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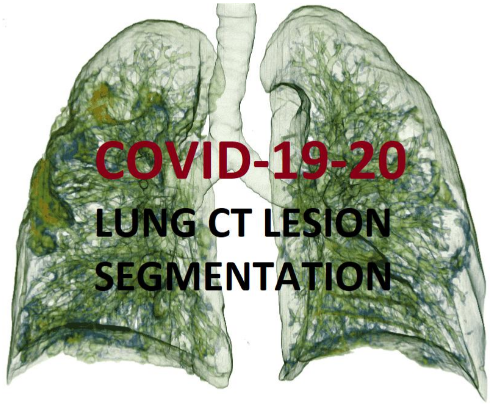

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Semi-supervised Method for COVID-19 Lung CT Lesion Segmentation

Shishuai Hu, Jianpeng Zhang, and Yong Xia*

School of Computer Science
Northwestern Polytechnical University
Xi'an China

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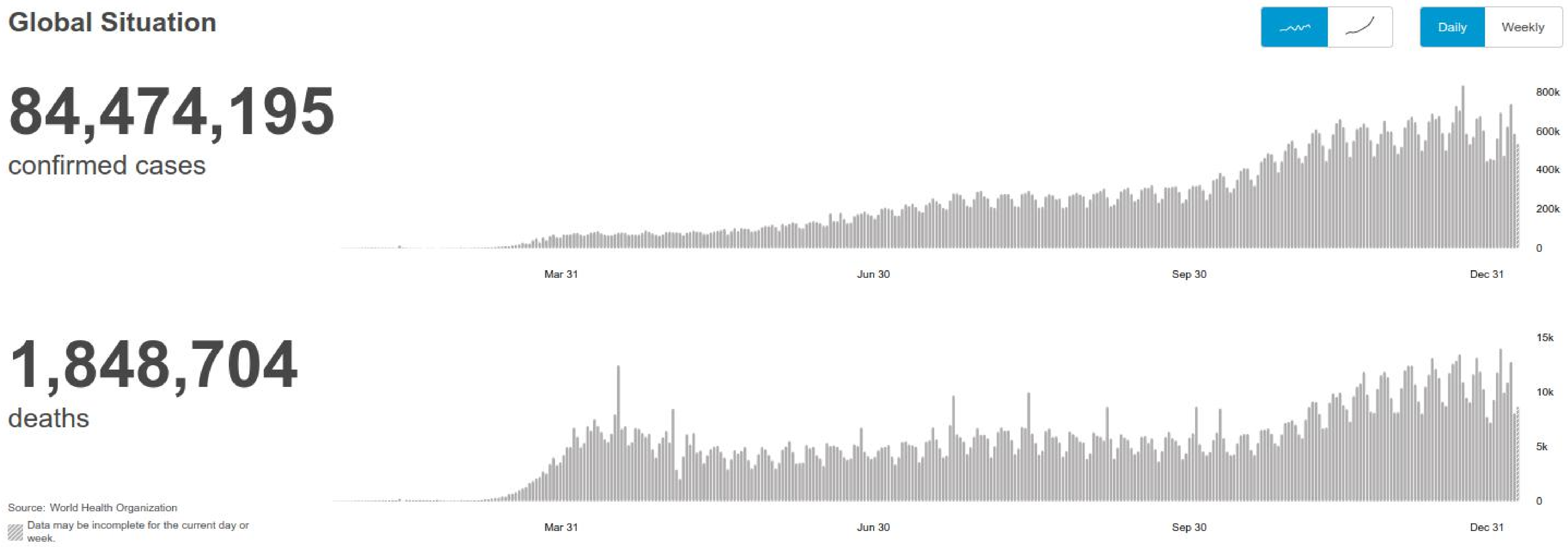


