Learning to generate pseudo-CT images from MR images for radiotherapy

Background

The use of Magnetic Resonance Imaging (MRI) alone for the dosimetric planning in radiotherapy would make it possible to exploit its high contrast for soft tissues while avoiding the errors inherent in registration with a dosimetric Computed Tomography. This technique raises the question of estimating electronic density from MRI images. This question is the subject of several recent studies that differ in the methods used to estimate electronic density in order to generate synthetic Computed Tomography (CT) (or pseudo-CT) from MRI images.

Different solutions, based on the conversion of MRI images into so-called pseudo-CT (pCT) images, have been proposed in the literature:

- Bulk density method
- Atlas-based method using deformable image registration (DIR)
- Direct conversion of MRI intensities using "calibration"
- Methods using machine learning and deep architectures more recently

The pCT generation method developed at Centre Oscar Lambret in the framework of several research projects is based on the atlas-DIR method introducing MRI intensity based corrections. In a first attempt to take into account the limitations of the atlas-based method, a hybrid solution was proposed that also used the actual MRI intensities.

Another solution is the usage of neural networks or other machine learning methods. The network/conversion is trained using the combination of CT and MRI scans for a large number of patients and is then used to convert patient MRI scans into pseudo-CT scans. One option is to divide the images in so-called patches that are matched. This allows the usage of a conventional T1 or T2 MRI scan. More recently, a convolution neural network (using patches) was developed based on dual-echo UTE images for PET-MRI attenuation correction. An alternative approach is a direct conversion using machine leaning on global images. Using a training dataset consisting of a large dataset of CT-MRI pairs, a direct correlation between MRI and CT intensities is obtained. These correlations are then applied to new MRI images to generate pCT. Most methods based on machine learning use aligned pairs of MRI/CT images for training. Misalignment has an important impact.

Another important aspect is the actual dose calculation on the generated pCT images. The Centre Oscar Lambret has a long experience on dose calculation for radiotherapy treatment planning. An in-house Monte Carlo platform was developed for validation of Cyberknife and Tomotherapy plans. The system is currently extended for conventional IMRT and VMAT treatments.

Key words MRI, synthetic Computed Tomography, radiotherapy, brachytherapy, DICOM, deep learning

Subject

The candidate will have to provide a state of the art on the subject. He will develop pseudo CT synthesis methods based on machine or deep learning. The original images used for learning will be provided by the radiotherapy department. The validation will be based on the dose calculation and will be carried out in partnership with the department of medical physics. The developed methods will have to be fast to be adapted to the context of online MR brachytherapy. This work is funded by the Inter Reg call for projects: https://interreg2seas.eu/fr/cobra

Requested expertise

The following expertise is especially considered: • Excellent record of academic and/or professional achievement • Very good English skills, written and spoken (B2 level appreciated). • Strong mathematical skills • Solid programming skills • Strong interests in one or more of the involved research areas (machine learning, deep learning, computer vision, high performance computing). The position is for a duration of three years.

Eligibility criteria:

• A Master degree in Computer Science, Mathematics, Physics or closely related disciplines

• Appropriate experience to undertake PhD research in the specified area.

Salary - The grant for the PhD student will correspond to a standard salary of PhD student. The PhD program is expected to start in November 2018.

Supervision

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