Segmentation of lungs on CT

tools to aid Radiotherapy Planning

CISUC
CENTRO DE INFORMÁTICA E SISTEMAS DA UNIVERSIDADE DE COIMBRA

IPOPORTO

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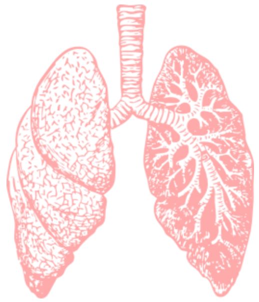


1 Contextualization

2 Segmentation algorithms

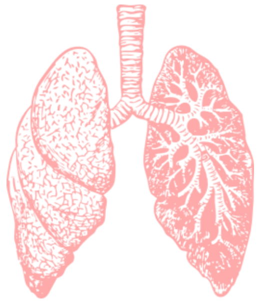
2.1 Region Growing

2.2 U-Net CNN

3 Comparison of approaches

4 Conclusions

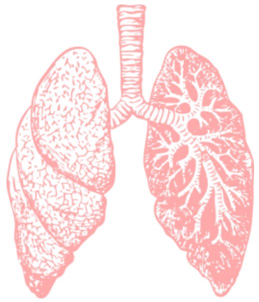
5 Future directions



Contextualization

Cancer and Radiotherapy Planning

Cancer

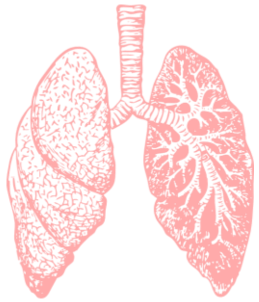


1,762,450 new cancer cases and 606,880 cancer deaths

Projected to occur in the United States in 2019

2nd largest cause of death in Europe

21.4% of cumulative risk of developing cancer before the age of 75 years. For dying, 17.7%, globally



Radiotherapy Planning

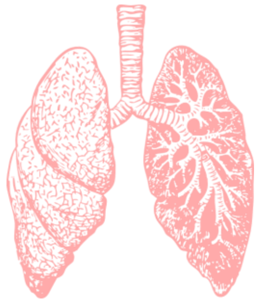
At least half of the cancer patients require radiotherapy

Radiotherapy alone is responsible for 78% of non-surgical cancer cures

Some normal tissue will be inevitable irradiated

Such radiation may lead to sequelae

Lungs segmentation



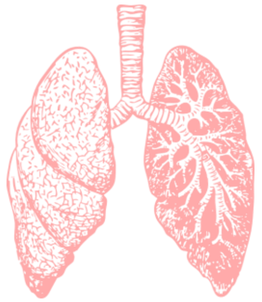
Sensitivity to toxicities of the lungs and heart limits the radiation dose escalation in some tumours

Risk of severe pneumonitis (fibroses)

No guideline or atlas is available, the delineation of the normal lung used for dose computation was not yet standardized

Underestimation of this volume may have two outcomes:

- *the participation exclusion of a patient from a clinical trial*
- *unnecessary limitation of the dose prescribed*

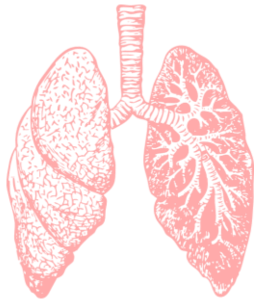


Objectives:

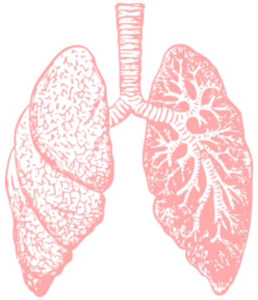
Evaluate the efficiency of traditional approaches on lung segmentation for Radiotherapy Planning

Use of a Deep Learning architecture for this task

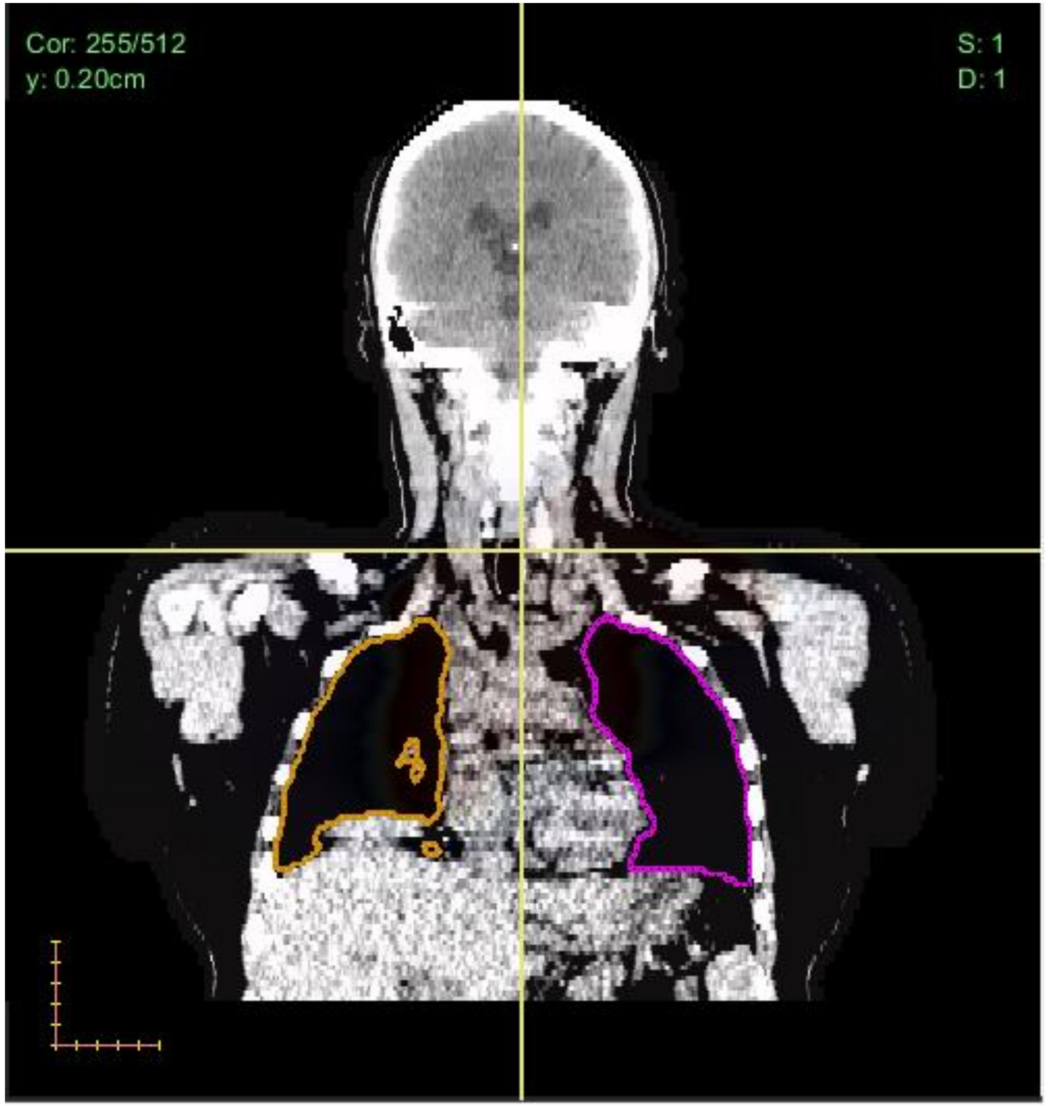
Compare both approaches in this particular problem



Dataset preparation



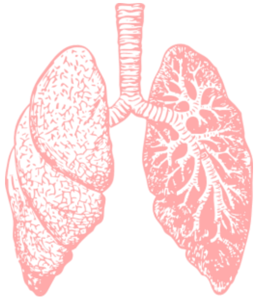
Name	Quantity
Patients	145
CTV	198
PTV	248
GTV	42
Lungs	93
Esophagus	121
Heart	97
Liver	20

