Project 11 Mid-Semester Update: 3D Segmentation of Hard and Soft Tissue for Simulating X-ray Image Formation with Deep Learning

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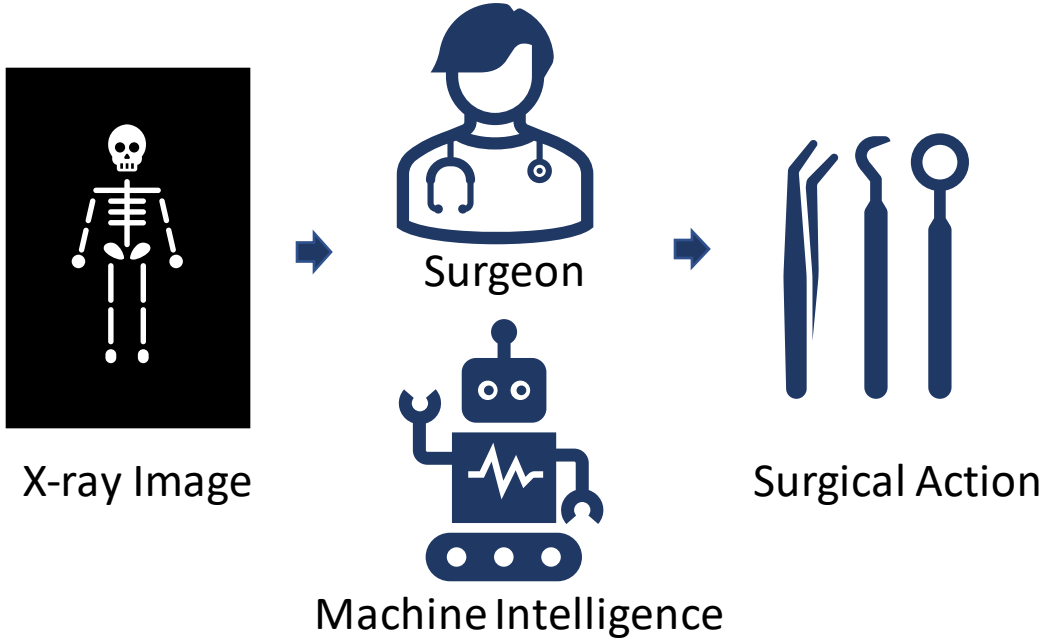
Mentors: Benjamin Killeen, Mathias Unberath

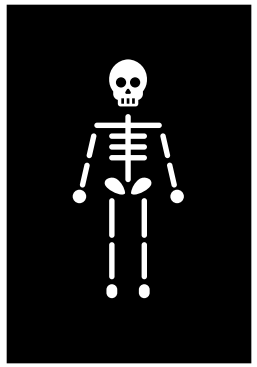
Project Review

Fluoroscopy-Guided Intervention- Today

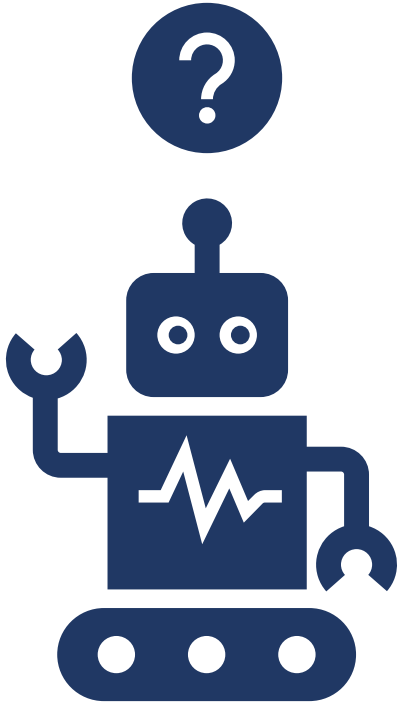
Fluoroscopy-Guided Intervention- Future



Project Review

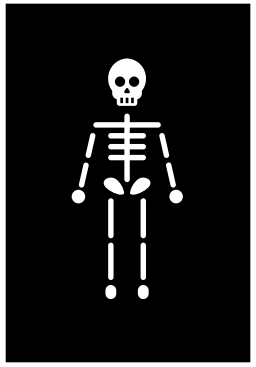


Real Clinical Data

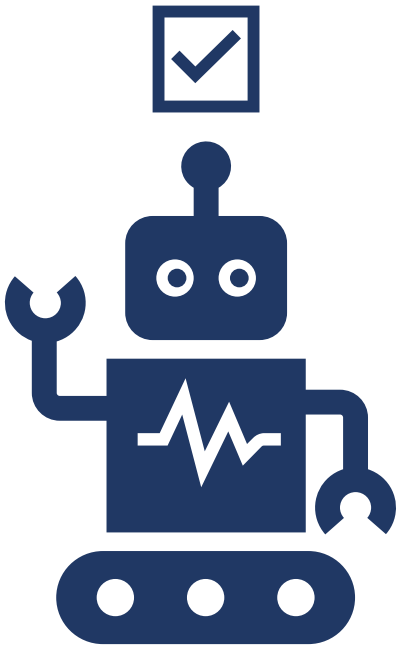


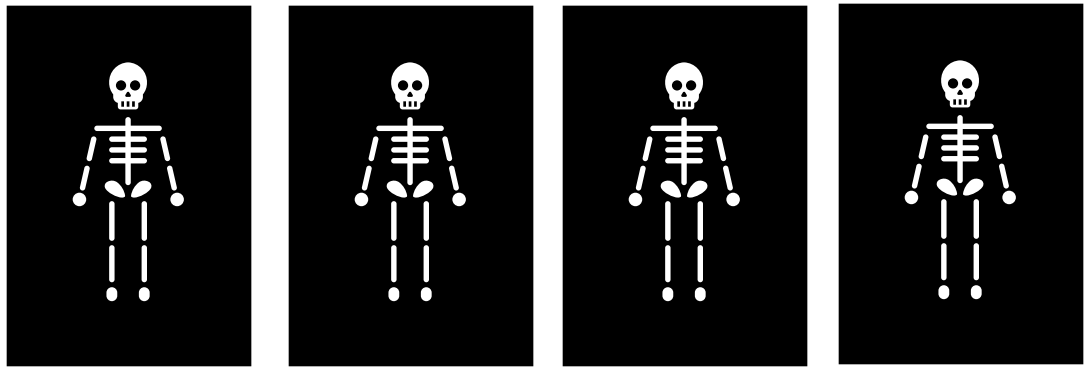
Limited clinical training data results in poor performance!

Project Review



Real Clinical Data





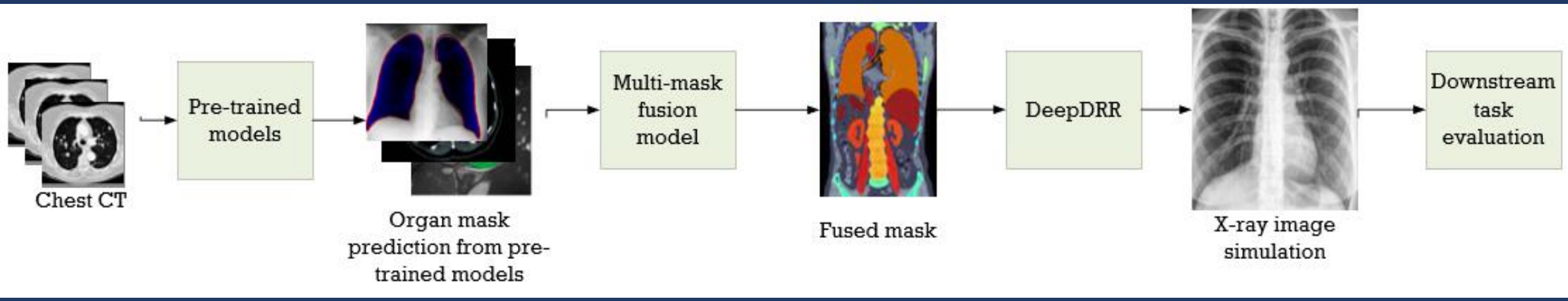
Simulated Training Data

In silico simulation of training examples may improve performance. The goal of this project is to improve the quality of simulated X-ray data.

