On TotalSegmentator's Performance on Low-Dose CT Images

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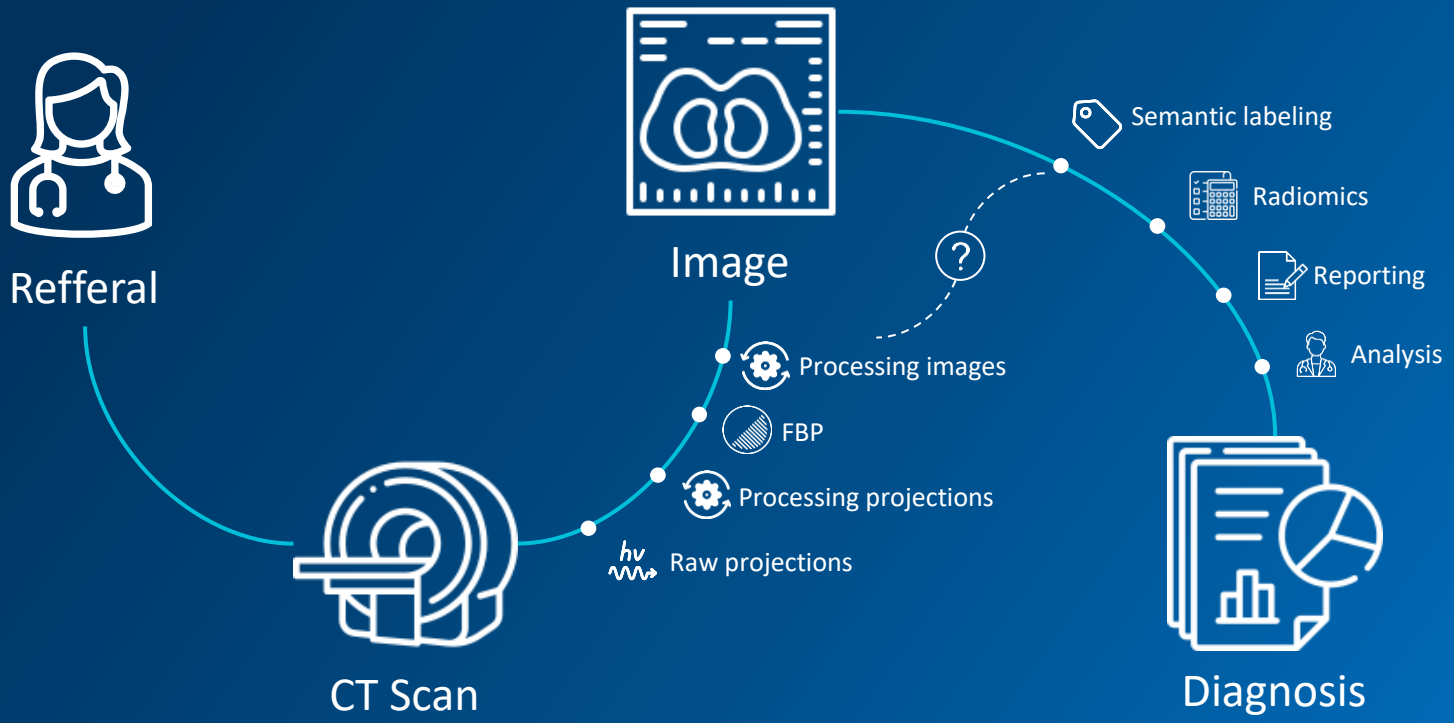
How low-dose protocols affect segmentation?



Segmentation Milestones

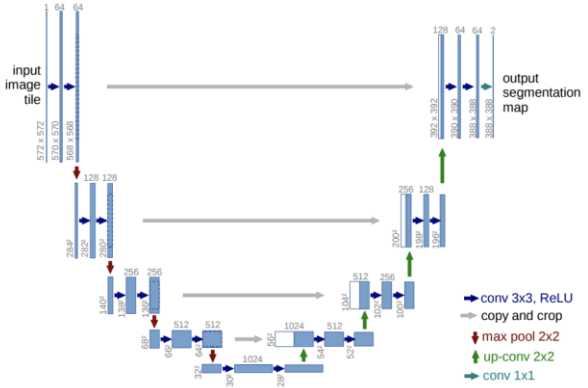
2015 — U-Net: Convolutional Networks for Biomedical Image Segmentation