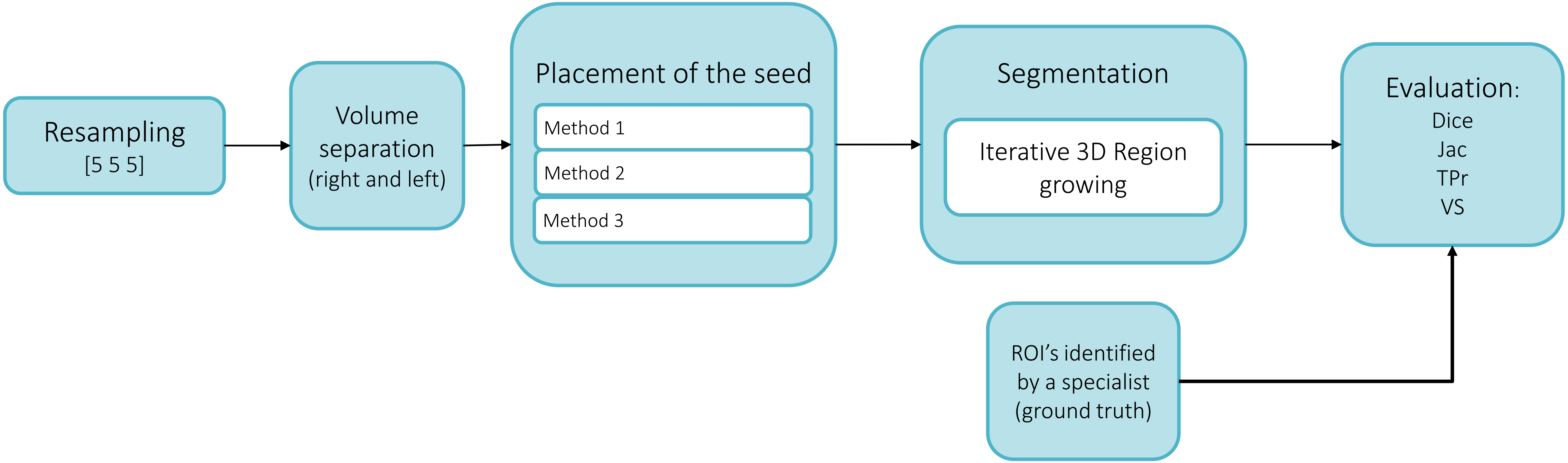


Group A

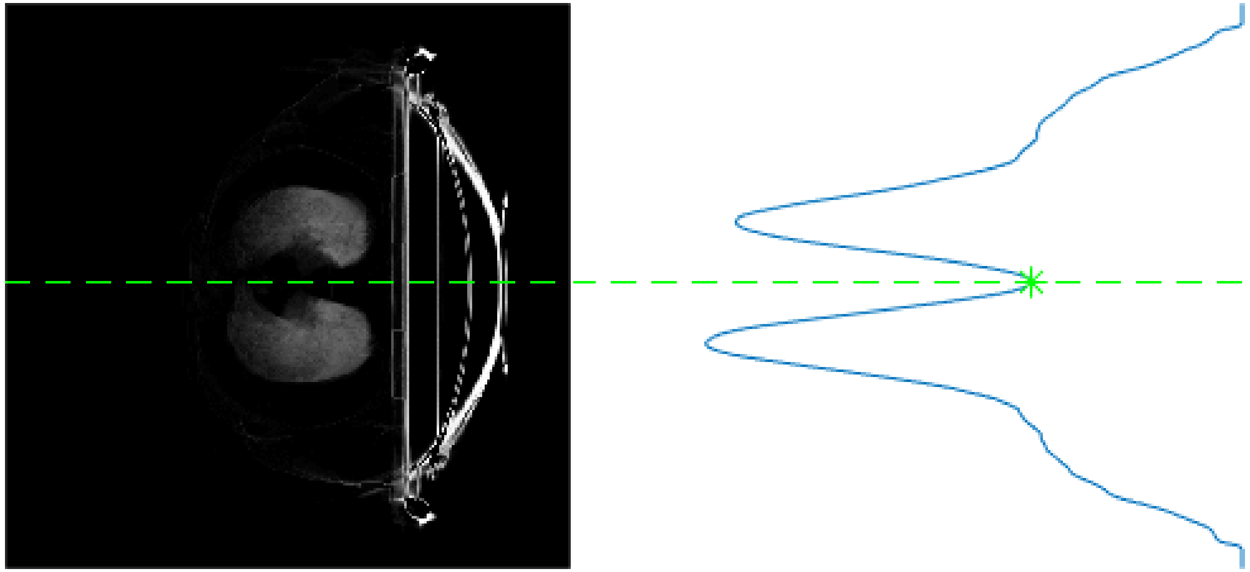
Group B

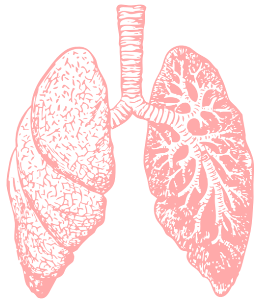
Region Growing



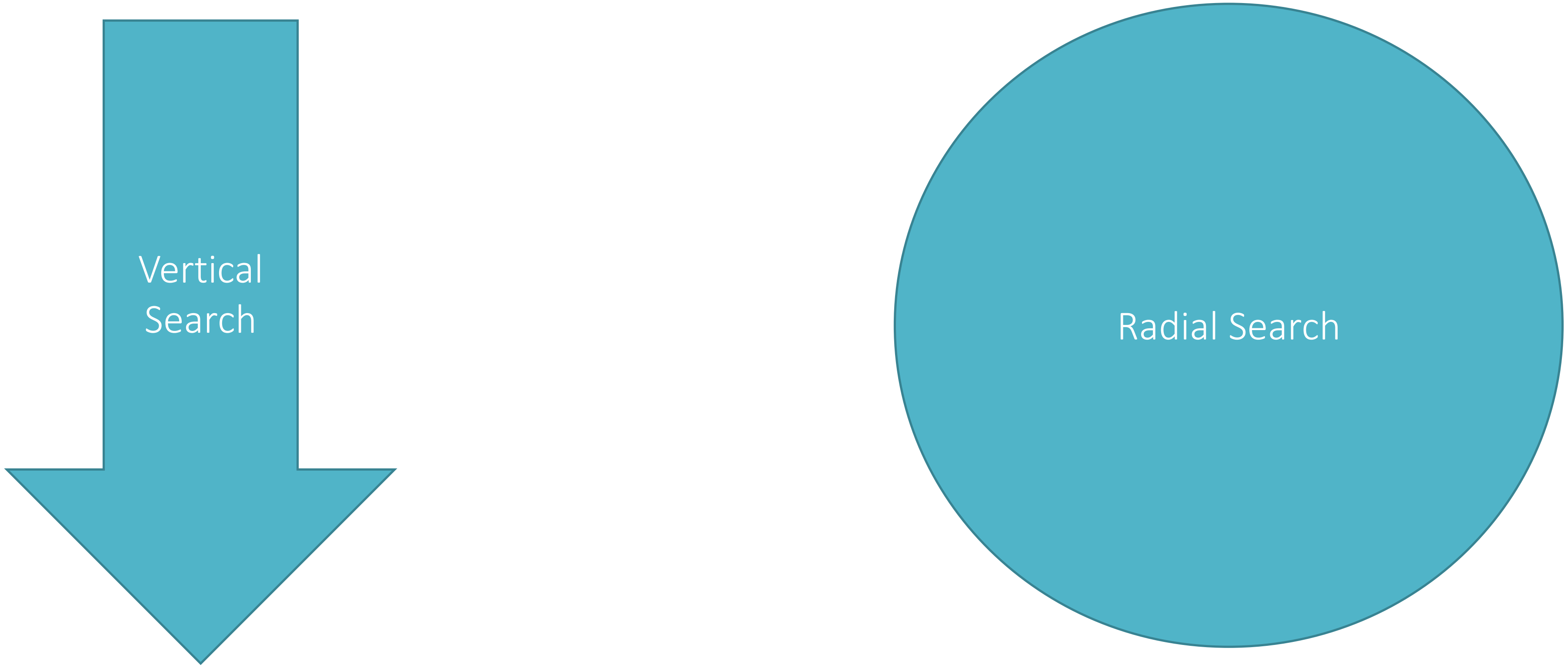

Resampling
[5 5 5]
Volume separation (right and left)
Placement of the seed
Method 1
Method 2
Method 3
Segmentation
Iterative 3D Region growing
Evaluation:
Dice
Jac
TPr
VS
ROI's identified by a specialist (ground truth)

