Maastricht University

Advanced Computed Tomography imaging in radiotherapy

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Valorization Addendum

“Advanced Computed Tomography imaging in radiotherapy”

Background

The prevalence of cancer is a growing healthcare problem and a leading cause of death worldwide. The number of cancer deaths can be reduced through new developments in cancer diagnosis and cancer treatment. Cancer diagnosis techniques including laboratory tests, biopsies, and non-invasive imaging are all essential to detect nonmetastatic cancers at an early stage. Cancer treatment encompasses several techniques such as surgery, systemic therapy, and radiotherapy. Innovations in cancer diagnosis and treatment are required to increase cancer treatment efficacy. These innovations are also needed to reduce treatment induced side-effects during the treatment period. Radiotherapy induced side-effects are uncomfortable and potentially exist in the further lifespan of the patient.

Products, Innovations, and societal or commercial relevance

DirectDensity™ image reconstruction algorithm

Several techniques to improve cancer treatment and its workflow have been studied in this thesis. The first part of this thesis had a more clinically oriented focus with the commissioning of the DirectDensity™ image reconstruction algorithm in MV photon therapy. This study was part of a market evaluation phase study of the Siemens Healthineers Confidence RT pro dual-spiral CT scanner. The publication of this work gained interest from medical physicists since it describes the complete commissioning workflow of this novel CT image reconstruction algorithm for several treatment sites. After this study was published and presented at the largest European conference for radiotherapy and oncology, Siemens Healthineers estimated in July 2019 that over 100 scanners were licensed worldwide with the DirectDensity™ image reconstruction algorithm (private correspondence with Siemens Healthineers). Market evaluation phase studies are essential for industrial partners that do not have direct access to clinical data and clinical expertise. Industrial partners look at clinical collaborations as an added value, and for them, it is absolutely required to evaluate the usability of the algorithm or device on more clinically oriented criteria. **Chapter 3** of this thesis contributed to the market evaluation phase of Siemens Healthineers’s DirectDensity™ image reconstruction algorithm.

VOXSI simulation software

The research carried out at Maastro and at other institutes worldwide has resulted in a large number of publications which have shown the benefits of dual-energy CT in radiotherapy. The acquired knowledge from past years and the best performing algorithms in dual-energy CT available in literature were combined in a free and open-access simulation software package for single- and dual-energy CT (VOXSI). VOXSI has been made publicly available for online download[1]. After development, this simulation software is being actively used for teaching and research purposes by several universities and companies. Later, open-source access and development support was provided to two international research institutions which are currently working on extension packages for proton radiography and advanced noise modelling. Other free open-access simulation software is often complicated to install and does not provide built-in image reconstruction and analysis software. Our simulation software directly enables advanced single-energy CT and dual-energy CT post-processing which is currently not available in any other software simulation package. VOXSI has been programmed in an object-oriented and a modular way, which enables the easy implementation of future science and technology inside the software.

Monte Carlo simulations

Monte Carlo simulation software is often used in radiotherapy to comprehend systems, experiments, or devices that deal with ionizing radiation. In this thesis, a Monte Carlo simulation model was developed from a novel imaging ring system on rails in collaboration with an industrial partner (medPhoton GmbH, Salzburg) (**Chapter 6** and **Chapter 7**). This imaging ring simulation model was actively used to explore image quality improvements and was also used to investigate clever artificial intelligence methods that are able to correct for photon scatter in head and neck cancer patients. Although further investigations are needed to investigate the scatter removal performance (**Chapter 7**) in larger body sites and for other imaging spectra, this algorithm showed superior results compared to other advanced corrections in smaller body sites and has potential to be implemented in clinical software. All research in this project was part of an Eurostars framework between Maastro/Maastricht University and medPhoton GmbH.

[1] https://voxsi.weebly.com

Automatic image segmentation software

The second part of this thesis was more focused on full-automatic image segmentation in preclinical research. Similar methods were also applied in **Chapter 5** to clinical dual-energy CT data in collaboration with OncoRay in Dresden. To make significant progress in curing many diseases it is necessary to perform meaningful preclinical research. Biological oriented researchers have limited their preclinical image analysis in the past to simplified analysis methodologies because extensive imaging analysis was extremely time consuming. I felt there was a great need to develop powerful technology that allows performing complex animal studies that require preclinical imaging. Two different methods were developed in **Chapter 8** and **Chapter 9** to segment volumes-of-interest on micro cone-beam CT scans of mice.

This work highlighted the great interest of preclinical researchers in automatic segmentation algorithms, but also the need of it. Dedicated automatic image segmentation algorithms improve the workflow speed and facilitate the preclinical workflow significantly. Furthermore, they have the potential to reduce the number of lab animals used in longitudinal preclinical research because the automatic analysis tools could replace existing methods which required sacrificing a cohort of animals.

Not every preclinical institution has access to automatic image segmentation algorithms or has the knowledge to build software themselves. Based on the research described in **Chapter 8** and **Chapter 9** of this thesis, a grant proposal was submitted and funded (OMEGA) to develop commercial automatic contouring software with deep learning to reduce animal experiments, as a collaboration of Maastricht University and a commercial spinoff company. In the OMEGA project, tools and software will be developed to broaden the use of preclinical CT segmentation software. These tools will be available and advertised to the preclinical research community as a commercial product and service.