Dependencies Updates

Dependencies	Needed by	Status / Contact	Remedies
Access to the workstation for training models in Dr. Unberath's lab	Feb 28th	✓	Run the training process on PC or Google cloud.
Full body CT dataset (already have one dataset with limited cases)	Feb 28th	✓	Use partial CT dataset for bones, soft tissue or other tissues.
Pretrained model for specific tasks	March 15th	✓	Change a task for downstream evaluation
Desktops / Laptops	Feb 28th	✓	-

Project Review - General project framework



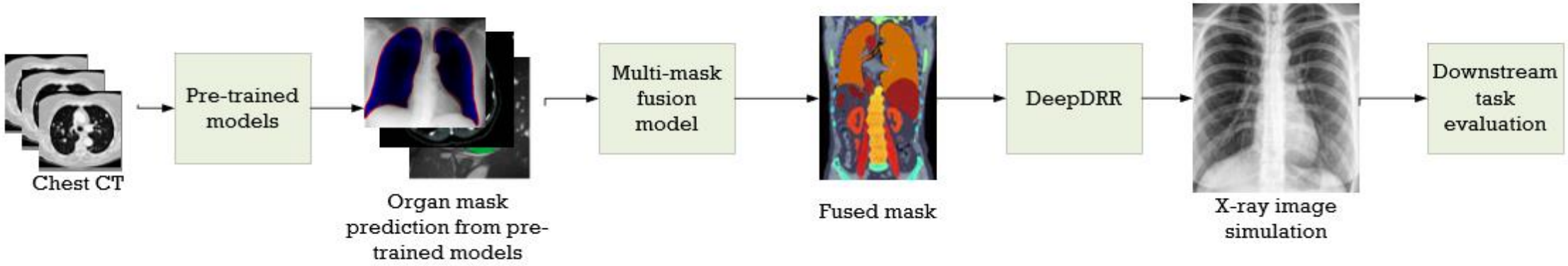
General framework of our project

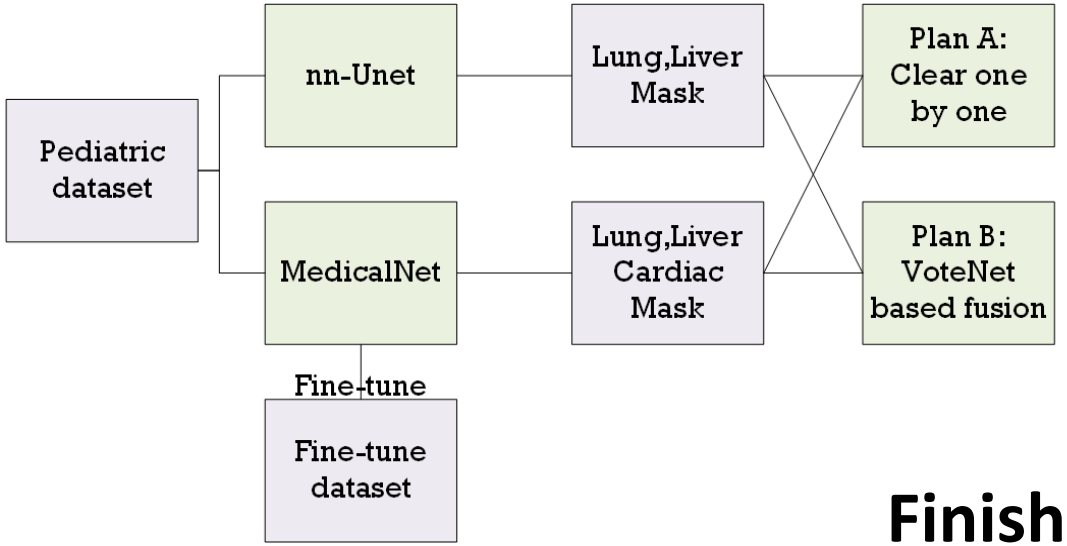
Efforts and Preliminary Results

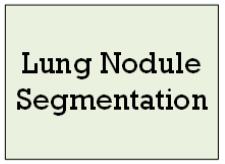
- Framework
- Method comparison report
- Results for pretrained models for 3D segmentation of Liver/Lung
- Downstream task for DeepDRR evaluation

Efforts and Preliminary Results:

General framework and current finished part







Finished part

SeanSDarcy2001 added helper network a4f021a 21 hours ago 43 commits

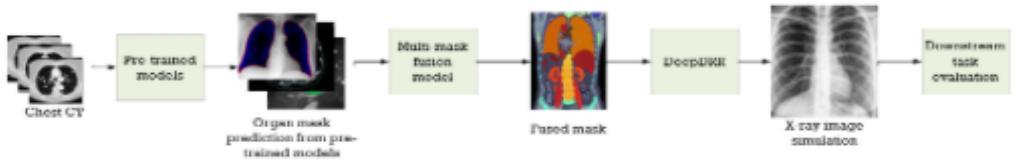
dataset	Add files via upload	23 hours ago
downstreamTasks/lung	added helper network	21 hours ago
models	Add files via upload	23 hours ago
utils	Add files via upload	23 hours ago
LICENSE	Initial commit	22 days ago
README.md	Update README.md	23 hours ago
main.py	Update main.py	23 hours ago

README.md

3D-CT-Segmentation

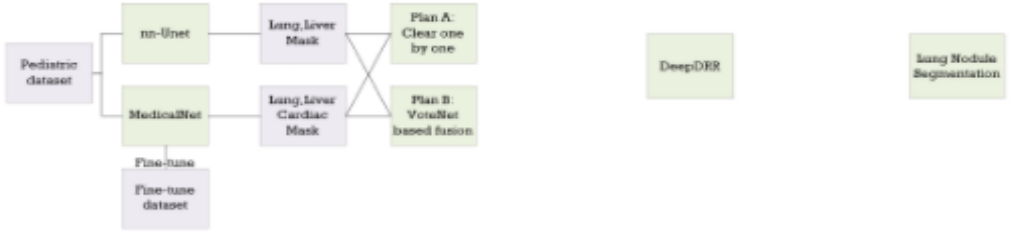
Introduction

This is the repo for "3D Segmentation of Hard and Soft Tissue for Simulating X-ray Image Formation with Deep Learning" program in CIS2, 2022 spring, JHU.



Current program structure

Current finished part



LABORATORY FOR Computational Sensing + Robotics

Our Github Repository

Efforts and Preliminary Results: Method comparison of 3D CT (multi-organ) segmentation

	NnU-Net [1] (Isensee et al.) (Dice score)	**R2U3D [2]** (Kadia et al.) (Dice score)	**3D U-net [3]** (Yang et al.) (Dice score)	**Hierarchical 3D-FCN [4]** (Roth et al.) (Dice score)	**2D-FCN [5]** (Zhou et al.) (mean IoUs)	**3D-Deep-CNN [5]** (Zhou et al.) (mean IoUs)
Lung	0.6920	**0.9920**	-	-	93.9(R) / 93.5(L)	95.1(R) / 94.4(L)
Heart	**0.9277**	-	0.8432	-	86.0	89.0
Liver	0.9524	-	-	**0.954**	90.8	91.1
Spleen	-	-	-	0.928	83.5	91.3
Prostate	0.7581	-	-	-	47.0	74.2