Volume Separation



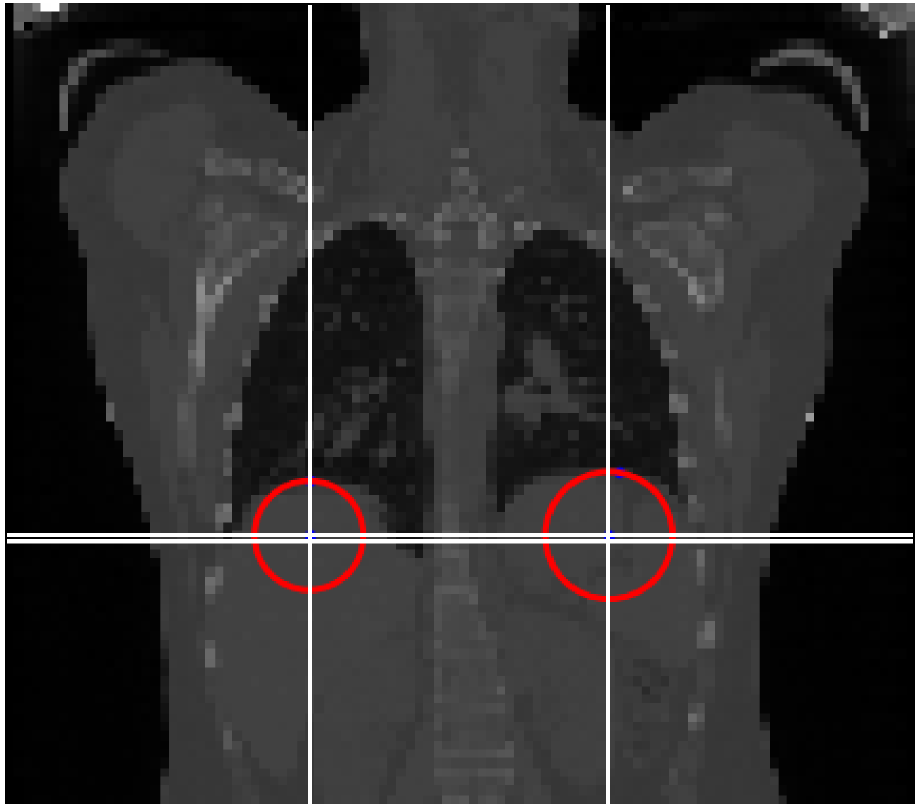


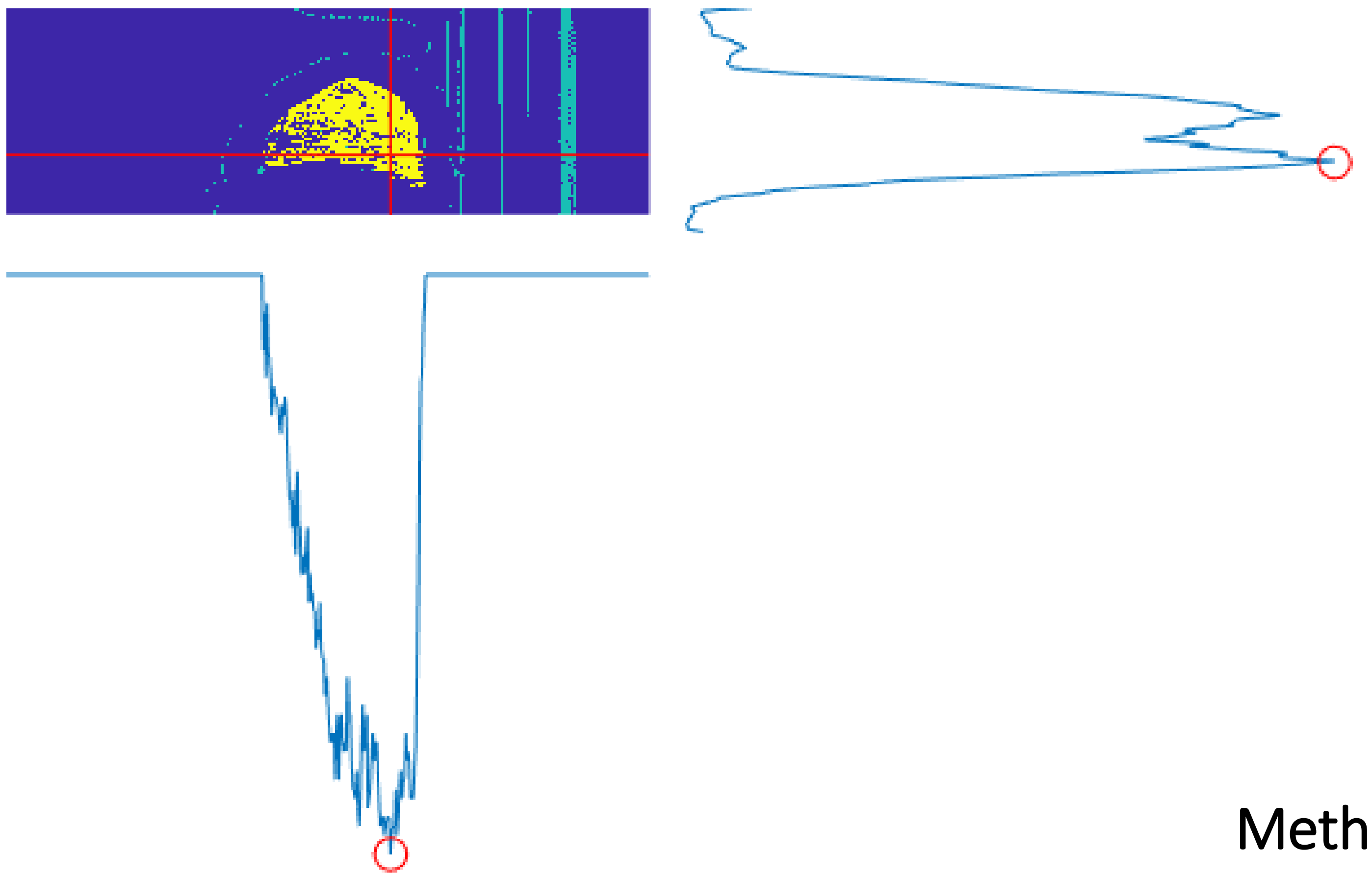
Placement of the seed



Method I

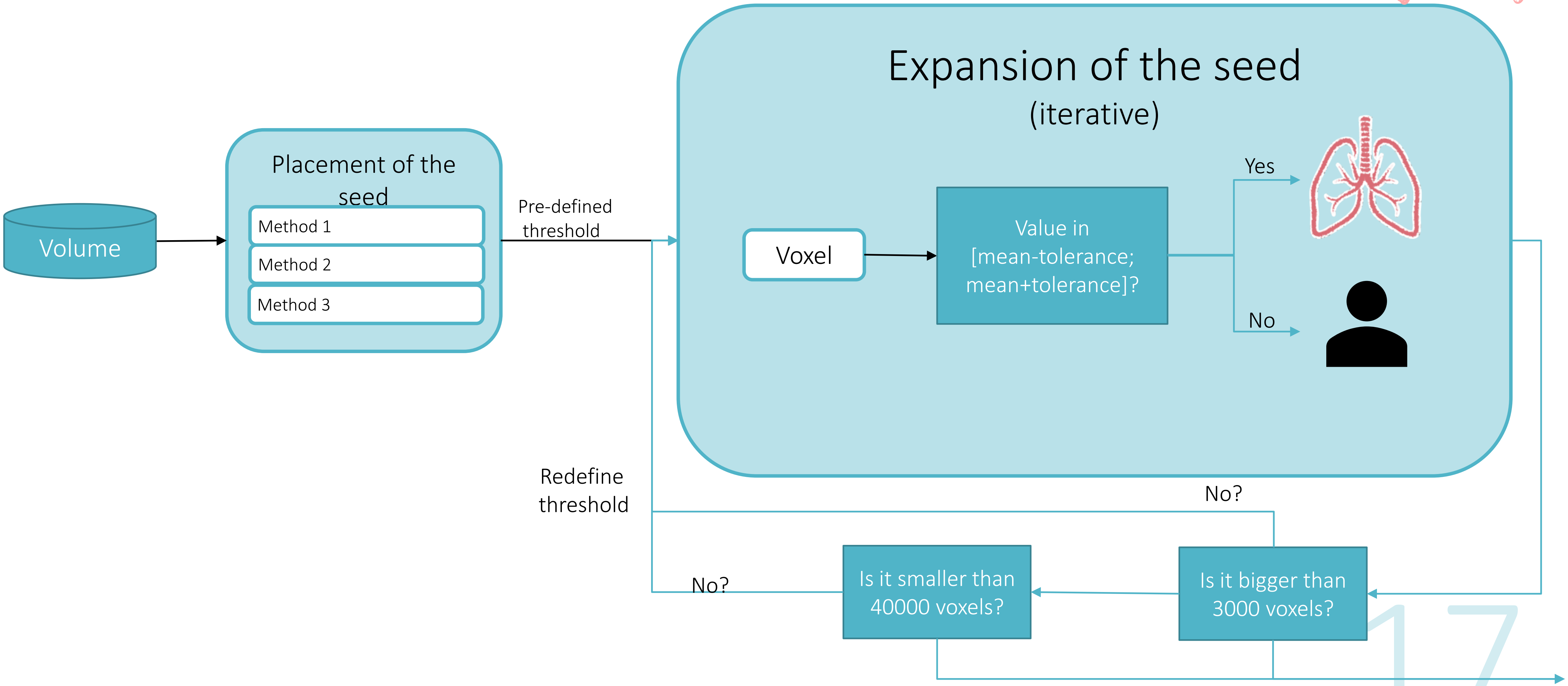
Method II





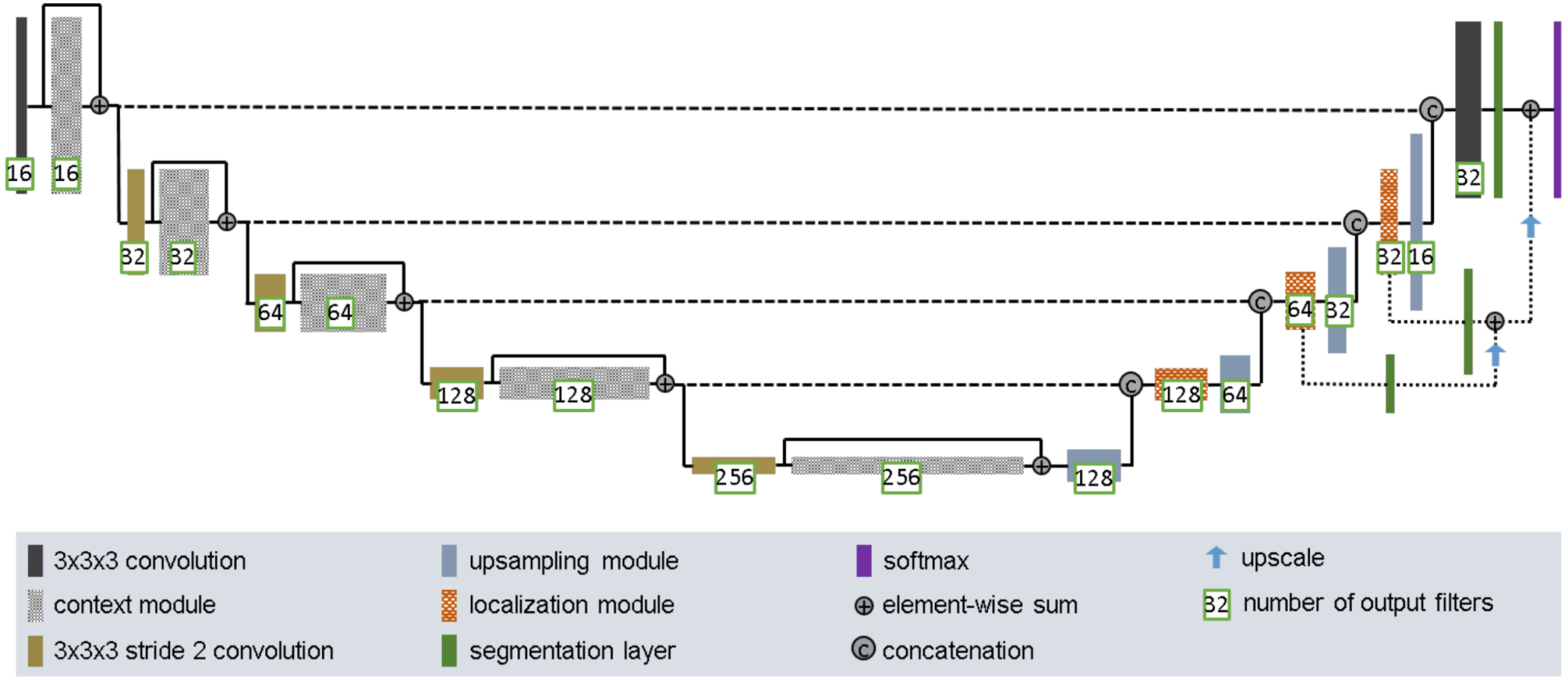
Method III

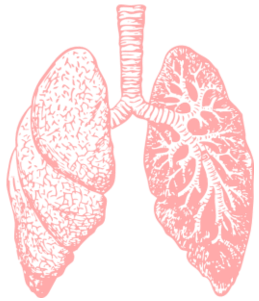
Iterative Region Growing

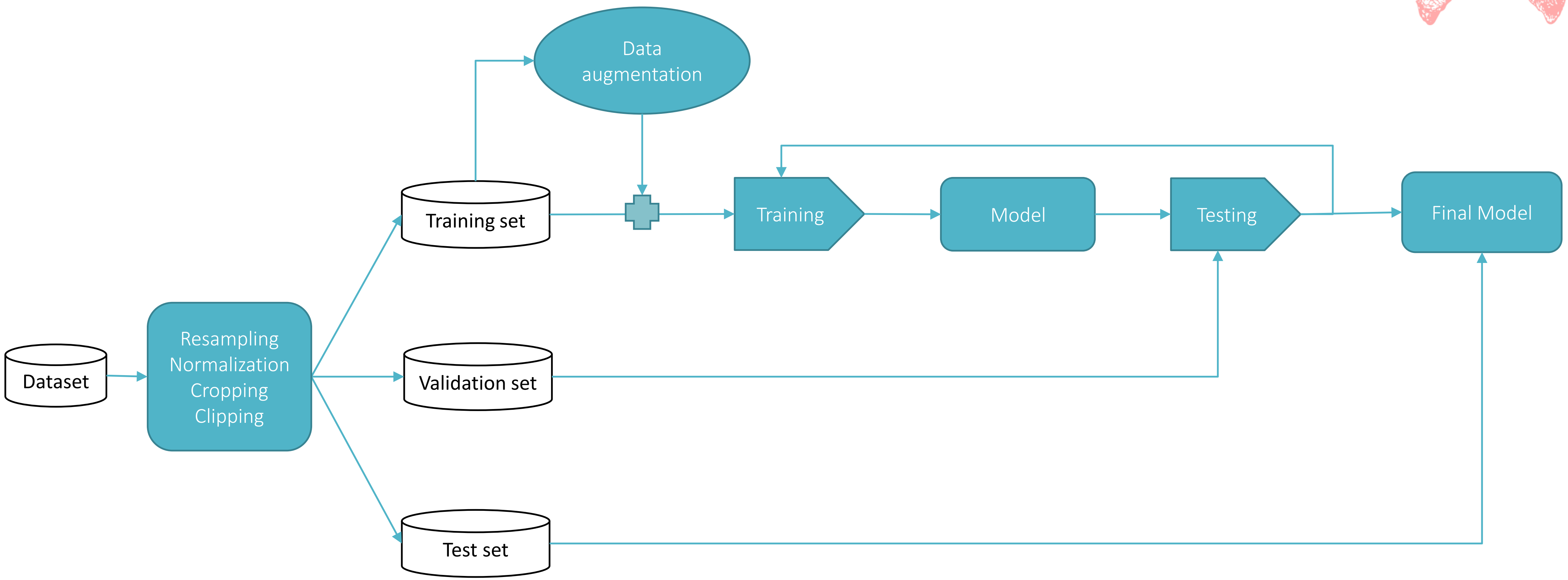


U-Net CNN

U-Net architecture



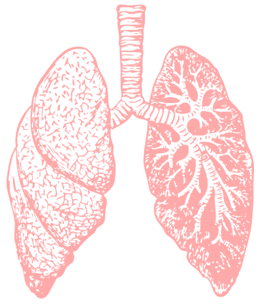



Data
augmentation
Training set
Training
Model
Testing
Final Model
Dataset
Resampling
Normalization
Cropping
Clipping
Validation set
Test set

14 models, parameters:

Parameter	Experimented Values
Volume Size	64^3,112^3
Up-convolution operation	Deconvolution, Upsampling
Batch Size	1,5
Validation Size	2,5
Number of Epochs	250,300
Patience	6,70,107
Early Stop	30,129,150
Flip	False, True
Permute	False, True
Distort	False, True

Results

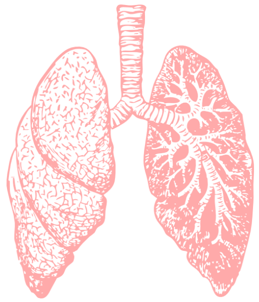


