Deep learning for improved tumour delineation in radiotherapy of head and neck cancer

PhD student Jintao Ren, Aarhus University Hospital.

Abstract

In radiation oncology, defining the target volume - gross tumour volume(GTV) - is one of the most important, time-consuming, but also uncertain steps in treatment planning. To improve, it is suggested to implement an automatic GTV delineation tool, which should be fast, accurate, robust, and flexible. Recent advances in machine learning, especially with deep learning, have shown its great ability for automatic segmentation in Medical Imaging. Better results are expected if more imaging modalities (CT, PET and MRI) and more data are used with the inclusion of patient's numerous clinical parameters. In this project, we aim to investigate and develop a new computer-assisted interactive tool for identification and delineation of radiation target volumes for Head and Neck (HNC) with support from start-of-the-art 3D convolutional neural networks (CNN), as a helper for the physician. This aims to address an imminent problem in practical radiotherapy, with a feasible and necessary solution.

Summary

In radiation oncology, treatment planning is individually planned for each patient based on oncologist's delineation of radiation target (malignancy) and healthy structures in medical images (CT, MR and PET scans). The limiting factor is the identification of the radiation target in the medical images. It is well-known that there are significant uncertainties in this identification, and these uncertainties are presently handled by adding a margin to the delineated target volume, thereby enlarging it and adding the considerable risk of dose spill-over to nearby organs at risk (OAR). With the lacks of the gold standard, studies on this field are mainly focused on the minimization of inter-observer variation (IOV). From the imaging point of view, there are two main approaches which could be used: multi-modal imaging and auto- segmentation. In recent years, advances in computer capabilities have made the development of automatic segmentation possible. The application of deep learning has been evaluated in Head and Neck Cancer (HNC) for OAR segmentation and has been attempted for target volume segmentation on CT and MR imaging separately. While Convolutional Neural Networks(CNN) is outperforming more conventional auto-segmentation tools, segmentation results are still not at a clinically acceptable level. Better results are expected if more imaging modalities (CT, PET and MRI) and more data are used. In addition to the multi-modal image-based reference factor, in clinical practice, the patient's numerous clinical parameters are also considered by oncologist performing the tumour segmentation, and treatment prescription. This also means a proper multimodal fusion is needed to be designed to integrate multi-modal images with clinical parameters to achieve consistent, common model output.

We aim to establish accurate tumour and pathologic lymph node segmentation using a large dataset (>300) of HNC patients with 3D multi-modal imaging - contrast-enhanced CT, FDG- PET, and MRI. We assume that the inclusion of clinical parameters as a modality in addition to image information for the neural network will improve the segmentation result. We hypothesize that such a multi-modal deep learning method will lead to a feasible clinical workflow where minimal interaction will lead to clinically acceptable segmentations. This will simultaneously translate into a reduction of the workload and most importantly of the inter-observer variation. This project aims to investigate and develop new computer-assisted tools for identification and delineation of radiation target volumes in medical images with support from start-of-the-art CNN. The tools will be potentially useful for delineation in any cancer site, and hence the scope of impact is huge.

To solve the problems, the following work-packages are planned:

- **WP1: Use of deep learning algorithms to segment tumours in CT, PET and MRI scans, based on the database of previously treated patients.** A convolutional neural network will be built to segmentation of both gross tumour volume and involved lymph nodes, in a set-by-step fashion, where complexity is increased while involving more representative image data with more artifacts and noise. Inclusion of clinical parameters as a modality in addition to image information for the neural network will be added to form an accurate and robust automatic complete GTV segmentation.
- **WP2: Development of an interactive feedback drawing tool assisting the physician in decision making for target border delineation, including results from (1).** Based on the research of WP1, a prototype interactive delineation tool will be developed for fast and accurate multi-modal GTV segmentation, which could recommend the physician a precise GTV delineation, this process includes requirements analysis, general design, detailed design, coding, testing, and delivery. The interobserver variation for manual delineation, automatic delineation, and delineation by physician using the interactive tool will be investigated, serving as a proof-of-concept for use of such a tool.

These approaches will provide a completely novel way to address the issue of tumour delineation for radiotherapy. The methods will be potentially useful for delineation in any cancer site. For this specific project, however, only head and neck cancer delineation will be investigated as exemplary case.