THERAPANACEA
Reinventing cancer care through AI

Full-body delineation of ROIs through anatomy-preserving deep learning ensemble networks

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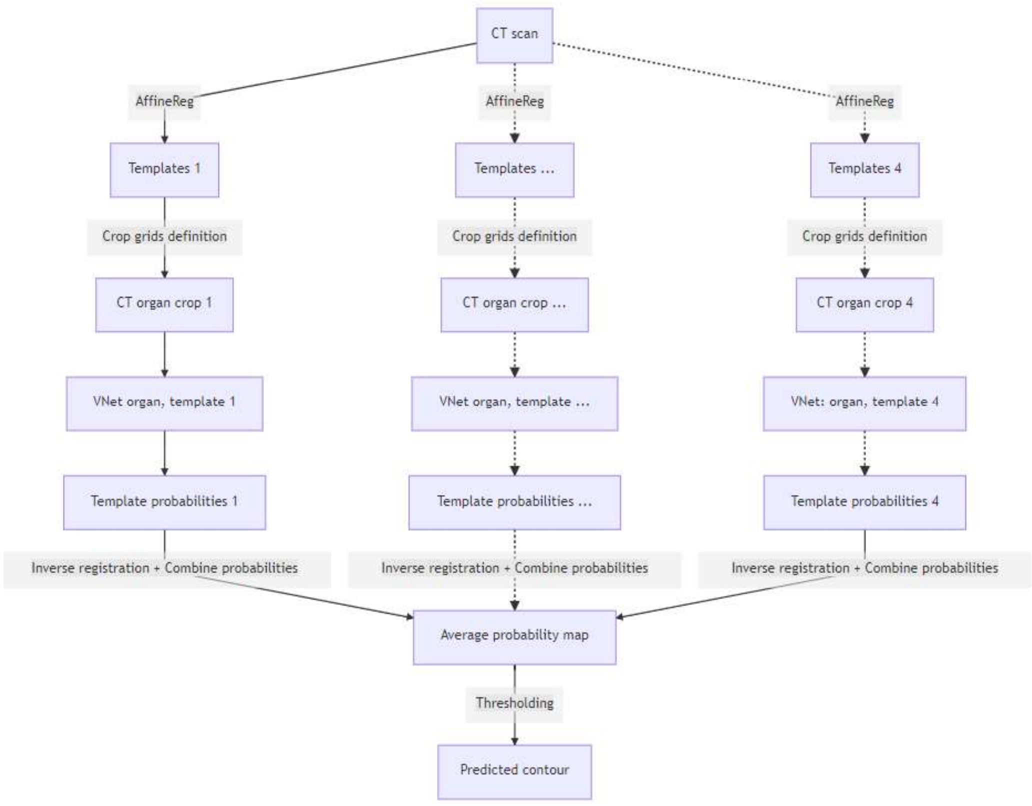
Purpose

Delineation of anatomical structures is a tedious/time-consuming task of radiation therapy associated with strong inter/intra-user variability. In this study, we introduce an automatic tool that detects and segments 80+ anatomical structures including lymph nodes. Our approach simultaneously (i) detects the organs present in the volume, (ii) delineates them through a combination of ensemble of neural networks that enforces anatomical consistency

Methods

The data set contains 22,000 volumes (after data augmentation) from several clinical sites. The annotations per organ varied; 680 for the cervical lymph nodes VIIA to 12,232 for the spinal cord. We deploy a full end-to-end ensemble neural networks approach involving three steps: (i) detection of the organs present in the volume through a deep neural network that registers the volume to an ensemble of whole-body annotated volumes, (ii) automatic delineation of each anatomical structure through a unique combination of data-driven & decisional artificial intelligence that enforces anatomical consistency. Multiple networks are trained using different whole body scans as reference space (Figure 1). Each of them relies on a different random separation between training (80%) and validation (20%) subsets. Evaluation was done using a random representative set of the data set, while the method was also tested on multicentric external cohorts - results presented in different submissions - (Head and Neck & Breast anatomies).