Iterative Region Growing

	Method 1	Method 2	Method 3
Percentage of valid seeds	78.03	78.03	**100.00***
Distance to centroid	21.47	18.61	**6.41***

Segmentation	Seed	DICE	Jac	TPr	VS
HU threshold	Method 1	0.661	0.576	0.605	0.703
HU threshold	Method 2	0.656	0.571	0.600	0.691
HU threshold	Method 3	0.812	0.707	0.740	0.858
HU threshold	GT centroid	0.812	0.707	0.740	0.861
Standard Region Growing	Method 1	0.736	0.703	0.716	0.779
Standard Region Growing	Method 2	0.720	0.687	0.700	0.752
Standard Region Growing	Method 3	0.894	0.853	0.871	0.926
Standard Region Growing	GT centroid	0.872	0.833	0.850	0.916
Iterative Region Growing	Method 1	0.736	0.703	0.716	0.836
Iterative Region Growing	Method 2	0.741	0.707	0.721	0.841
Iterative Region Growing	Method 3	**0.923**	**0.882**	**0.900**	**0.956**
Iterative Region Growing	GT centroid	0.886	0.846	0.863	0.930

Results

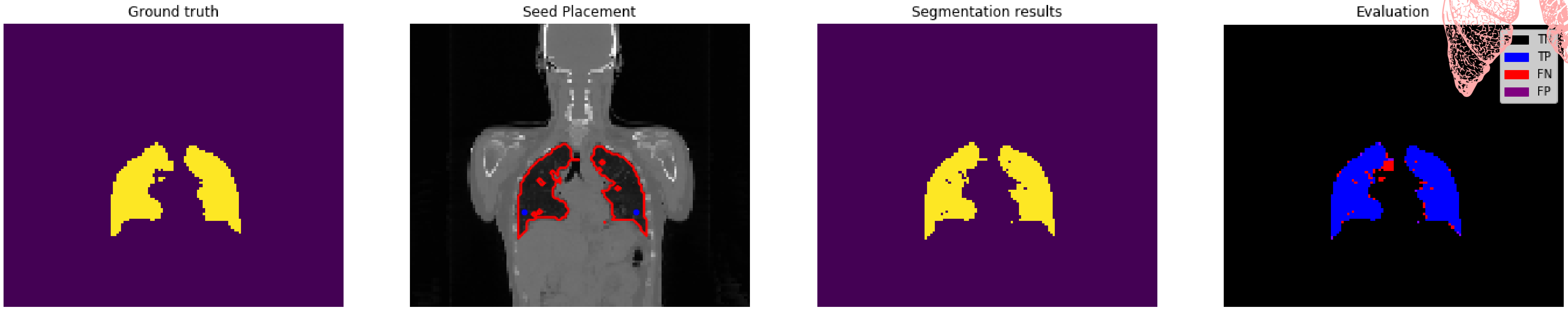


Iterative Region Growing

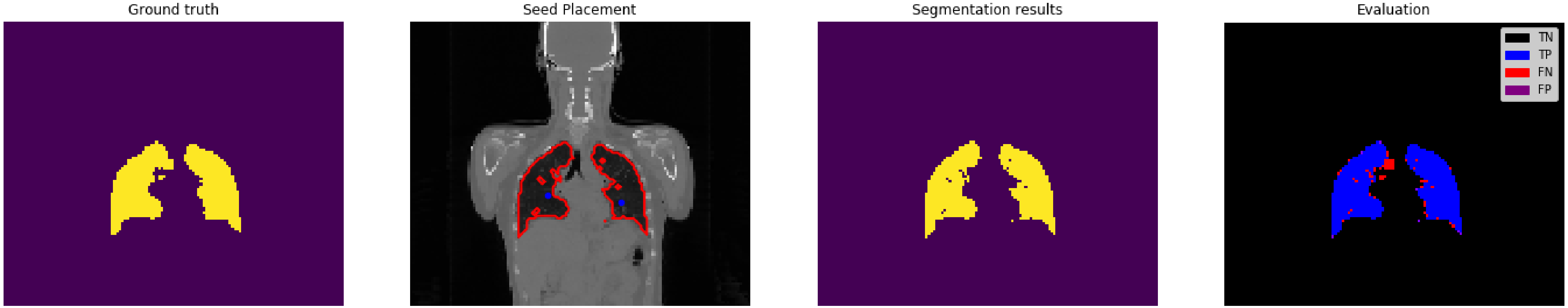
	Method 1	Method 2	Method 3
Percentage of valid seeds	78.03	78.03	**100.00***
Distance to centroid	21.47	18.61	**6.41***

Segmentation	Seed	DICE	Jac	TPr	VS
HU threshold	Method 1	0.639	0.559	0.587	0.671
HU threshold	Method 2	0.634	0.554	0.580	0.663
HU threshold	Method 3	0.812	0.707	0.740	0.858
HU threshold	GT centroid	0.786	0.685	0.717	0.834
Region Growing	Method 1	**0.925**	**0.883**	**0.900**	0.952
Region Growing	Method 2	0.895	0.854	0.870	0.922
Region Growing	Method 3	0.894	0.853	0.871	0.926
Region Growing	GT centroid	0.892	0.852	0.870	0.931
Iterative Region Growing	Method 1	**0.925**	**0.883**	**0.900**	0.952
Iterative Region Growing	Method 2	0.914	0.872	0.888	0.945
Iterative Region Growing	Method 3	0.923	0.882	**0.900**	**0.956**
Iterative Region Growing	GT centroid	0.900	0.859	0.877	0.939