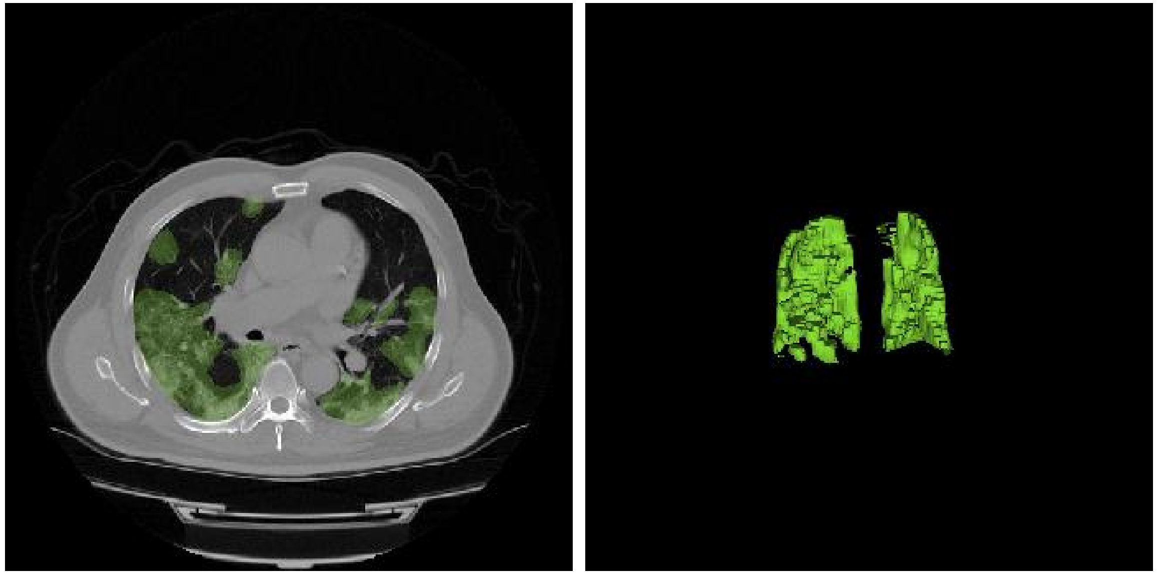
Globally, as of **5:47pm CET, 5 January 2021**, there have been **84,474,195 confirmed cases** of COVID-19, including **1,848,704 deaths**, reported to WHO. [1]

[1] WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/

The manifestation of the viral infection in the lung has been one of the earliest indicators of disease and may play an important role in the clinical management of patients. [2] - **Automated lung lesions segmentation on CT images can accelarate this process.**

Challenges

- Lesion distribution - usually **multifocal and peripheral.**
- Labeled CT images - **limited.**
- Image sources - **multi-institutional, multi-national** and **originate from patients of different ages, genders and with variable disease severity.**



Lung and viral infection regions

[2] COVID-19 Lung CT Lesion Segmentation Challenge - 2020. https://covid-segmentation.grand-challenge.org/

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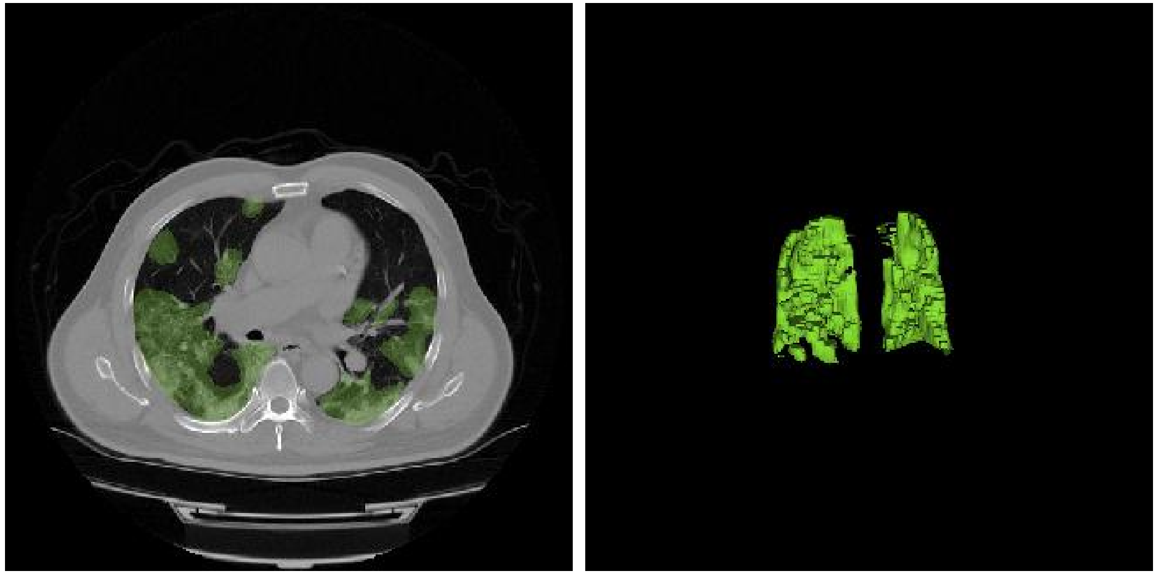
- **Generalization ability**



Lung and viral infection regions

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Lesion distribution matters

- Reverse Attention [3] - **improve the sensitivity of the model**.