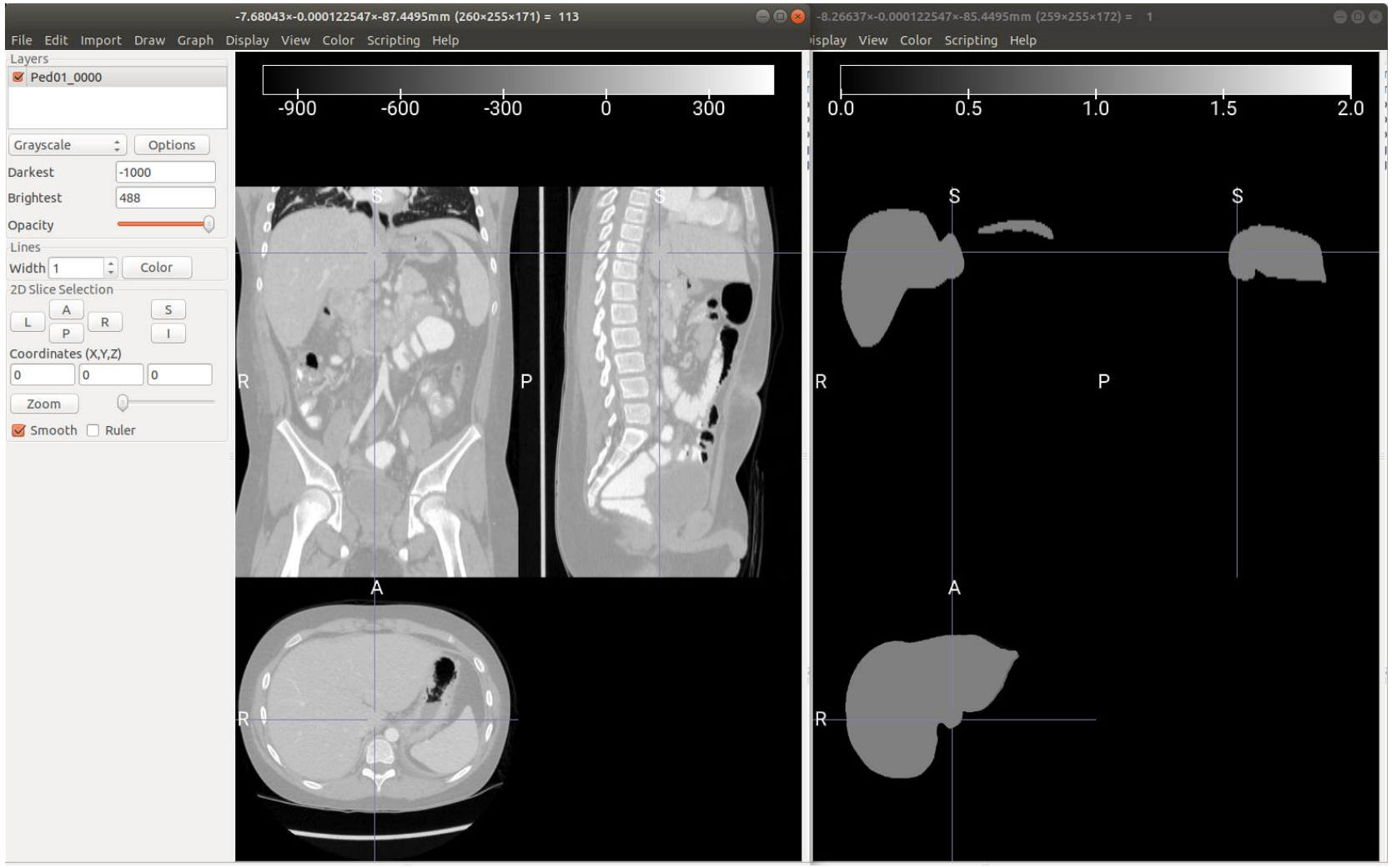
IoU = intersection over union

[1] Isensee F, Petersen J, Klein A, et al. nnU-Net: Self-adapting Framework for U-Net-Based Medical Image Segmentation. arXiv:180910486 [cs]. Published online September 27, 2018. Accessed February 24, 2022.
[2] Kadia DD, Alom MZ, Burada R, Nguyen TV, Asari VK. R2U3D: Recurrent Residual 3D U-Net for Lung Segmentation. IEEE Access. 2021;9:88835-88843. doi:10.1109/ACCESS.2021.3089704
[3] Yang X, Bian C, Yu L, Ni D, Heng PA. Hybrid Loss Guided Convolutional Networks for Whole Heart Parsing. In: Pop M, Sermesant M, Jodoin PM, et al., eds. Statistical Atlases and Computational Models of the Heart. ACDC and MMWHS Challenges. Lecture Notes in Computer Science. Springer International Publishing; 2018:215-223. doi:10.1007/978-3-319-75541-0_23
[4] Roth HR, Oda H, Hayashi Y, et al. Hierarchical 3D fully convolutional networks for multi-organ segmentation. arXiv:170406382 [cs]. Published online April 20, 2017. Accessed February 24, 2022. http://arxiv.org/abs/1704.06382
[5] Zhou X. Automatic Segmentation of Multiple Organs on 3D CT Images by Using Deep Learning Approaches. In: Lee G, Fujita H, eds. Deep Learning in Medical Image Analysis : Challenges and Applications. Advances in Experimental Medicine and Biology. Springer International Publishing; 2020:135-147. doi:10.1007/978-3-030-33128-3_9

Efforts and Preliminary Results:

Segmentation masks generated by nnUNet

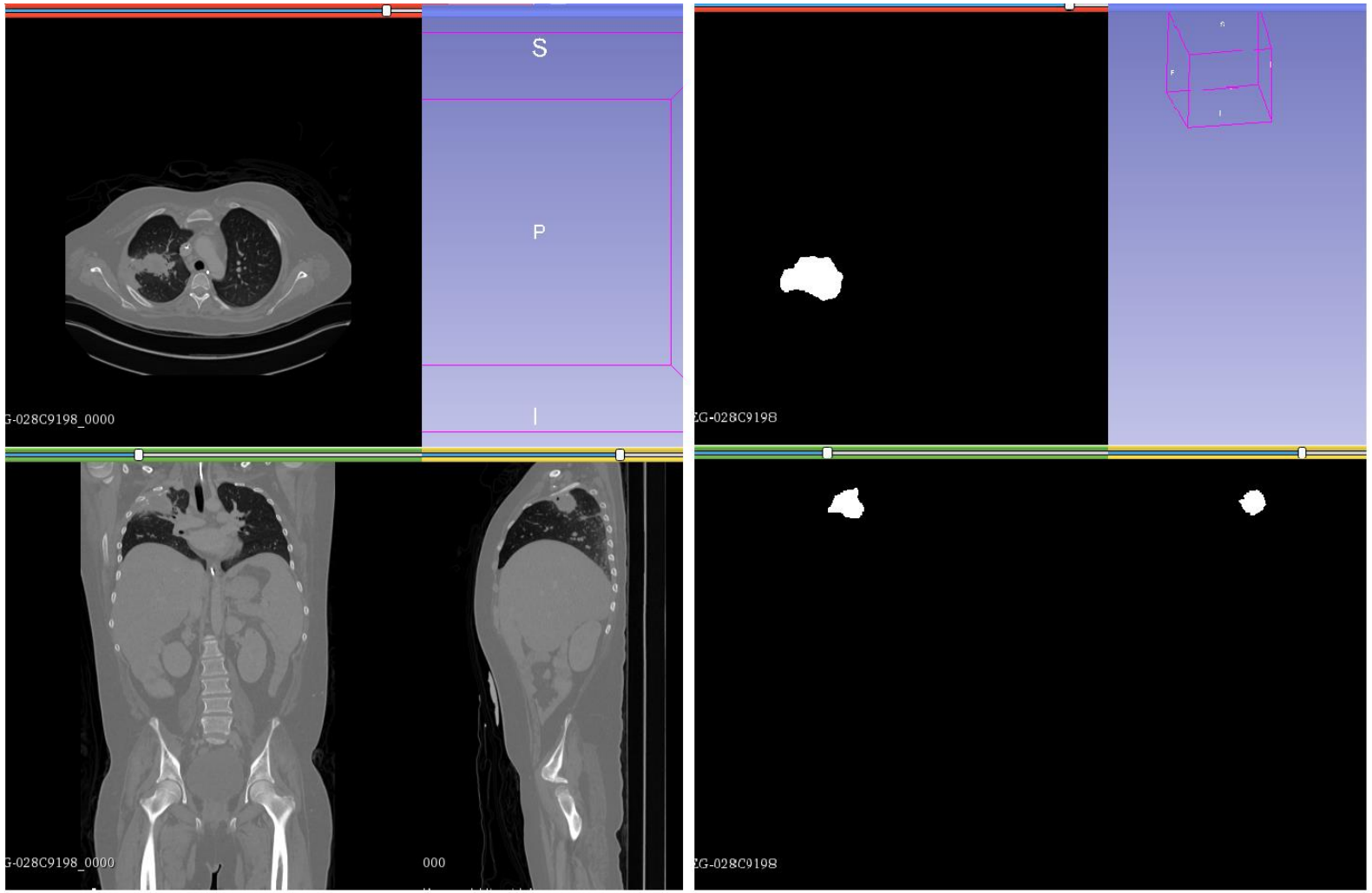
Target:
Liver



Efforts and Preliminary Results:

Segmentation masks generated by nnUNet

Target:
Lung



Difficulties and Problems along with Potential Solutions

- Need to combine multiple masks from different models for different tissue types
  Possible solutions:
  1) Clear one by one
  2) VoteNet based fusion
- Need to carry out evaluation for middle stages (e.g. How good is different 3D segmentation models, what is the affect on final DRR quality)
  Possible solutions:
  1) Dice coefficient / Hausdorff distance
  2) Skip the midstage evaluation and try out every method for the whole DRR and downstream procedure

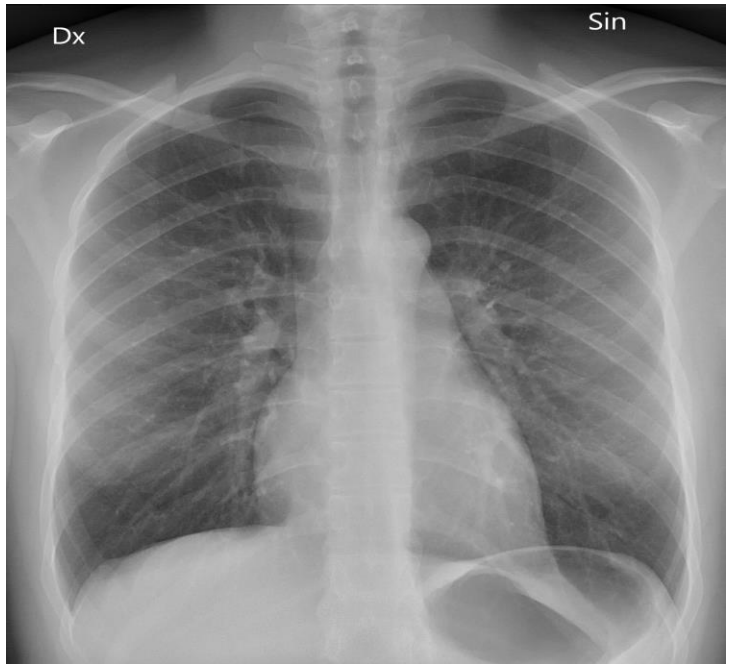
Difficulties and Problems along with Potential Solutions

- Need to show how the whole DeepDRR improve (or not) with refined 3D CT segmentation
  Possible solutions:
  Downstream tasks