First method

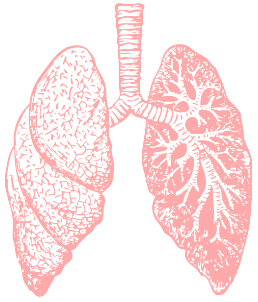


Third method



Results

U-Net CNN

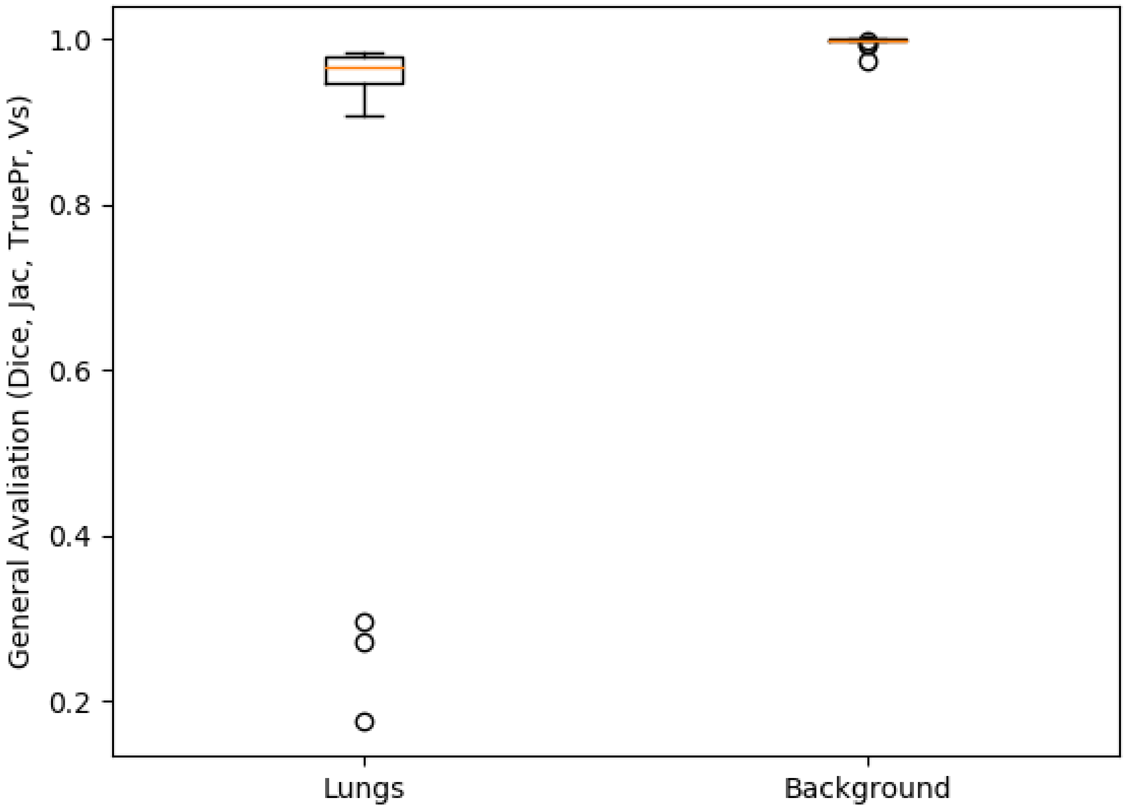


Model	Multiclass Dice mean	Metrics mean	Multiclass Dice median	Metrics median
1	96.6 ± 0.6	96.5 ± 0.7	96.8 ± 0.6	96.7 ± 0.7
2	96.3 ± 1.9	96.1 ± 1.9	96.6 ± 1.9	96.6 ± 1.9
3	96.5 ± 0.6	96.4 ± 0.8	96.6 ± 0.6	96.6 ± 0.8
4	96.4 ± 0.6	96.2 ± 0.9	96.5 ± 0.6	96.3 ± 0.9
5	96.2 ± 0.8	96.1 ± 1.0	96.2 ± 0.8	96.0 ± 1.0
6	96.2 ± 0.9	95.9 ± 1.2	96.5 ± 0.9	96.2 ± 1.2
7	88.0 ± 17	88.5 ± 13.2	93.0 ± 17	91.3 ± 13.2
8	96.3 ± 0.6	96.2 ± 0.7	96.5 ± 0.6	96.5 ± 0.7
9	95.8 ± 1.3	95.3 ± 1.5	96.0 ± 1.3	95.2 ± 1.5
10	96.9 ± 0.7	96.7 ± 0.9	97.1 ± 0.9	97.0 ± 0.9
11	97.3 ± 0.5	97.1 ± 0.7	97.4 ± 0.5	97.2 ± 0.7
12	97.4 ± 0.7	97.3 ± 0.9	97.7 ± 0.7	97.6 ± 0.9
13	97.4 ± 0.6	97.2 ± 0.9	97.8 ± 0.6	97.4 ± 0.9
14	**97.5±0.7**	**97.3±0.9**	**97.7±0.7**	**97.7±0.9**

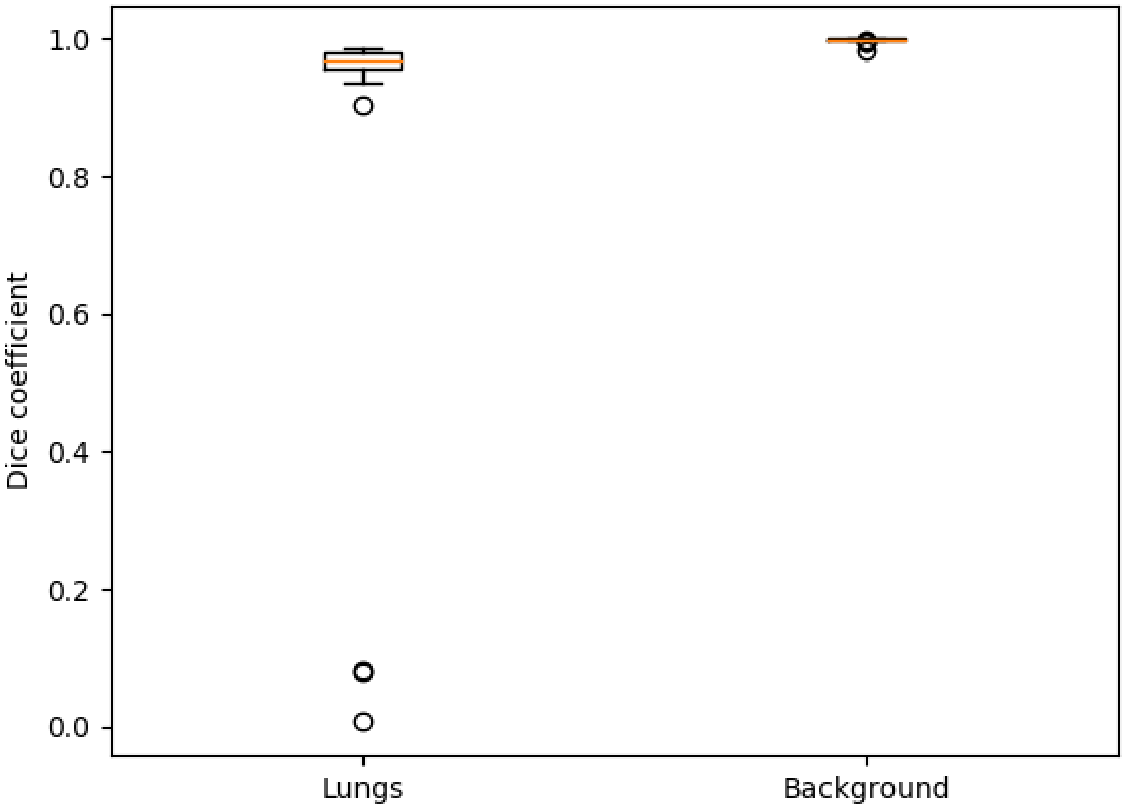
No data augmentation
Upsampling

Group B

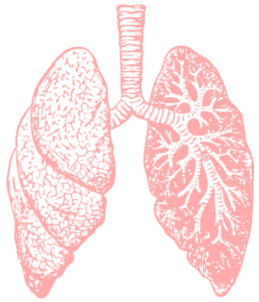
Model	Multiclass Dice mean	Metrics mean	Multiclass Dice median	Metrics median
1	91.0±22.1	91.8±17.4	96.9±22.1	96.5±17.4