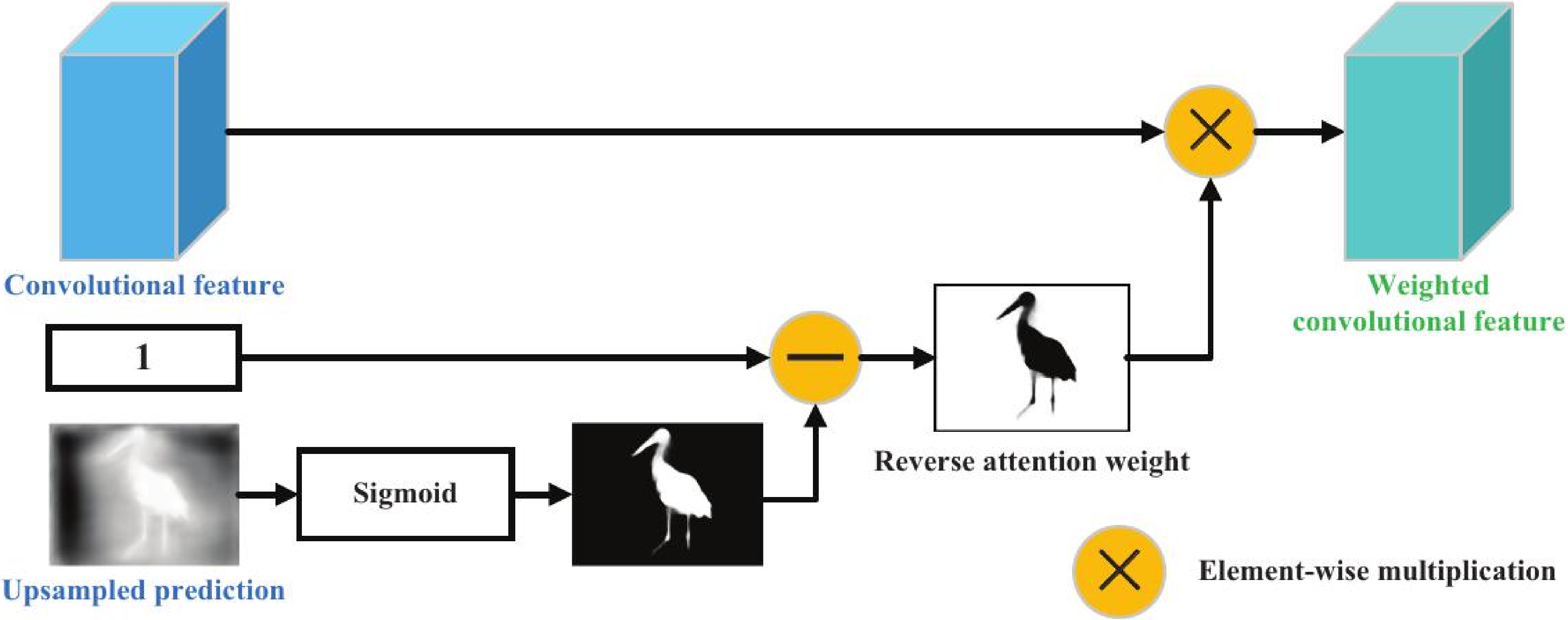


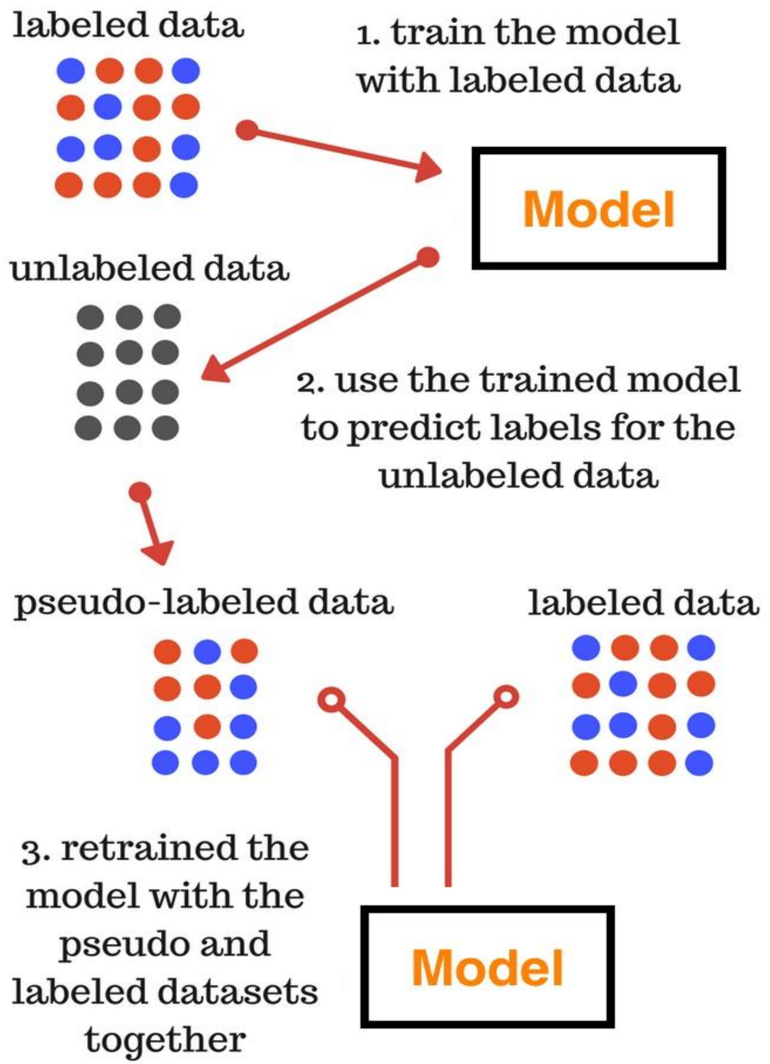
Illustration of the reverse attention block, whose input and output are highlighted in blue and green respectively.

[3] Chen S, Tan X, Wang B, et al. Reverse attention for salient object detection[C]//Proceedings of the European Conference on Computer Vision (ECCV). 2018: 234-250.

Generalization ability matters

➢ Semi-supervised Method

- **Labeled** CT images are rare and expensive.
- **Unlabeled** CT images are much cheaper.



Semi-supervised learning with pseudo labels

[4] Lee D H. Pseudo-label: The simple and efficient semi-supervised learning method for deep neural networks[C]//Workshop on challenges in representation learning, ICML. 2013, 3(2).

U-Net with Reverse Attention Module (RA-UNet)