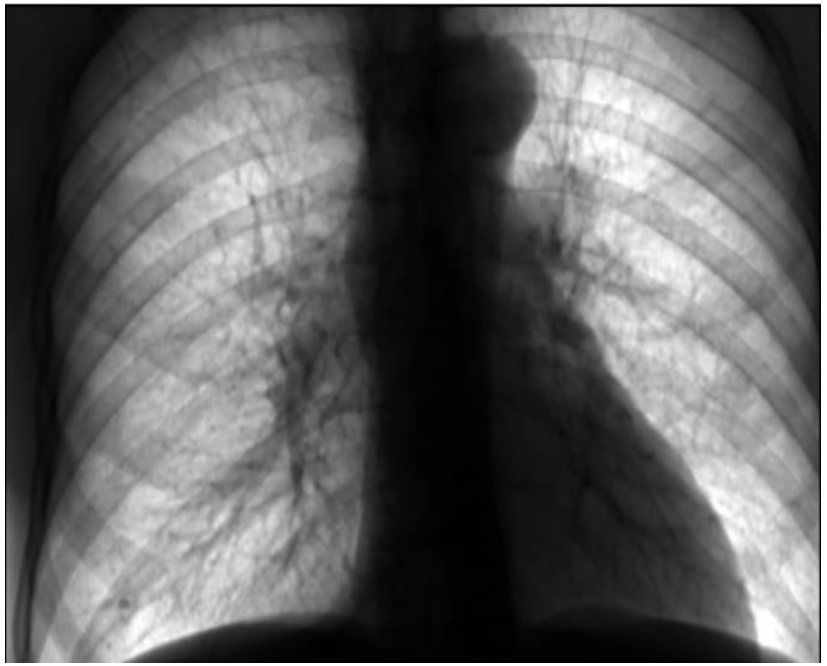
What's Next

- Label fusion
- Middle stage evaluation for 3D CT segmentation
- Integration with DeepDRR
- Downstream tasks for DRR evaluation

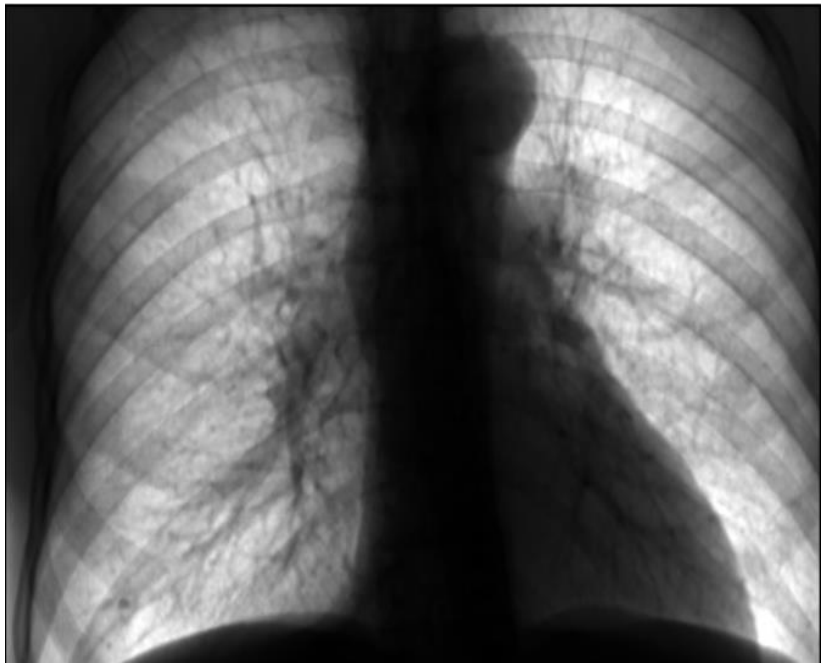
Downstream Evaluation:
Have we improved DRR quality?



Real Radiograph



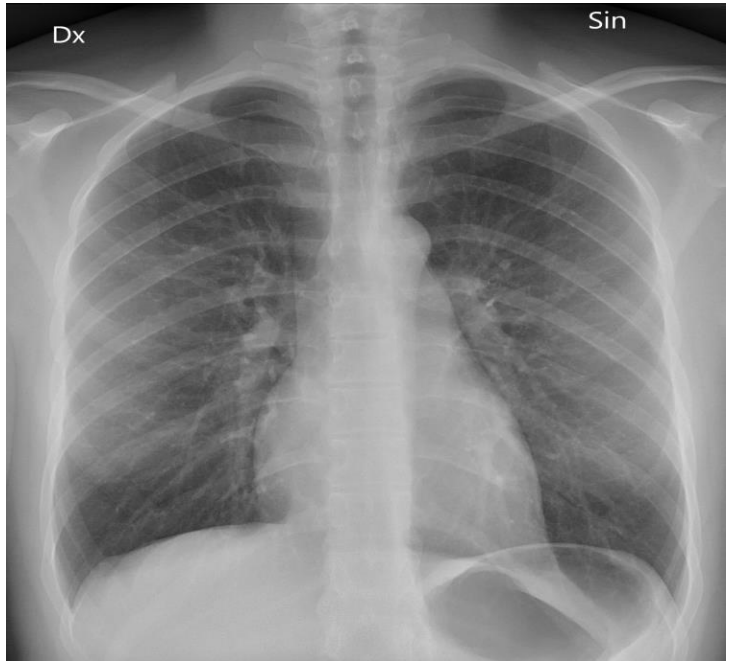
Digitally Reconstructed Radiograph



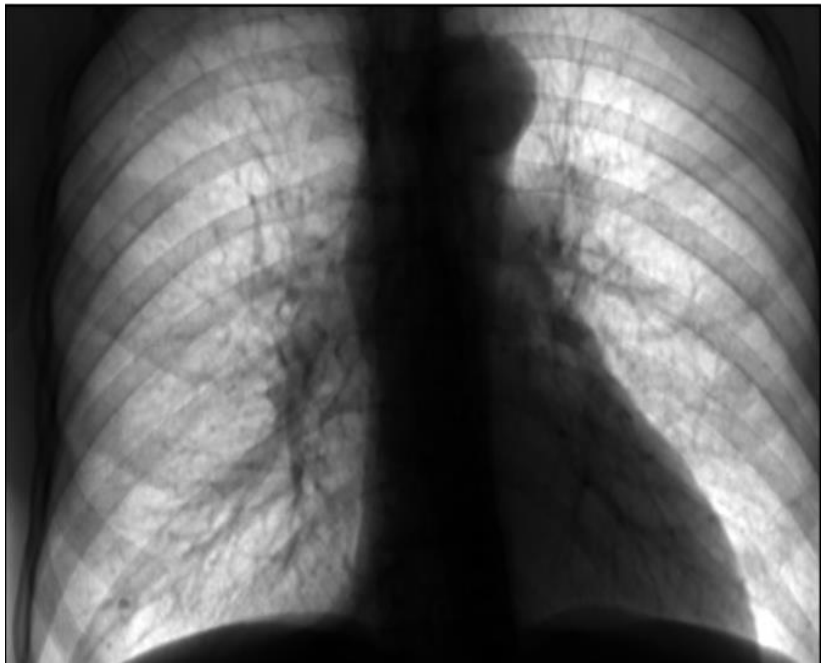
New Digitally Reconstructed Radiograph

Downstream Evaluation:
Have we improved DRR quality?

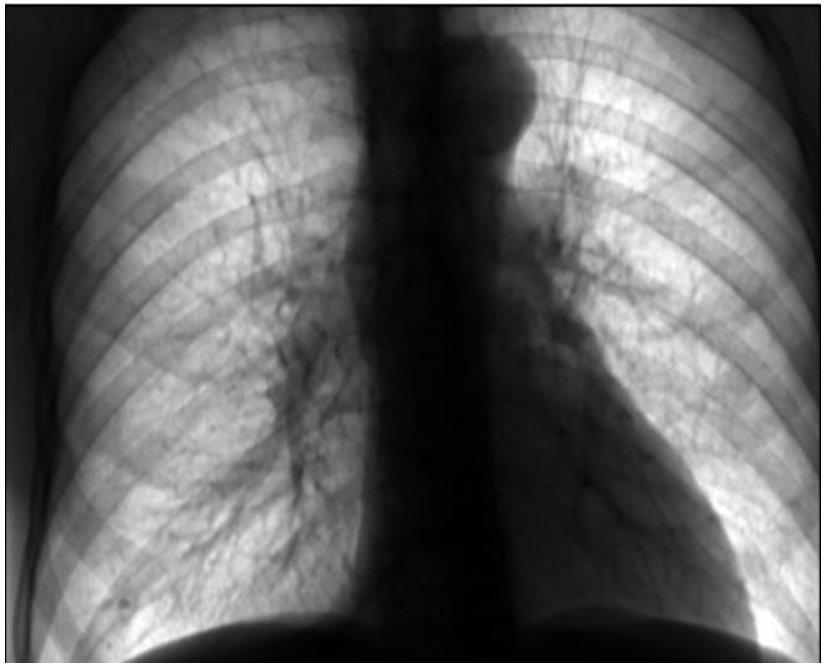
- Synthetic data quality is measured by improved performance for models trained on synthetic data but tested on real data.