General Avaliation (Dice, Jac, TruePr, Vs)
1.0
0.8
0.6
0.4
0.2
Lungs
Background



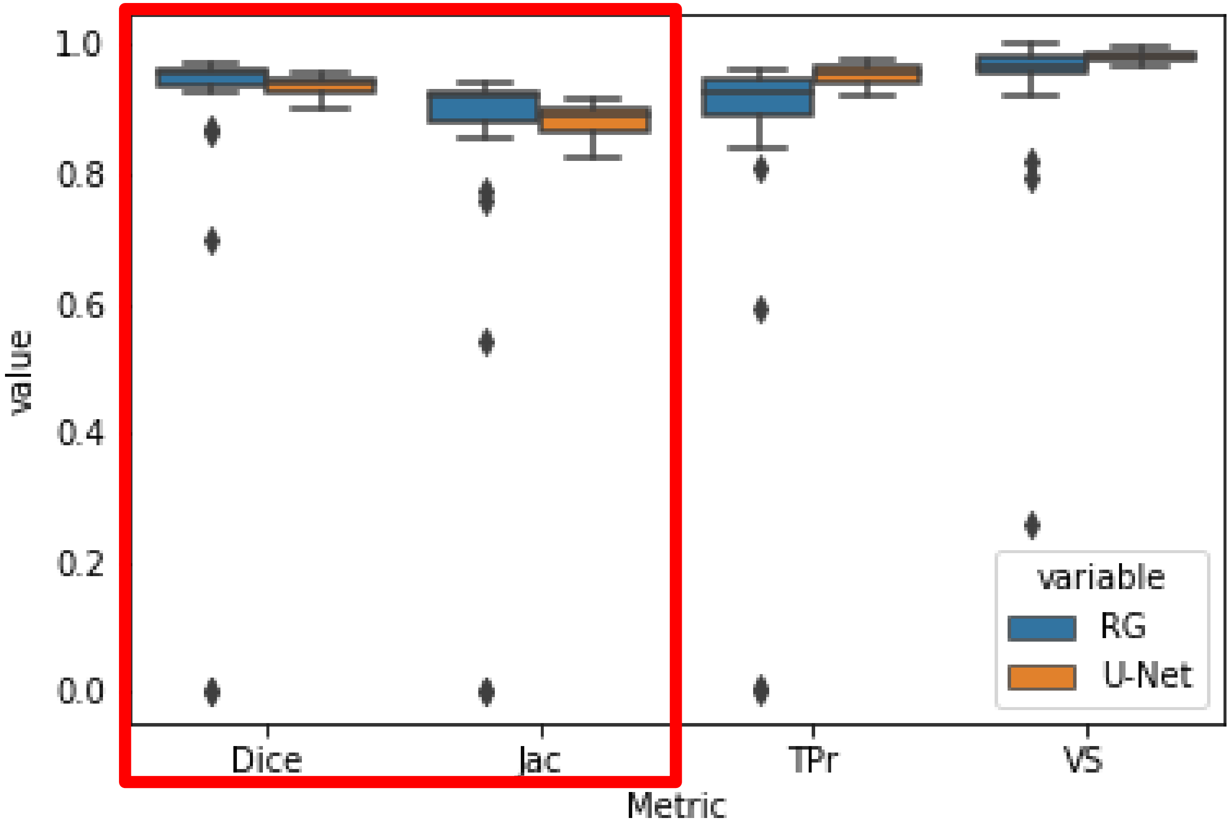
Dice coefficient
1.0
0.8
0.6
0.4
0.2
0.0
Lungs
Background



Comparison

Comparison IRG vs U-Net

Metric	Iterative Region Growing mean	Iterative Region Growing median	U-Net CNN mean	U-Net CNN median
Dice	0.872±0.247	**0.958±0.247**	**0.938±0.013**	0.944±0.013
Jac	0.826±0.242	**0.920±0.242**	**0.884±0.023**	0.894+0.023
TPR	0.844±0.243	0.928±0.243	**0.955±0.015***	**0.958±0.015***
VS	0.933±0.137	0.968±0.137	**0.981±0.008***	**0.981±0.008***



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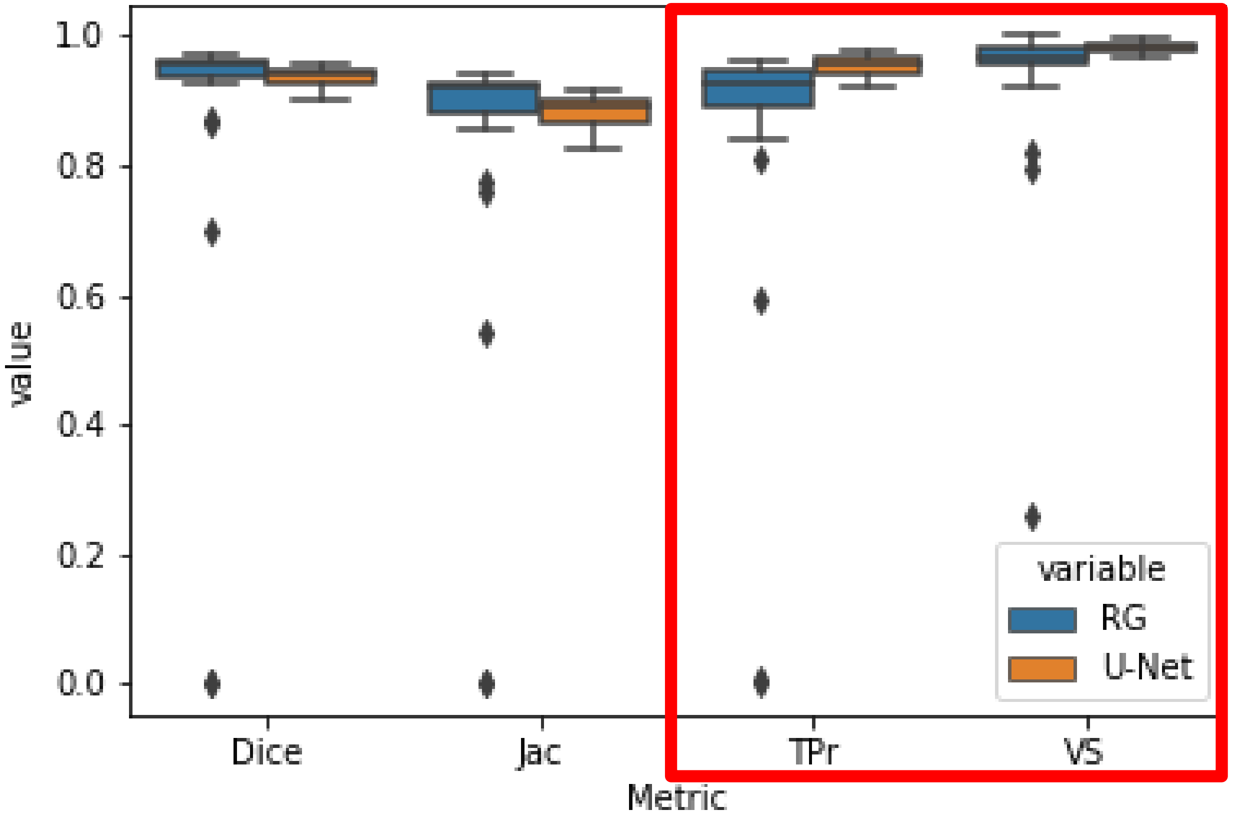
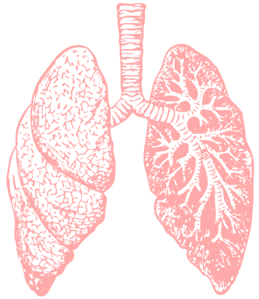
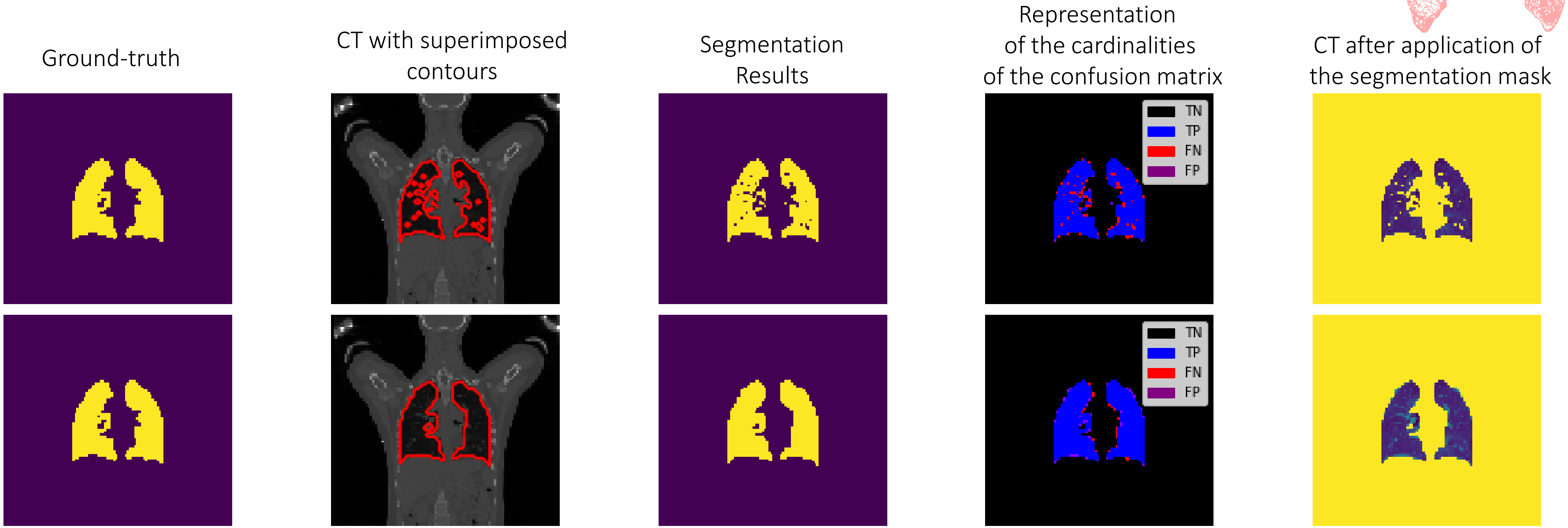
Jac	0.826±0.242	**0.920±0.242**	**0.884±0.023**	0.894+0.023
TPR	0.844±0.243	0.928±0.243	**0.955±0.015***	**0.958±0.015***
VS	0.933±0.137	0.968±0.137	**0.981±0.008***	**0.981±0.008***