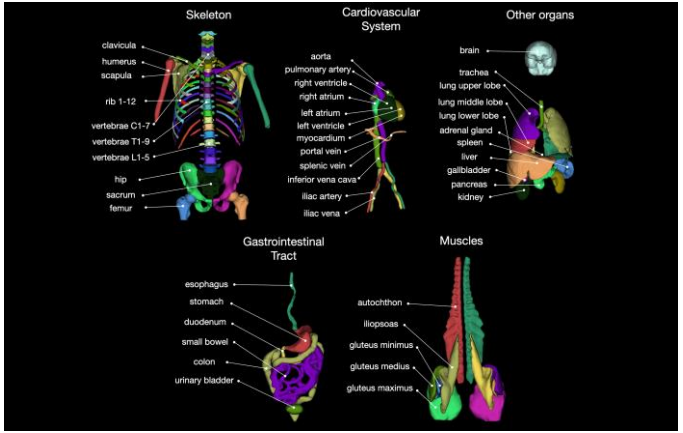
A novel encoder-decoder architecture with skip-connections. Originally applied for segmentation of neuronal structures in electron microscopic stacks.

2018 — nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation

”nonew-Net”. The method automatically configures itself, including pre-processing, network architecture, training and post-processing for any new task

2022 — TotalSegmentator: robust segmentation of 104 anatomical structures in CT images



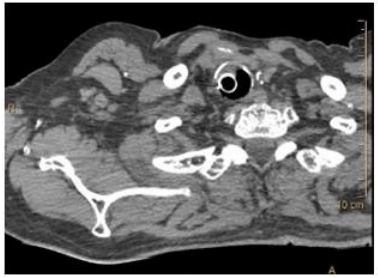


CT Image Formation

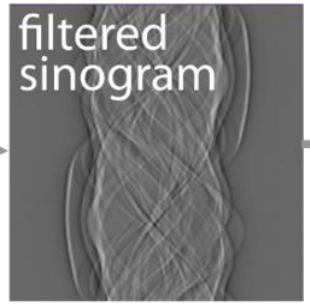
projection space | image space

Here we know noise model and can realistically simualte it

Here we subjectively judge about image quality



Processing and high pass filtering



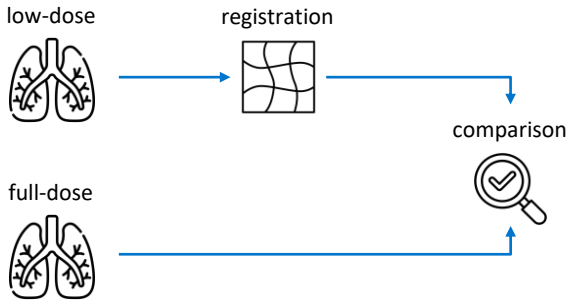
Filtered Back Projection

Processing

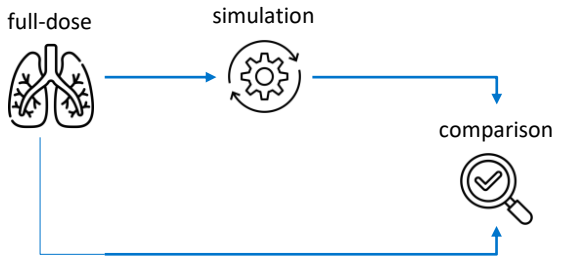
Approaches to the analysis of dose robustness

Real | Data | Simulated

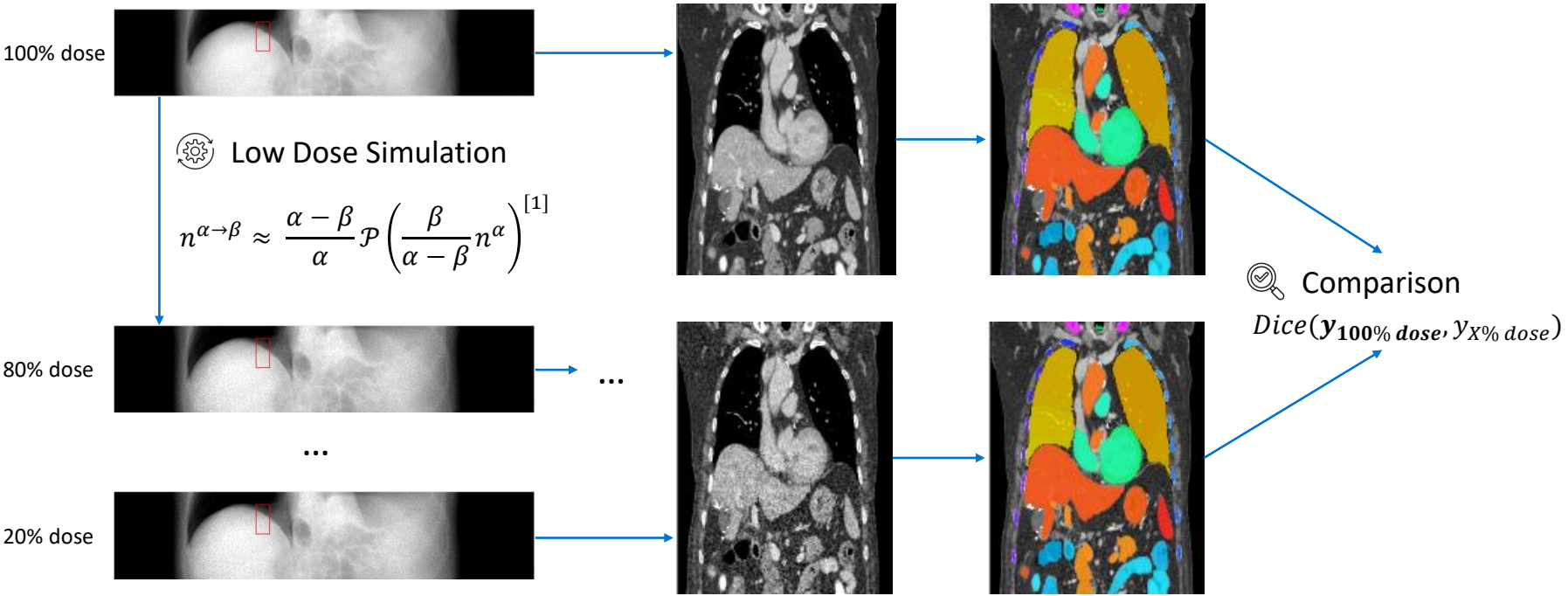
- Low-dose data is taken from real acquisitions
- Leads to unpaired low- and full-dose images
- Low quantity