Real Radiograph

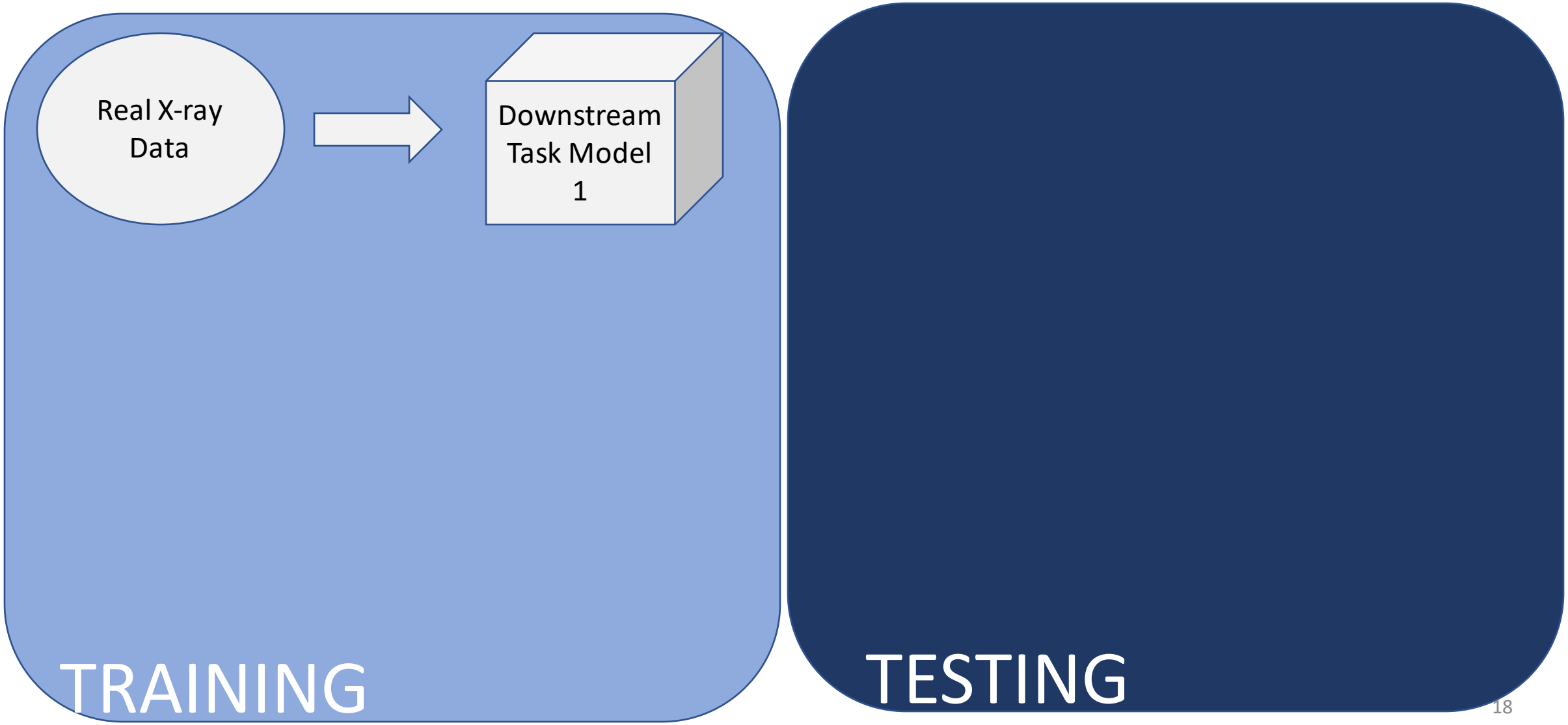


Digitally Reconstructed Radiograph

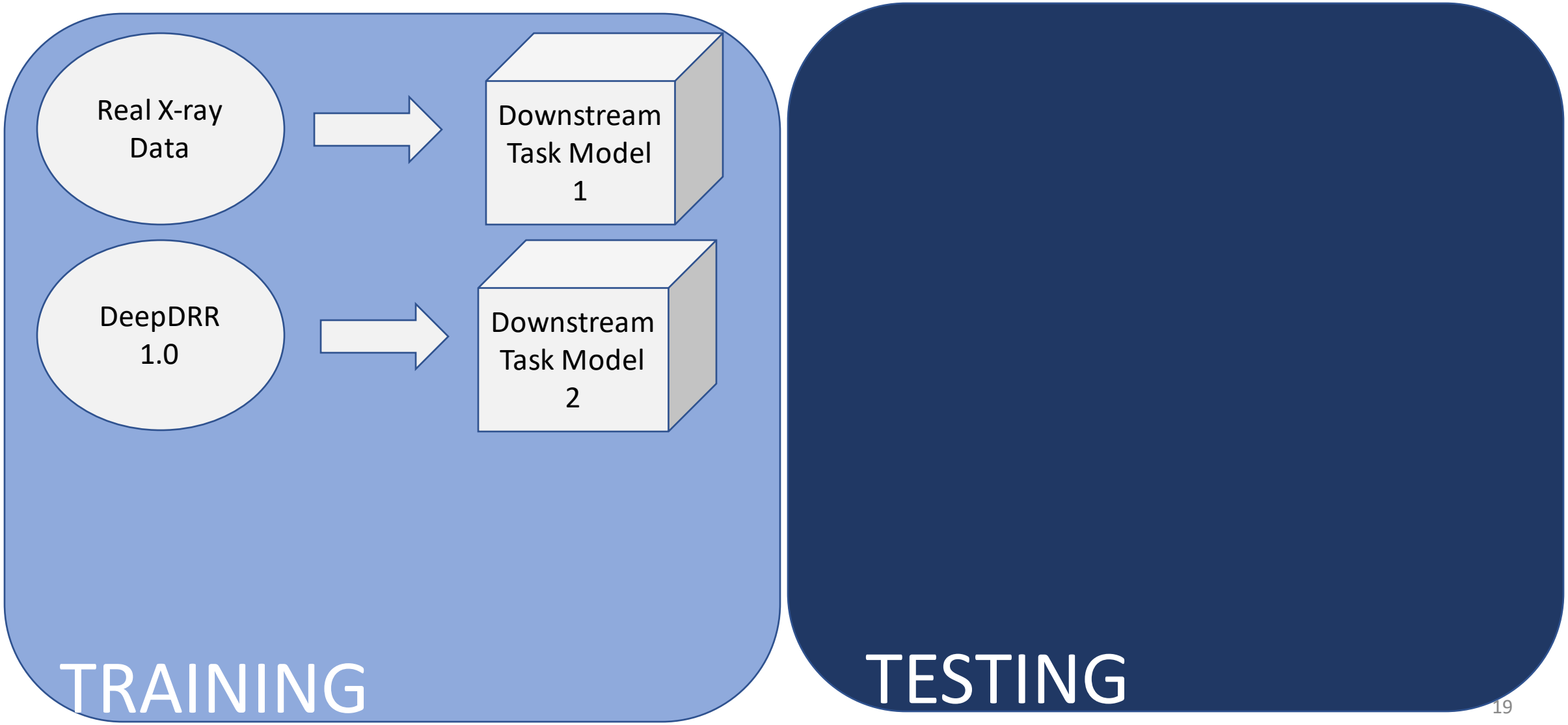


New Digitally Reconstructed Radiograph

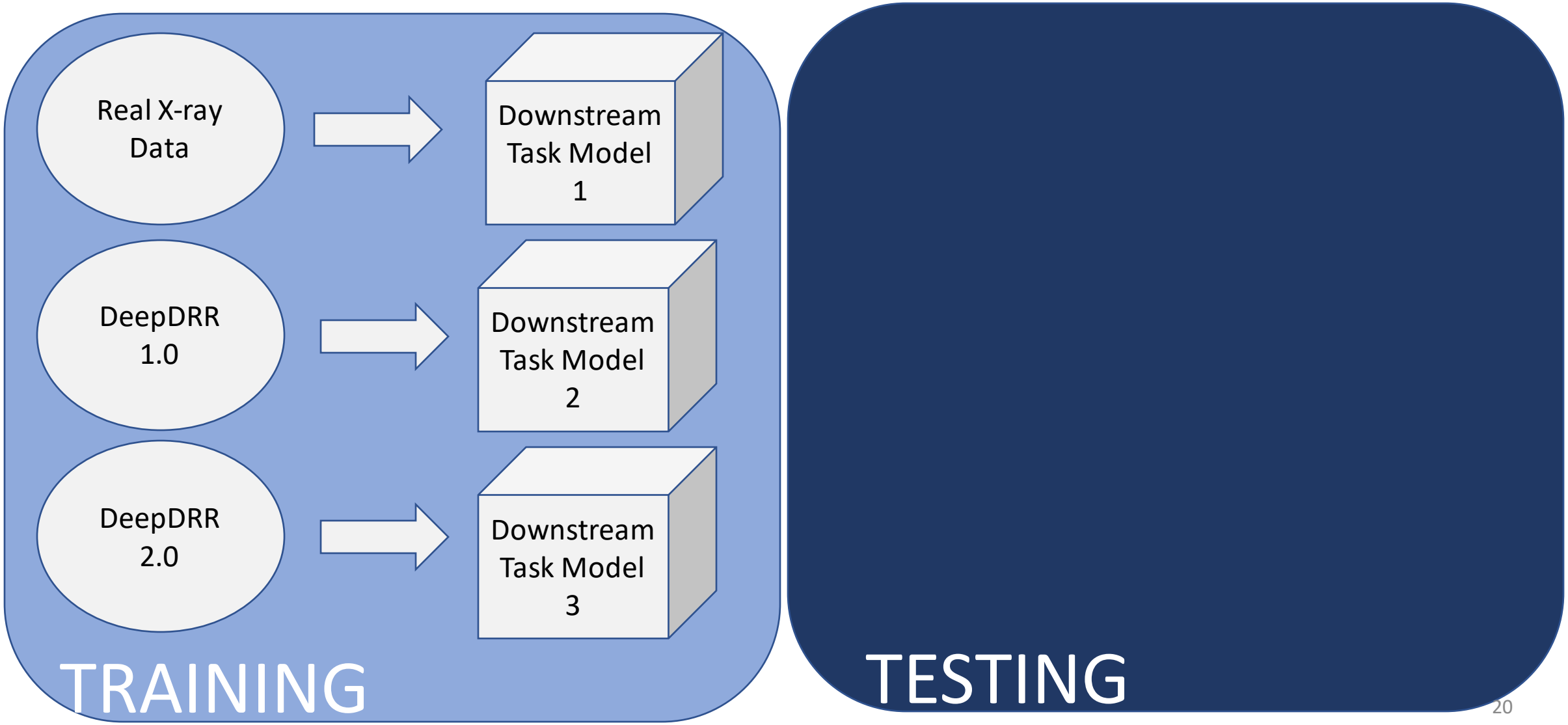
Downstream Evaluation:
Have we improved DRR quality?