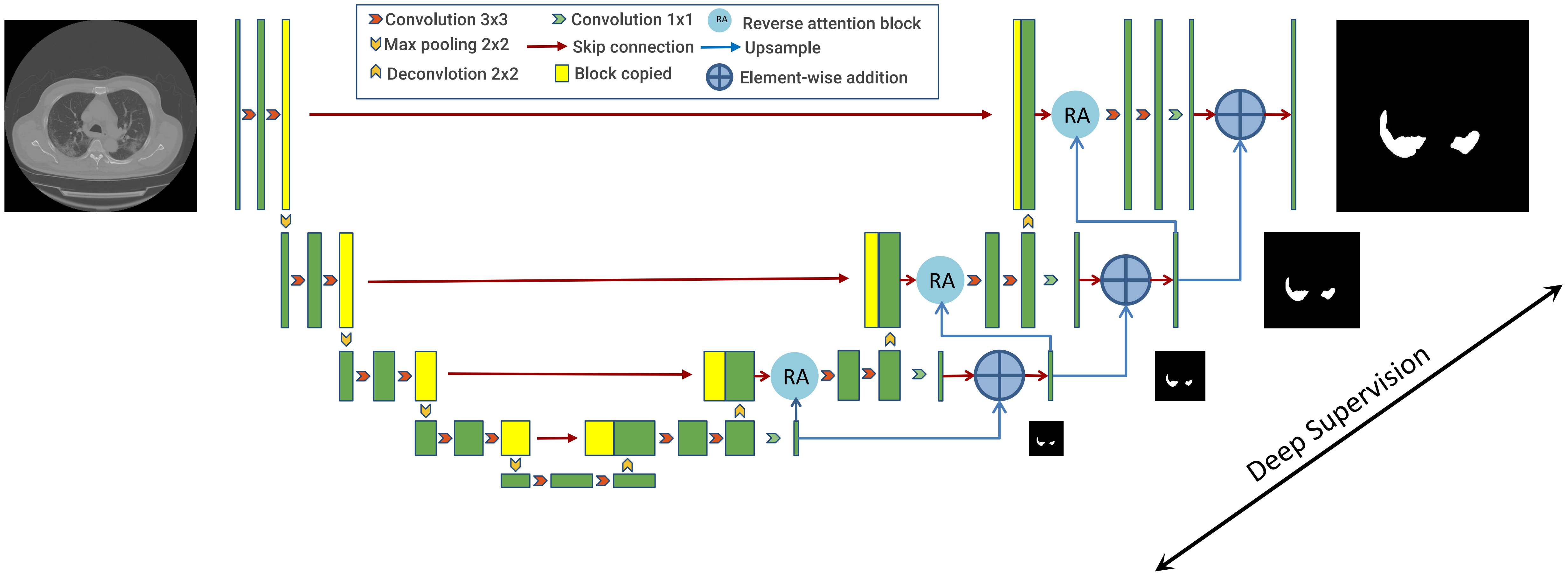