- Low-dose data is simulated
- Perfectly registered
- **Accurate simulations require raw data and information about a CT system**



Method



[1] Žabić, Stanislav, et al. "A low dose simulation tool for CT systems with energy integrating detectors." *Medical physics* 40.3 (2013): 031102.

Experiment

- 42 patients, 99 CT scans
- Raw projections of the abdominal area in helical geometry with 8 cm collimation and pitch factor 1.38
- Reconstructed using 420mm field of view with pixel numbers along X and Y set to 512
- 5 dose levels: 20%, 40%, 60%, 80%, 100%
- TotalSegmentator model consisting of 5 models for different body parts

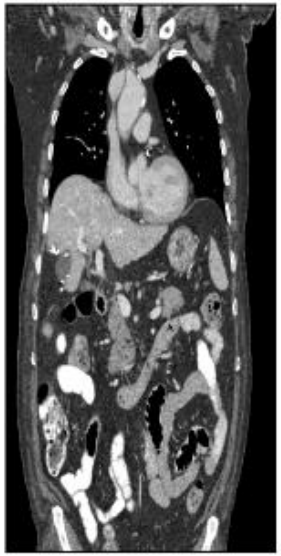
Results

Table 1. Dice scores calculated between segmentations of full- and low-dose CT images for different dose levels. Since the full-dose segmentation was used as a reference, the scores for the 100% dose level equal 1.0.

Model Name	Dose Level				
	20%	40%	60%	80%	100%
totsegm-all	0.983 ± 0.008	0.990 ± 0.005	0.993 ± 0.003	0.996 ± 0.002	1.000 ± 0.000
totsegm-organs	0.987 ± 0.011	0.992 ± 0.007	0.995 ± 0.004	0.997 ± 0.003	1.000 ± 0.000
totsegm-vertebrae	0.988 ± 0.002	0.993 ± 0.002	0.995 ± 0.001	0.997 ± 0.001	1.000 ± 0.000
totsegm-cardiac	0.982 ± 0.010	0.989 ± 0.006	0.993 ± 0.004	0.996 ± 0.002	1.000 ± 0.000
totsegm-muscles	0.986 ± 0.004	0.992 ± 0.003	0.995 ± 0.002	0.997 ± 0.001	1.000 ± 0.000
totsegm-ribs	0.974 ± 0.006	0.984 ± 0.004	0.990 ± 0.002	0.994 ± 0.002	1.000 ± 0.000

- The median and the median absolute deviation aggregate the results across multiple CT images as some scores are falling into the extreme of the value range
- The absolute decline does not exceed 3%, even at the 20% dose level.

Results



(a) A CT image at 100% dose level.

(b) Segmentation results at 100% dose level

(c) A CT image at 20% dose level.

(d) Segmentation results at 20% dose level

(e) Differences between the segmentation results

Summary & Conclusion

- We analyzed the robustness of the TotalSegmentator model for anatomical segmentation with respect to lower doses in CT imaging.
- By employing raw CT projections, we could accurately simulate low-dose CT data that were intrinsically registered with the original CT images.
- The results reveal surprising robustness of the model even at 20% dose level
- The study is limited due to absence of the ground-truth segmentations
- Future work may include analysis of segmentation models for pathologies

Questions

Please, send your questions to the corresponding author:
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Thank you!