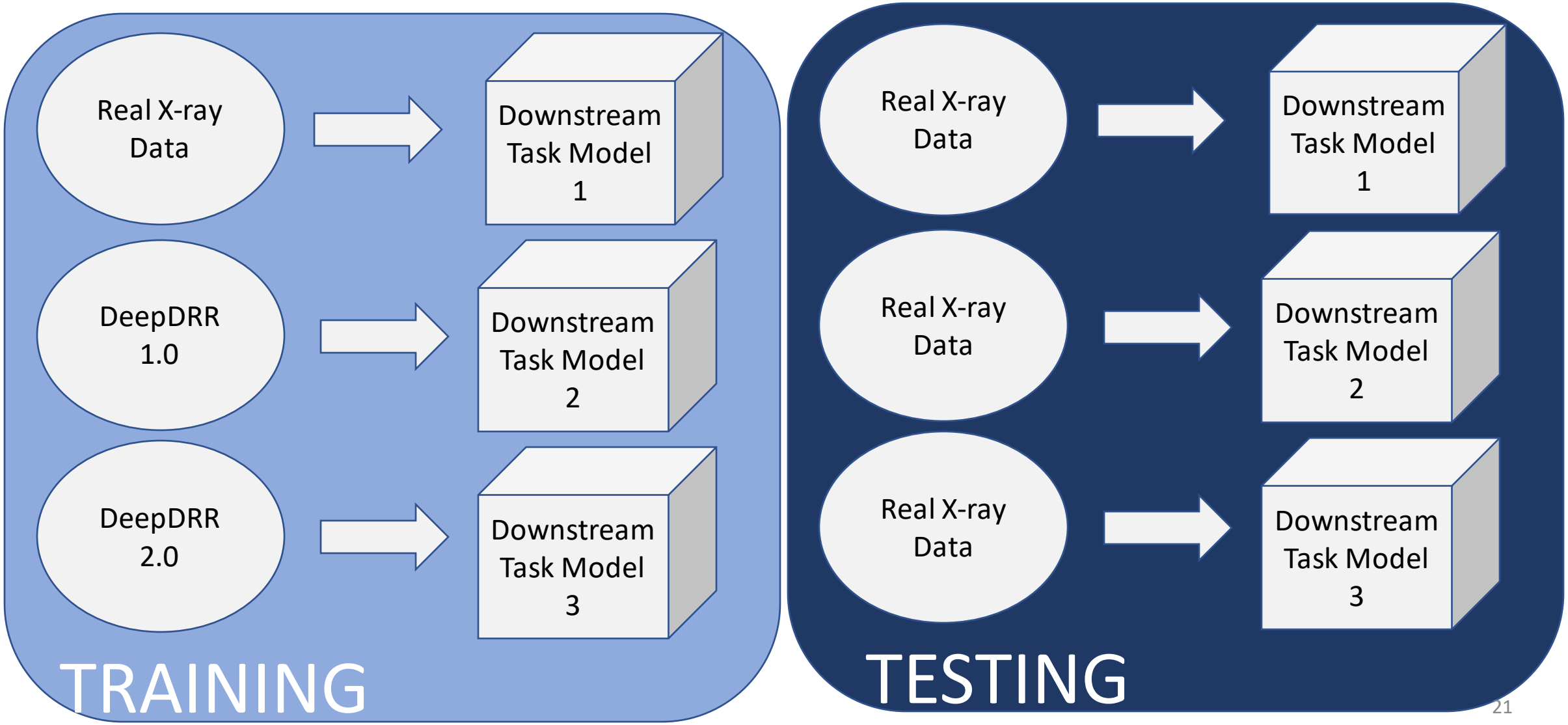
Downstream Evaluation:
Have we improved DRR quality?



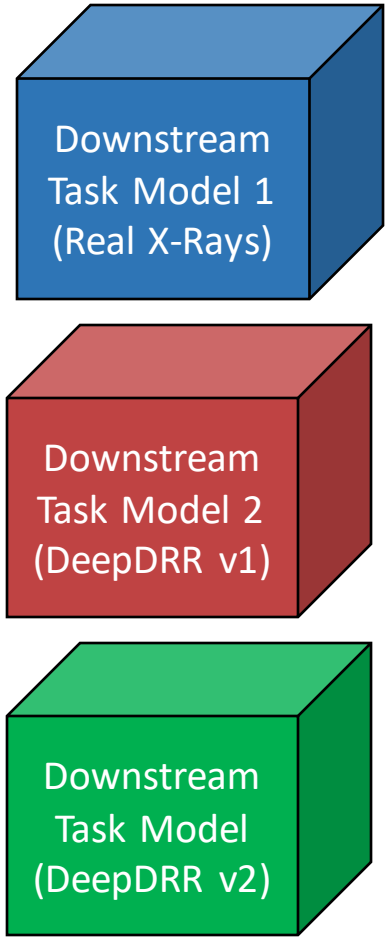
Downstream Evaluation:
Have we improved DRR quality?



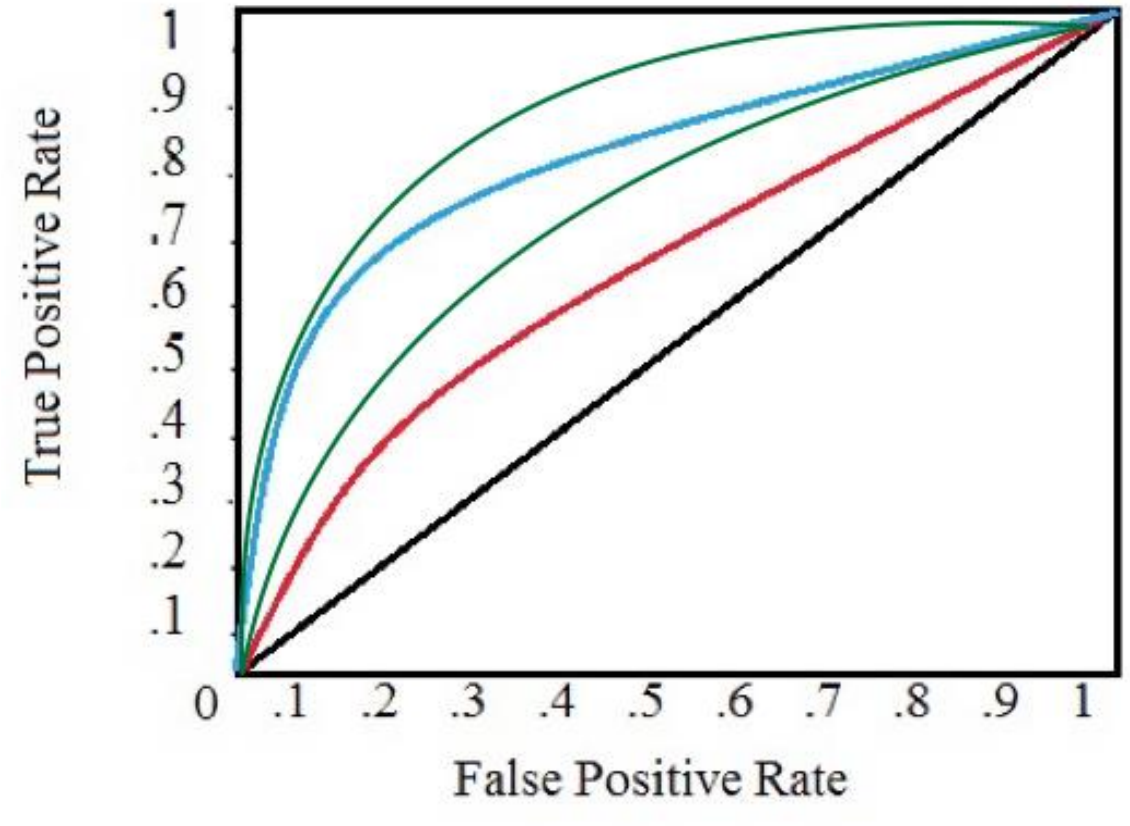
Downstream Evaluation:
Have we improved DRR quality?