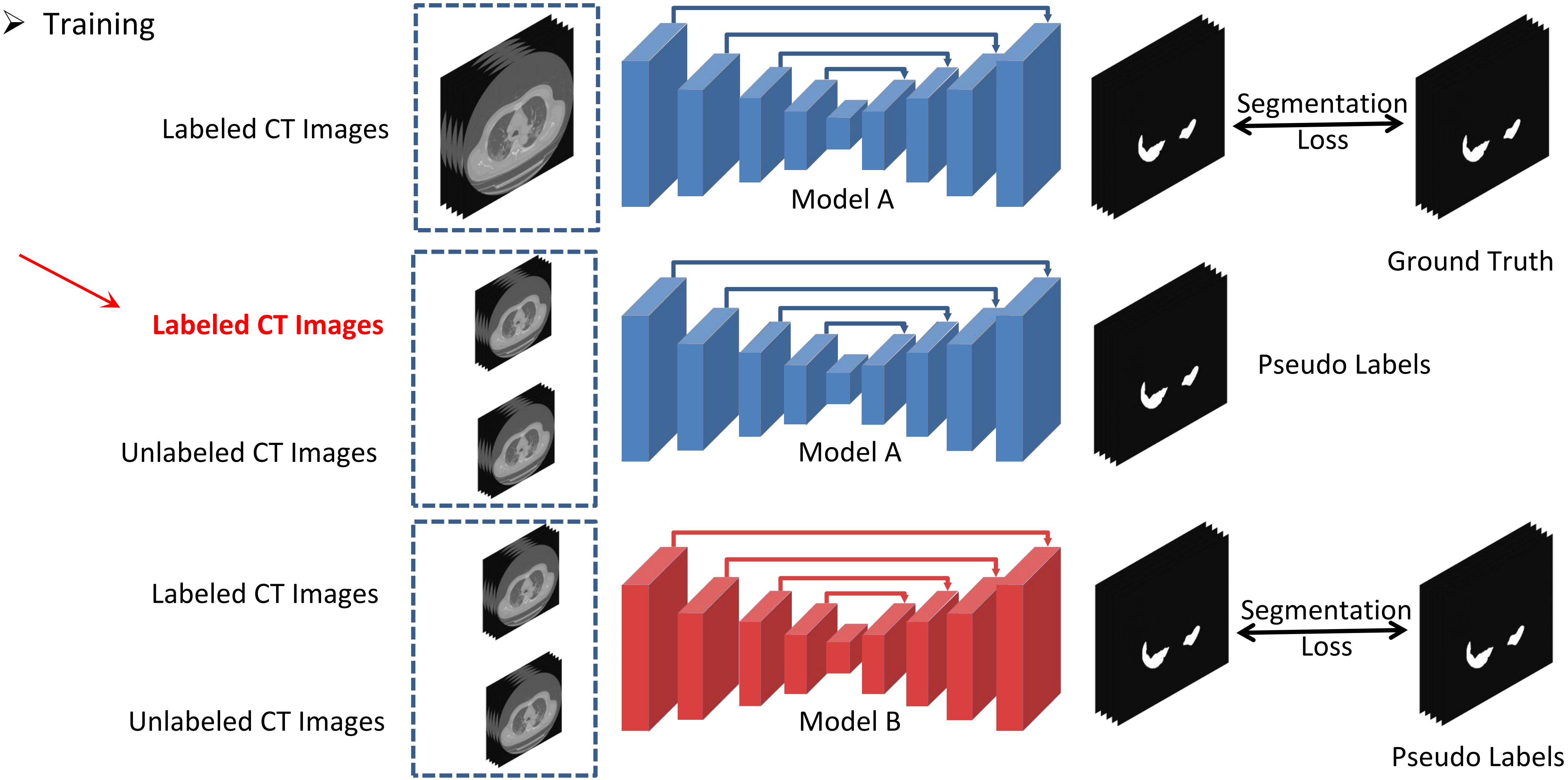