Figure 1: Inference process flow chart



Results

Mean Dice scores (MDS), mean contour distance (MCD) and mean Hausdorff distance (MHD) were evaluated for all anatomical structures. Encephalon was the structure with the best performance (MDS: 0.99, MCD/MHD: 0.23mm/5.5mm) while chiasma the worst (MDS: 0.45, MCD/MHD: 6.83/1.24), a structure that inherits strong difficulties even for clinical experts when contoured on a CT. Running time is approximately 3 seconds per anatomical structure present in the image. The average dice score for all organs was 0.79, the standard deviation 0.10. More than 50% of the structures had a MDS above 0.8 and only 4 among them under 0.6. Representative results on a Head and Neck and Prostate cases (Figure 2) as well as dice scores (Table 1) for a randomly selected subset of organs are presented.

Figure 2: Automatic delineation of OAR and target volumes

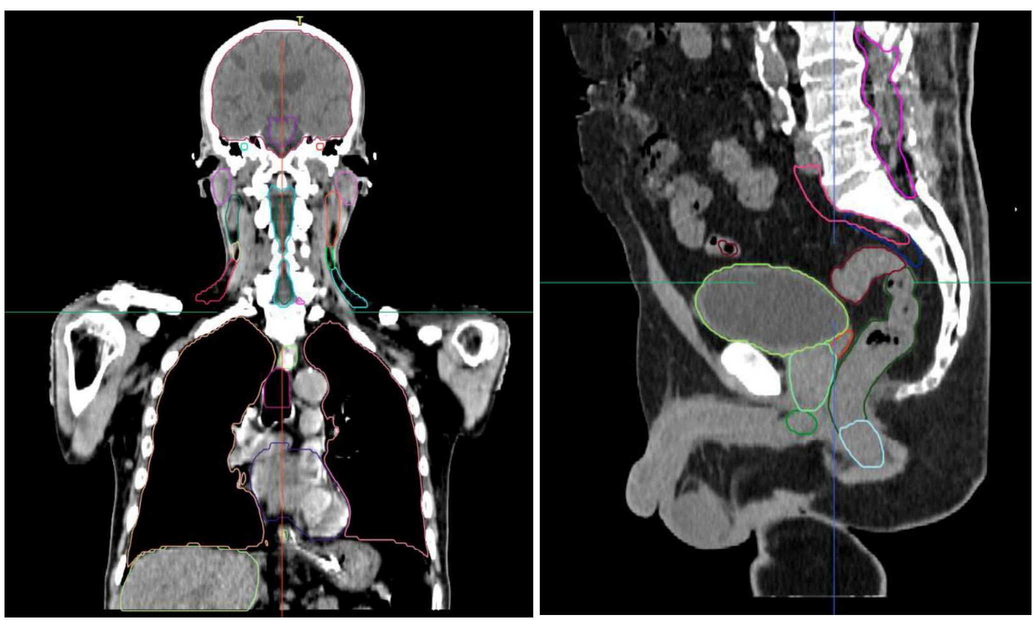


Table 1: Quantitative results example of the testing set

Organ	MDS (range)
Eyes	0.91 ±0.04
Optical nerves	0.66 ±0.06
Parotids	0.803 ±0.12
Submandibles	0.83 ±0.17
Cervical lymph nodes III	0.79 ±0.05
Esophagus	0.72 ±0.15
Breast	0.88 ±0.15
Heart	0.92 ±0.03
Bladder	0.93 ±0.07

Conclusion

We introduced a fully automatic deep learning ensemble network approach that couples organ detection & anatomy-preserving annotation. The obtained results are highly promising – exceeding human precision in a number of cases – and consist of a prominent avenue for automatization, standardization and healthcare cost reduction in radiation therapy.