Downstream Evaluation:
Have we improved DRR quality?



Testing Accuracy (Real X-ray Images)

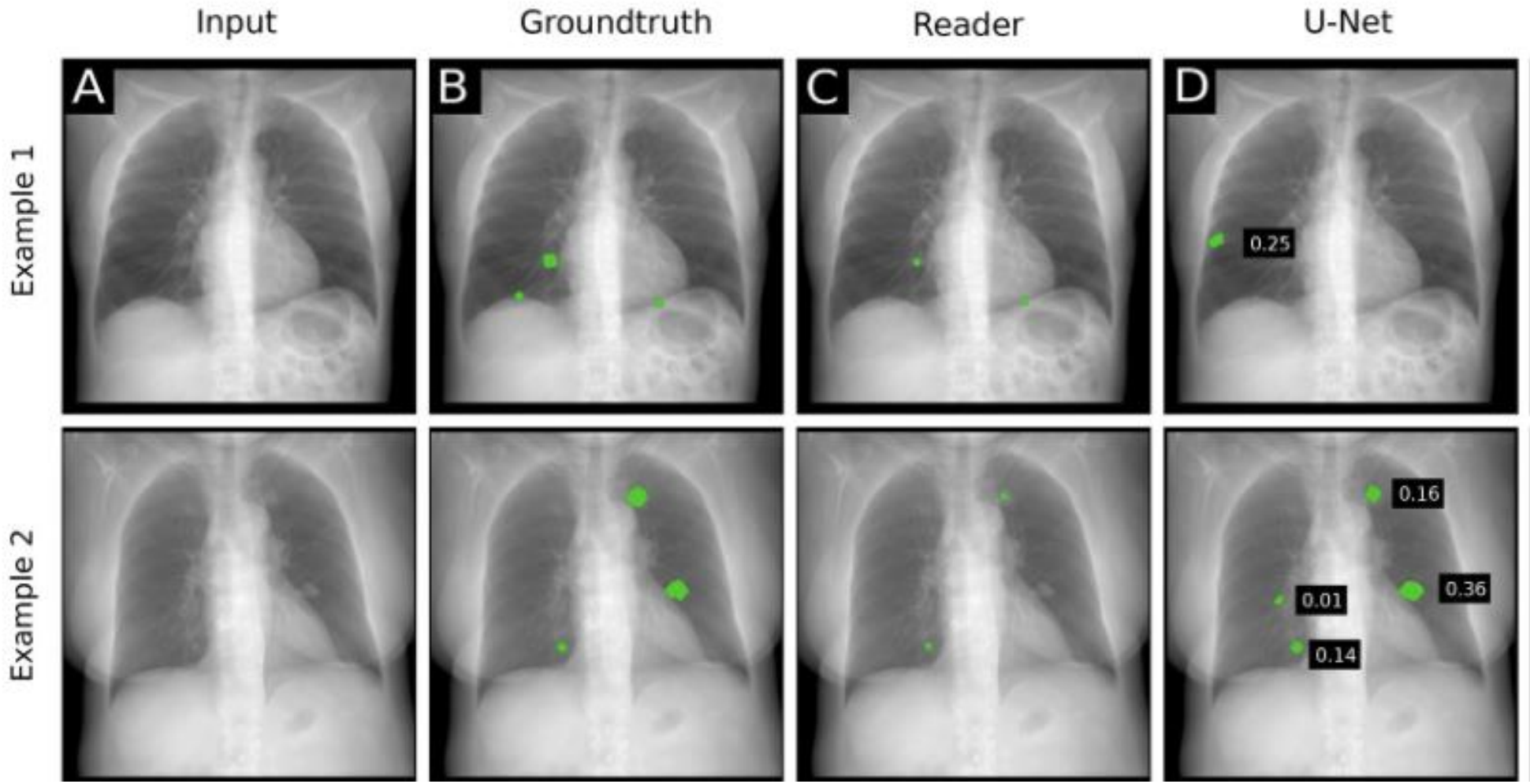


Downstream Evaluation:

The Tasks

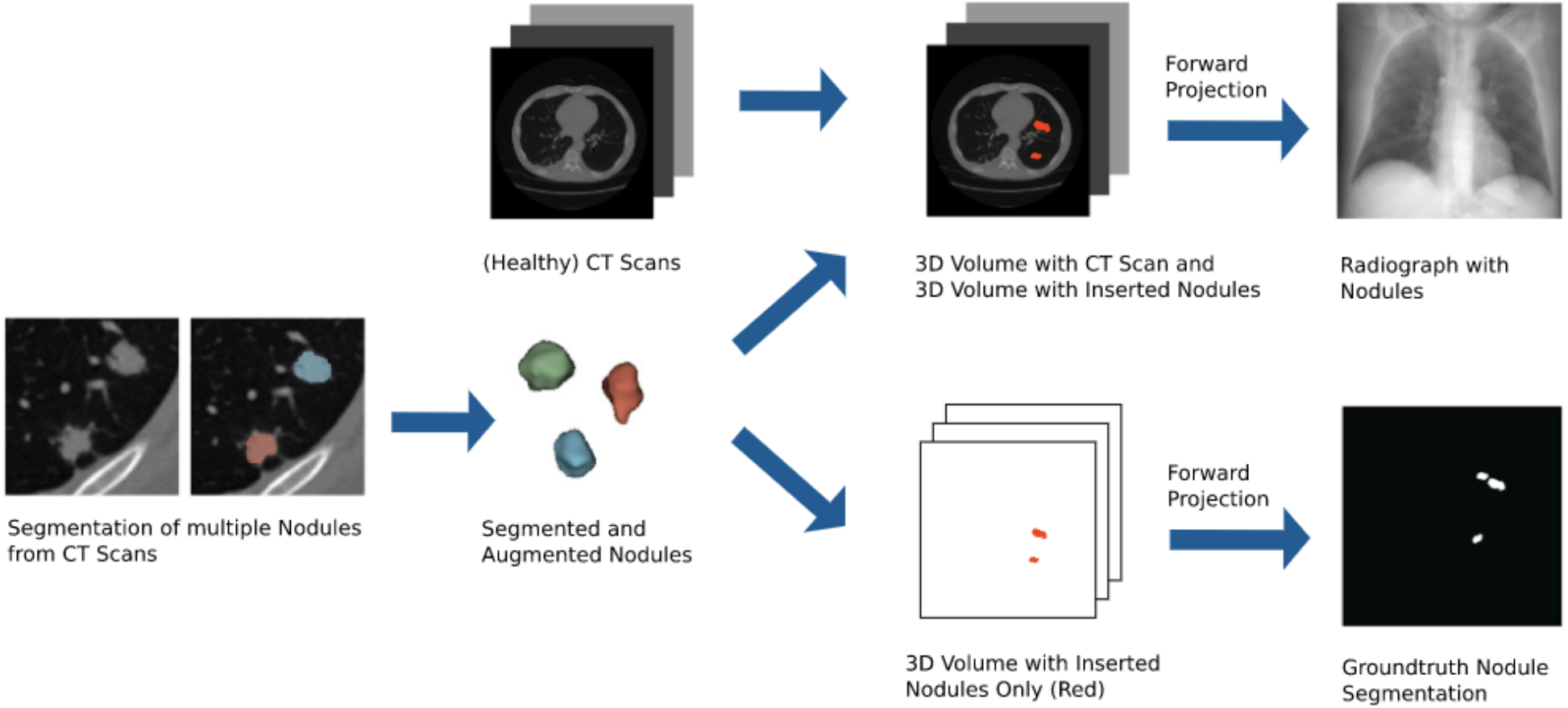
- Lung
  - Pulmonary nodule detection task
    - LUNA16 dataset (source)
      - 888 CT scans
    - U-Net + Lesion Scoring network based on Schultheiss et al. (source)
- Liver
  - Liver tumor detection task
    - Liver Tumor Segmentation dataset (source)
      - 130 CT scans
    - Similar approach as above
- Bone
  - Landmark detection task
    - CTPelvic1k dataset (source)
  - Already done with first iteration DeepDRRs
- Cardiac
  - TBD