Diagram of 2D RAU-Net

Semi-supervised Learning

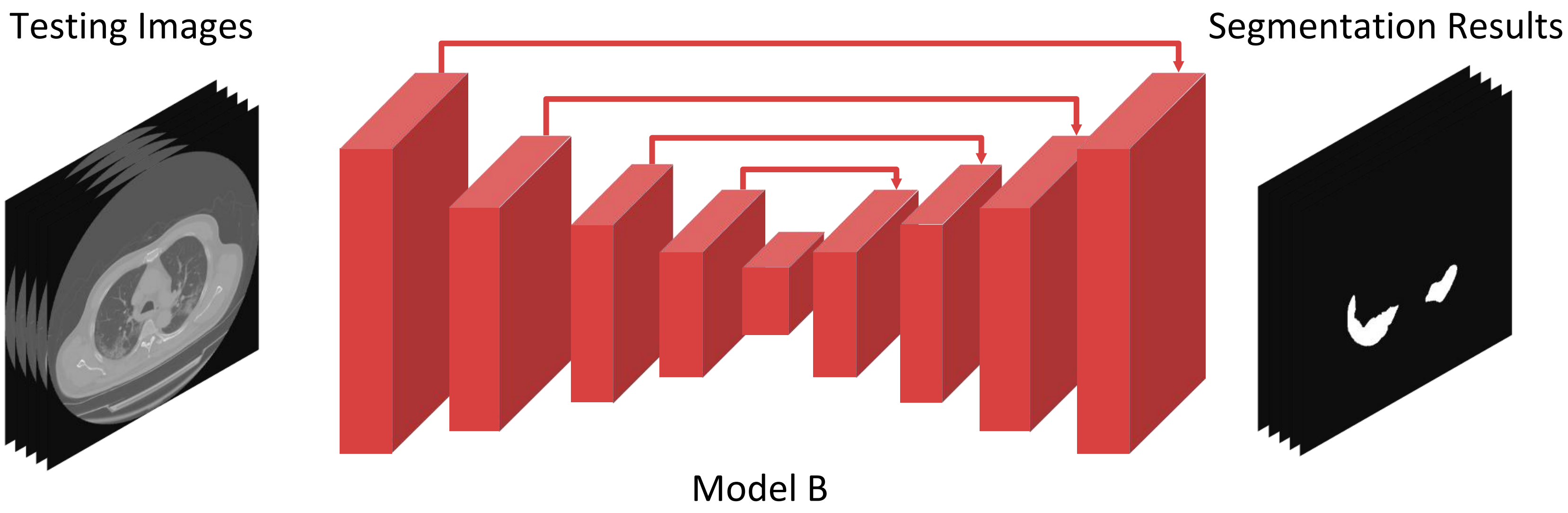
- Training



Semi-supervised Learning - Training

Semi-supervised Learning

- Testing



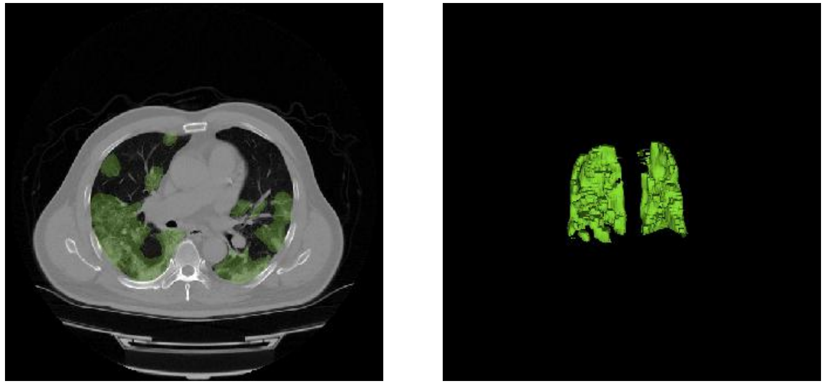
Semi-supervised Learning - Testing

Datasets

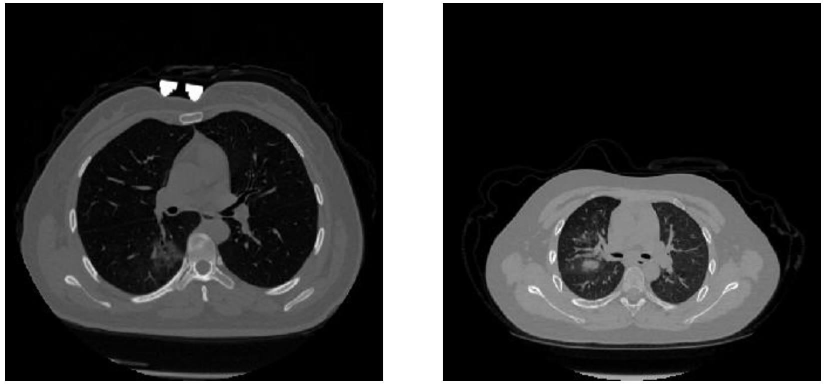
- Labeled data
  - COVID-19 segmentation challenge dataset [2] - 200 cases (Version 1)
- Unlabeled data (external data)
  - TCIA CT Images in Covid-19 [5] - 400 cases (exclude cases appear in chellenge dataset)

Evaluation Metrics

- Dice similarity coefficient (Dice)
- Precision (Pre.)
- Recall (Rec.)



Lung CT image slice and lesion annotations from COVID-19 Lung CT Lesion Segmentation Challenge dataset



Lung CT image slices from TCIA Covid-19 CT images dataset

[5] An P, Xu S, Harmon SA, Turkbey EB, Sanford TH, Amalou A, Kassin M, Varble N, Blain M, Anderson V, Patella F, Carrafiello G, Turkbey BT, Wood BJ (2020). CT Images in Covid-19 [Data set]. The Cancer Imaging Archive. DOI: https://doi.org/10.7937/tcia.2020.gqry-nc81

Backbone Network

- nnUNet [6]

Ablation Study

Ablation study on training set (5-fold cross validation)

Methods	Dice	Pre.	Rec.
2D nnUNet	69.01%	77.72%	67.30%
3D Lowres nnUNet	72.38%	79.10%	71.28%
3D Lowres RA-UNet	72.26%	78.86%	72.04%
3D Fullres nnUNet	72.38%	77.98%	72.16%
3D Fullres Semi-nnUNet w GT	76.30%	**82.01%**	75.67%
3D Fullres Semi-nnUNet w/o GT	**76.65%**	81.99%	**75.94%**

