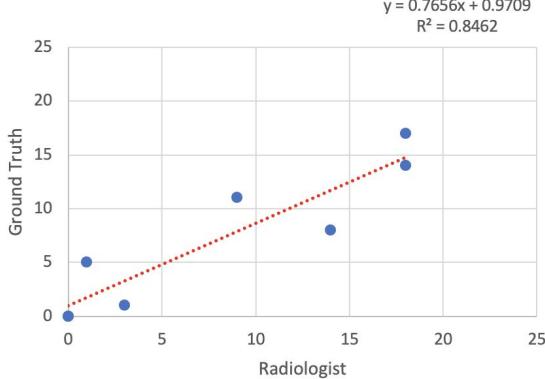


Discussion

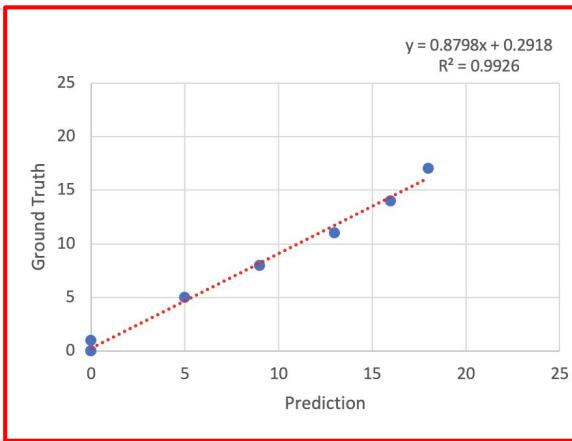
GT, Prediction, Radiologist

Regression Statistics	GT-Radiologist	GT - Prediction	Prediction - Radiologist
Correlation Coefficient	0.9199	0.9963	0.9177
R Square	0.8462	0.9926	0.8423
Adjusted R Square	0.8205	0.9914	0.8160
Standard Error	2.7917	0.6109	3.3968
Observations	8	8	8
p-value	<0.01	<0.001	<0.01

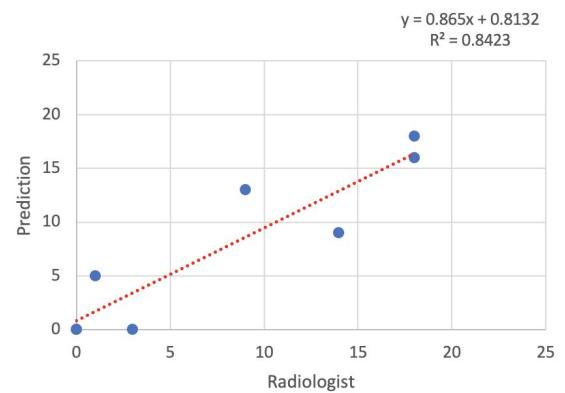
A) TSS (GT - Radiologist)



B) TSS (GT - Prediction)



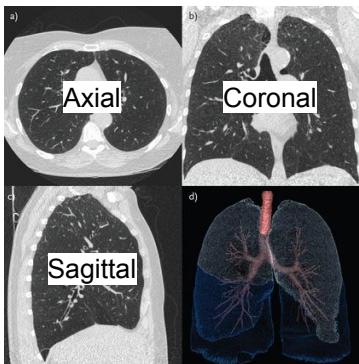
C) TSS (Prediction - Radiologist)



Future Development

Datasets

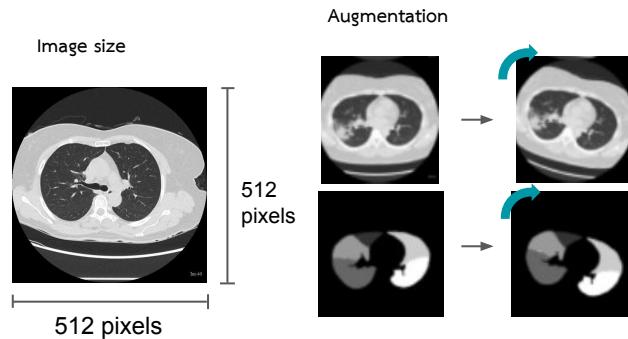
- Increase datasets
- Type lesion labeling (GGO, Consolidation)
- Labeling 3 dimension (Axial, Coronal, Sagittal)



<https://breathe.ersjournals.com/content/9/1/36.figures-only>

Model

- Train with image size 512x512 pixels
- Augmentation (Rotation)
- Deploy model on cloud



User Interface

- Visualization 3 dimension
- Classify type of lesion and predict disease
- Database system
- Upload dataset 3 planes (e.g. DICOM files)
- Deploy UI on cloud



Google Cloud



Azure



Streamlit
Cloud

Conclusion

Semantic Segmentation



Chest (Axial) CT-scan



Model

Lung Lobe Model

Model:
3D-Unet+Densenet169

Color: Raw Image

DSC: 92.89%

Lesion Model

Model:
3D-Unet+Densenet169

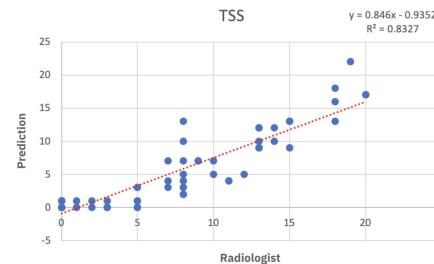
Color: CLAHE

DSC: 84.22%

TSS Result

Correlation Coefficient : 0.91

R Square: 0.83



UI Usability Test

Overview score:

Very Good