Pulmonary Nodule Detection: The Task



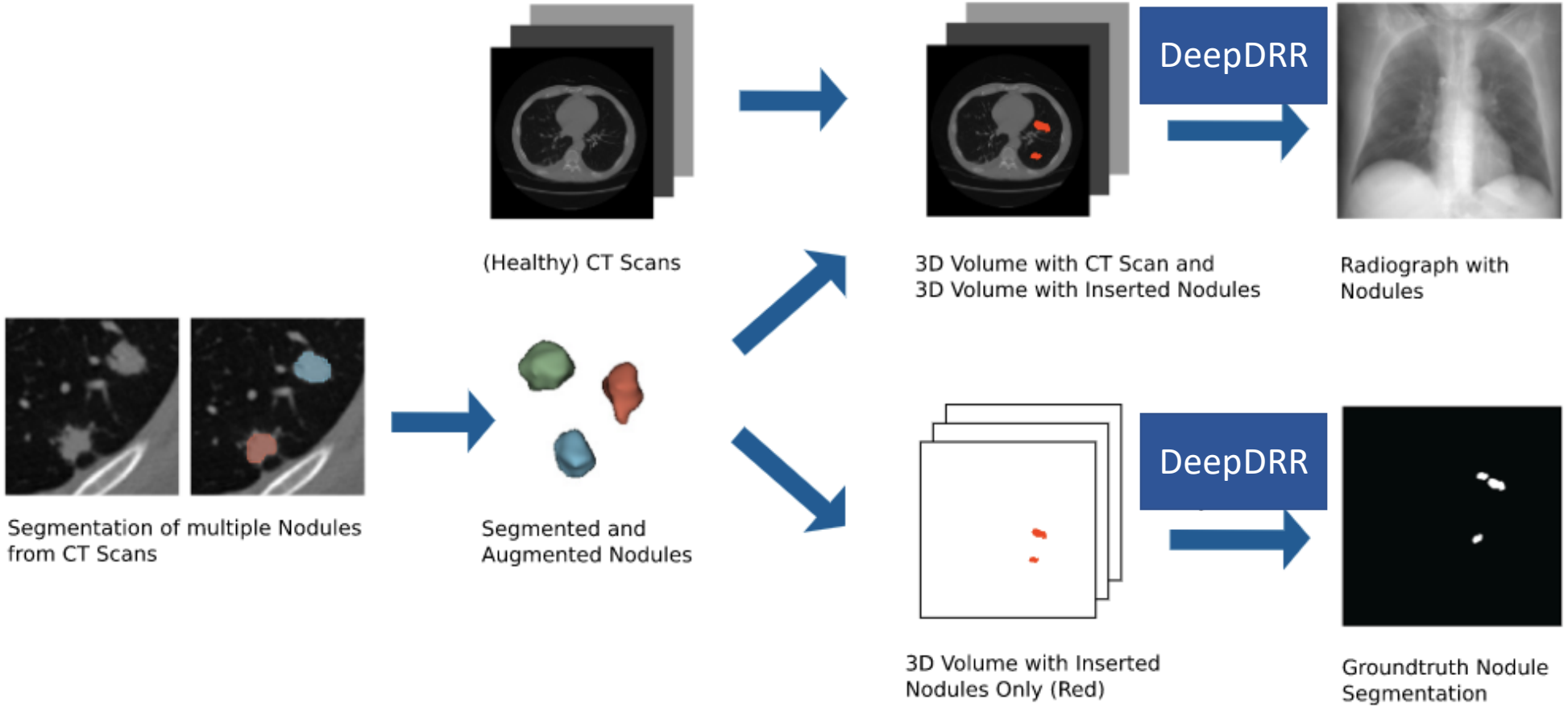
Source: Schultheiss, M., Schmette, P., Bodden, J., Aichele, J., Müller-Leisse, C., Gassert, F. G., ... & Pfeiffer, D. (2021). Lung nodule detection in chest X-rays using synthetic ground-truth data comparing CNN-based diagnosis to human performance. *Scientific Reports*, *11*(1), 1-10.

Pulmonary Nodule Detection: Ground-truth Generation



Source: Schultheiss, M., Schmette, P., Bodden, J., Aichele, J., Müller-Leisse, C., Gassert, F. G., ... & Pfeiffer, D. (2021). Lung nodule detection in chest X-rays using synthetic ground-truth data comparing CNN-based diagnosis to human performance. *Scientific Reports*, *11*(1), 1-10.

Pulmonary Nodule Detection: Ground-truth Generation



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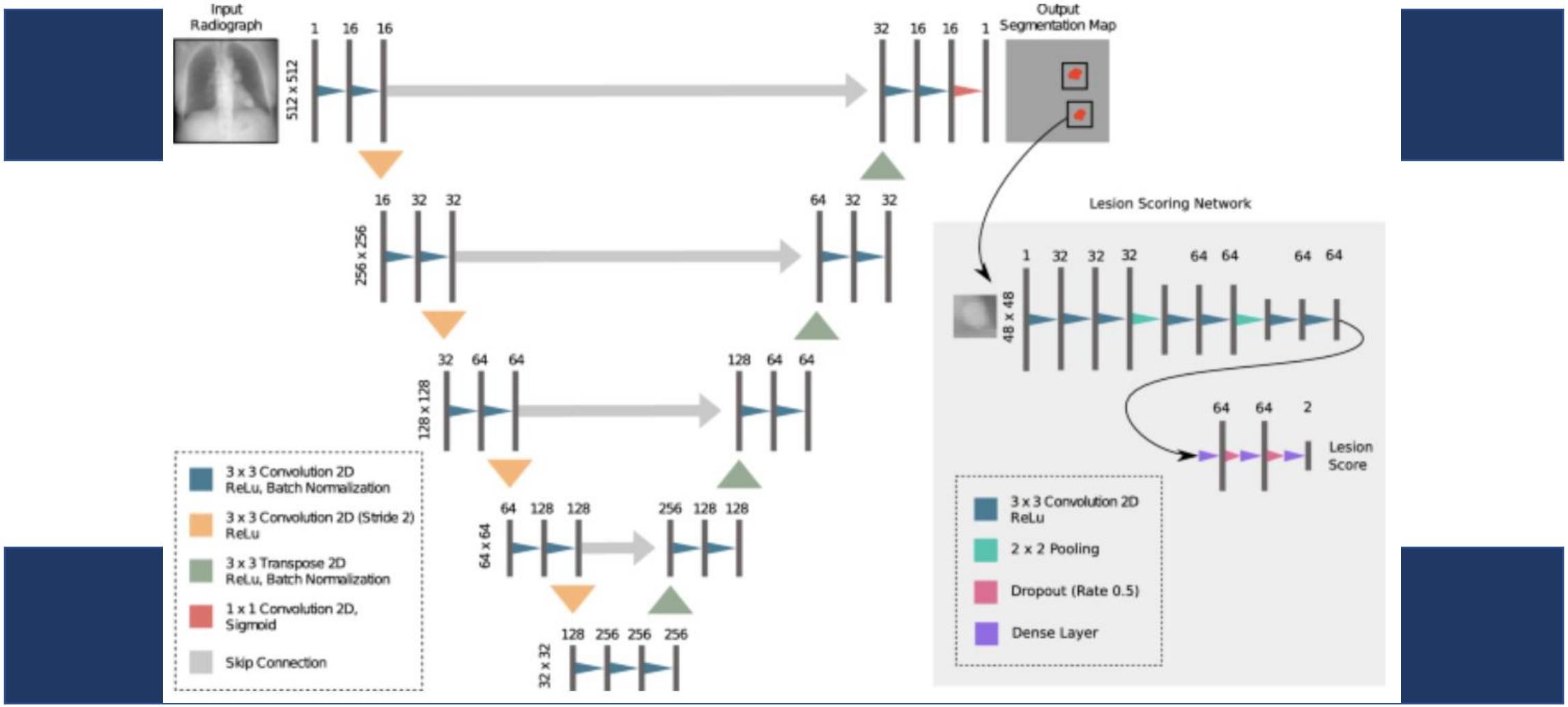
Pulmonary Nodule Detection: U-Net + Lesion Scoring Network



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Downstream Evaluation: Next steps

- Ground-truth generation
  - Insert perturbed nodules
- Modify scripts for liver downstream task

Milestones

Milestones	Expected Date	
Comparison report of existing models	Feb 22	✓
Scripts for general framework	March 8	✓
Segmentation masks using pretrained model	Newly added	✓
★ Downstream tasks selected	March 10	✓
★ Scripts for lung downstream task	March 17	
Scripts for lung, cardiac and/or liver segmentation	March 22	
Integration with DeepDRR	March 29	
Scripts for bone, soft tissue and air segmentation	April 6	
★ Scripts for remaining downstream tasks	April 6	
Report of results	April 12	

★ = new proposed milestone

Plan - Updated