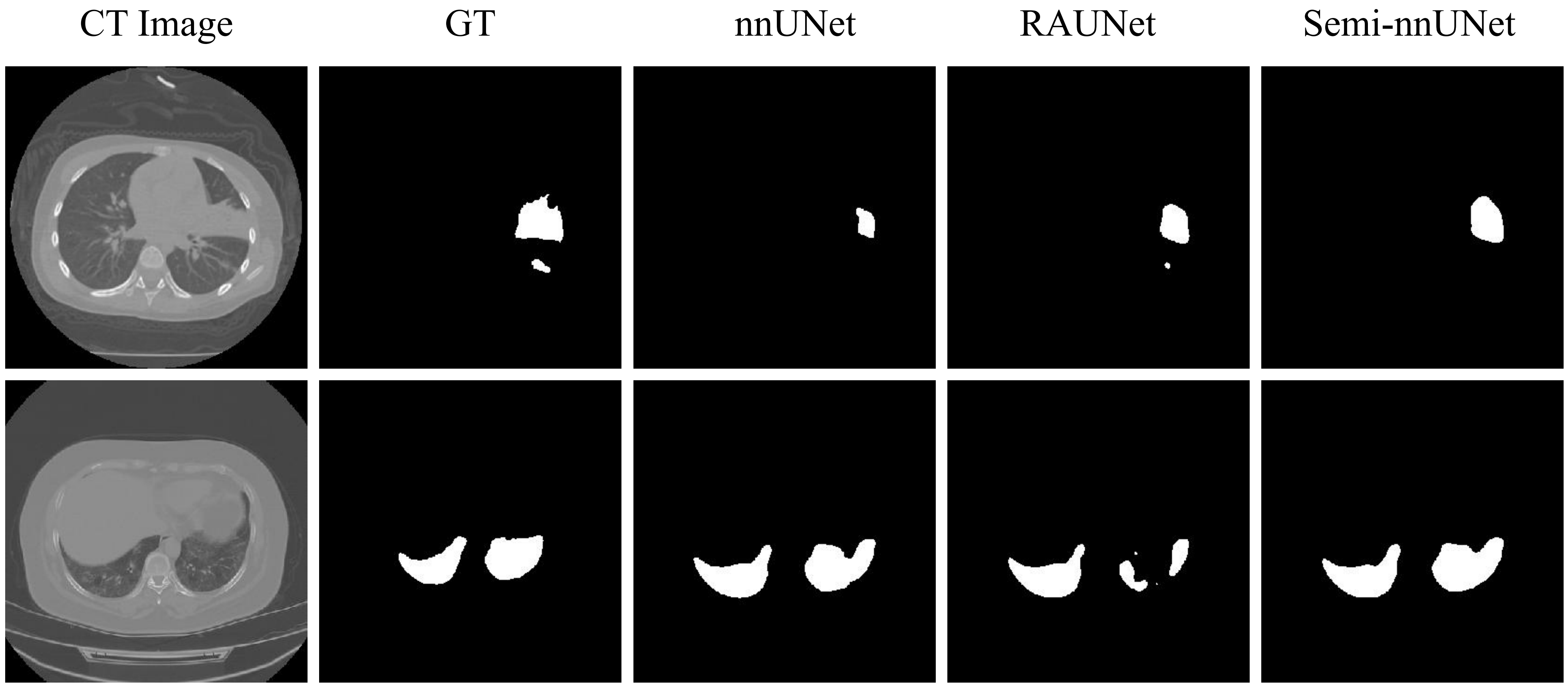
[6] Isensee F, Jaeger P F, Kohl S A A, et al. nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation[J]. Nature Methods, 2020: 1-9.

Comparision with Other Methods

Compare with other methods on the testing leaderboard

User	Dice Score	Jaccard Coefficient	Normalized Volume Diff	Hausdorff 95	Surface Dice at 1mm
sshu	**0.6659 ± 0.2390**	**0.5399**	0.7434	134.3897	**0.5799**
CSCYQJ	0.6581 ± 0.2447	0.5327	**0.5713**	2320.5037	0.5719
ttime	0.6577 ± 0.2399	0.5306	0.6356	128.9435	0.5694
Isensee	0.6543 ± 0.2710	0.5369	0.8482	2297.8055	0.5704
dev.sungman	0.6534 ± 0.2495	0.5280	1.2208	154.0145	0.5627
brunom0liveira91	0.6492 ± 0.2451	0.5226	0.8245	118.7694	0.5603
wangliwen1994	0.6485 ± 0.2629	0.5267	0.9662	4473.7645	0.5536
vitali.liauchuk	0.6461 ± 0.2540	0.5212	0.7203	129.7144	0.5601
LCSBmedAI	0.6448 ± 0.2677	0.5241	1.1581	121.0697	0.5531
claire.tang	0.6441 ± 0.2612	0.5214	0.9285	**117.1646**	0.5621

Visualization



Conclusion

- **Reverse Attention Block** can improve sensitivity.
- With **semi-supervised training** strategy, baseline model can generalize well to new data from a variety of sources.

Future work

- More powerful semi-supervised method.
- Combine Reverse Attention Block with other powerful backbone segmentation networks.

Thanks for your attention!

Acknowledgement

The annotation of the dataset was made possible through the joint work of Children's National Hospital, NVIDIA and National Institutes of Health for the COVID-19-20 Lung CT Lesion Segmentation Grand Challenge.