





FACULTY OF ENGINEERING

# Dilated Residual U-Net for Multi-organ Segmentation in Thoracic CT

Is 2D better than 3D segmentation?

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Figure: Risks of side effects in the surrounding organs increases during breast cancer radiotherapy.





# **Motivation**







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# 3D U-Net<sup>[1]</sup>



[1] Çiçek *et. al.* MICCAI 2016 [2] Yee *et. al.* 2017





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#### **Pre-Processing**







#### **2D UNet + DR Architecture**







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### **Loss Functions**

• Multi-class Dice Loss<sup>[1]</sup>:

$$\begin{aligned} \zeta_{dc}(y, \hat{y}) &= 1 - \frac{1}{N} \left( \sum_{k} \frac{\sum_{n} y_{nk} \hat{y}_{nk}}{\sum_{n} y_{nk} + \sum_{n} \hat{y}_{nk}} \right) \\ & \swarrow \end{aligned}$$
No of classes Predicted voxel of class k Ground truth

• Tversky Loss<sup>[2]</sup>:

$$TL(y, \hat{y}) = 1 - \frac{\sum_{k=1}^{N} y_{nk} \hat{y}_{nk}}{\sum_{k=1}^{N} y_{nk} \hat{y}_{nk} + \alpha \sum_{k=1}^{N} y_{nk} \hat{y}_{nk} + \beta \sum_{k=1}^{N} y_{nk} \hat{y}_{nk}}$$
$$\alpha = \beta = 0.5$$

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Milletari *et. al.* MICCAI 2016
 Salehi *et. al.* MICCAI MLMI 2017





# SegTHOR Dataset<sup>[1]</sup>

- 60 CTs from patients with non small cell lung cancer
- Resolution: 0.98 × 0.98 × 2.50 mm<sup>3</sup>
- Dimensions:
  - N × 512 × 512 voxels
  - $N \rightarrow 150$  to 284 slices



• Data Split:







# **ISBI SegTHOR**

Methods	Training DSC	Validation DSC	Testing DSC	Testing HD
2D DR U-Net	0.978	0.936	0.887	0.446
2D DR U-Net (Augmented)	0.974	0.945	0.914	0.254
2D DR U-Net (Augmented) + Tversky Loss	0.975	0.946	0.916	0.250



DSC: 0.942(0.028) HD: 0.092(0.054)



DSC: 0.921(0.016) HD: 0.016(0.174)



DSC: 0.909(0.062) HD: 0.304(0.161)





# **Quantitative Analysis**

**DICE Score for different Organs at Risk** 







### **Quantitative Analysis**







# **ISBI SegTHOR Leaderboard**

RESULTS														
#	User	Entries	Date of Last Entry	Team Name	Rank	Dice			Hausdorff					
					<all></all>	<eusophagus></eusophagus>	Esophagus	Heart 🔺	Trachea	Aorta 🔺	Esophagus	Heart 🔺	Trachea	Aorta 🔺
1	gaoking132	4	03/20/19		1.50 (1)	1.00 (1)	0.8651 (1)	0.9536 (2)	0.9276 (1)	0.9464 (2)	0.2590 (1)	0.1272 (2)	0.1453 (1)	0.1209 (2)
2	MILab	7	03/21/19		3.50 (2)	3.50 (3)	0.8594 (4)	0.9500 (5)	0.9201 (6)	0.9484 (1)	0.2743 (3)	0.1383 (5)	0.1824 (3)	0.1129 (1)
3	hyang	10	03/21/19	I-V	5.00 (3)	10.00 (8)	0.8381 (9)	0.9542 (1)	0.9233 (3)	0.9443 (6)	0.3534 (11)	0.1208 (1)	0.1973 (5)	0.1290 (4)
4	elias	3	03/19/19		5.12 (4)	5.50 (5)	0.8527 (7)	0.9526 (3)	0.9216 (5)	0.9415 (8)	0.2853 (4)	0.1302 (3)	0.1776 (2)	0.1895 (9)
5	ZWB	7	03/22/19		6.25 (5)	4.00 (4)	0.8597 (3)	0.9459 (9)	0.9217 (4)	0.9433 (7)	0.2883 (5)	0.1594 (7)	0.2045 (7)	0.1551 (8)
6	dp	7	03/21/19		8.25 (6)	10.00 (8)	0.8339 (12)	0.9519 (4)	0.9157 (8)	0.9351 (14)	0.3351 (8)	0.1325 (4)	0.2041 (6)	0.1980 (10)
7	grr	7	03/20/19		9.00 (7)	5.50 (5)	0.8582 (5)	0.9456 (11)	0.9153 (9)	0.9391 (10)	0.2928 (6)	0.1867 (12)	0.2090 (8)	0.2010 (11)
8	Dianna	3	03/24/19	MSELab	11.12 (8)	2.00 (2)	0.8617 (2)	0.9426 (14)	0.9134 (10)	0.9355 (12)	0.2736 (2)	0.1756 (10)	0.2469 (14)	0.3780 (25)
9	svesal	10	03/22/19		11.12 (8)	6.50 (6)	0.8579 (6)	0.9415 (15)	0.9257 (2)	0.9375 (11)	0.3308 (7)	0.2262 (23)	0.1929 (4)	0.2971 (21)
10	smilenaxx	10	03/21/19		11.75 (9)	19.50 (13)	0.7766 (24)	0.9435 (13)	0.9186 (7)	0.9393 (9)	0.5340 (15)	0.1733 (9)	0.2101 (10)	0.1480 (7)





# Conclusion

- 2D U-Net+DR outperformed 3D U-Net with less trainable parameters
- Incorporating global contextual information improve the performance
- Fast (≈ 5.08 seconds) and robust method
- MR images, may be beneficial for some OARs with poorly-visible boundaries such as the esophagus







# Thank you for your attention!

**Questions?** 



https://www5.cs.fau.de/~vesal