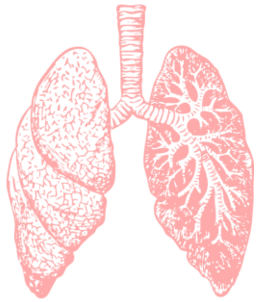
* Statistically significant results







Comparison of the segmentations resultant from the IRG method (top) and U-Net CNN (bottom)



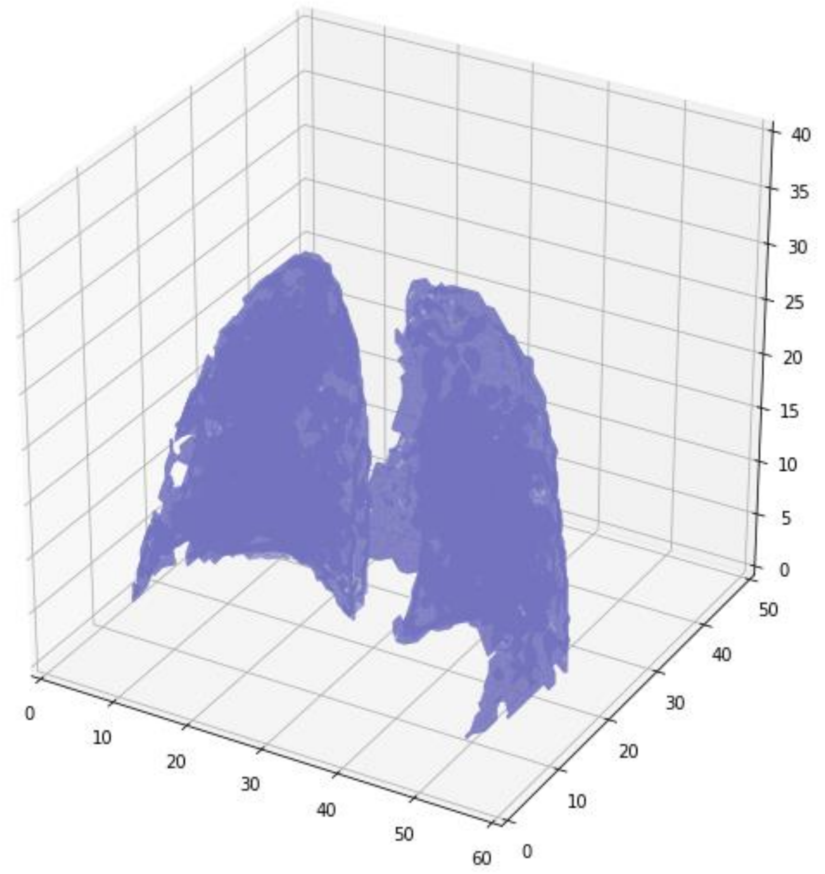
Conclusions

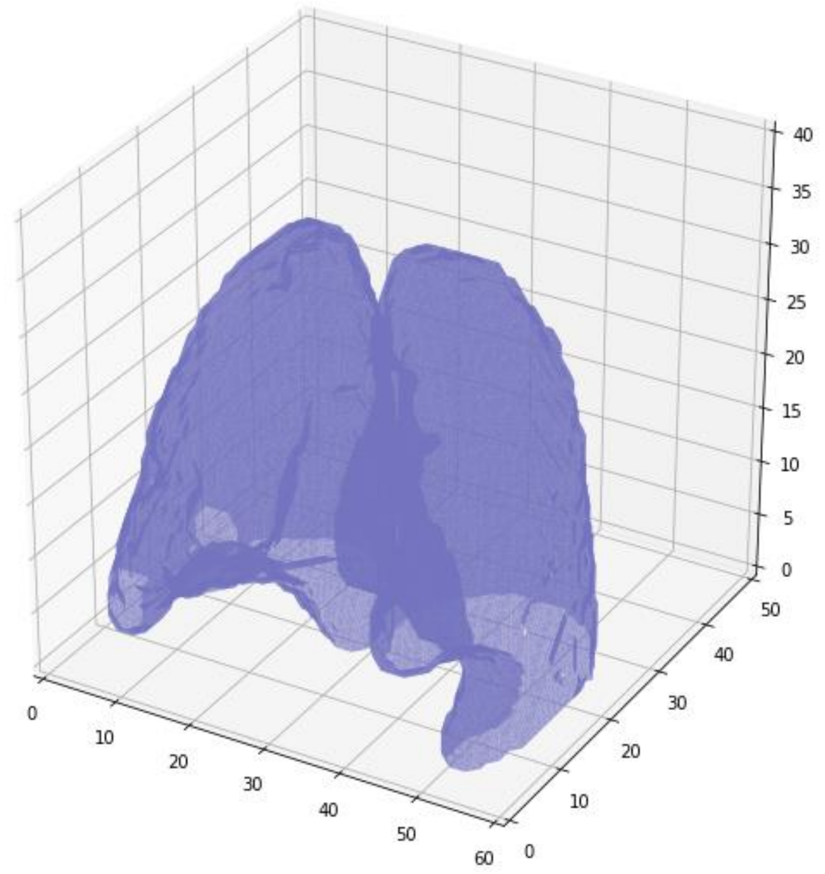
There were significant differences for U-Net on VS and TPr

Region Growing is better on DICE and Jac, but there are no significant differences

This algorithms may help to reduce the time spent by clinicians

Future directions





Questions?