Vacancy for MSc Student: Evaluation of deep learning-based pseudo-CT generation for attenuation correction in PET-MRI

Within the UMC Utrecht department of Medical Physics, research is focused on exploring the clinical and physical limits of current and future technologies for medical imaging and image-guided interventions. To improve innovative cancer therapies, such as integrated MRI-guided radiotherapy (MR-LINAC), High Intensity Focused Ultrasound (MR-HIFU) and Peptide Receptor Radionuclide Therapy (PRRT), diagnostic imaging capabilities with improved integrated sensitivity and specificity are required. In one of our research lines we aim to develop a next-generation fully integrated wide-bore positron emission tomography / magnetic resonance imaging (PET-MRI) system to provide these diagnoses (Fig. 1) and to assess the feasibility of using the system for the planning of cancer therapies.

In Positron Emission Tomography (PET) imaging (Fig. 2), a patient or animal is injected with a radioactive substance emitting positrons during decay. The positron annihilates with an electron from the subject's body, thus producing two gamma photons which propagate through the body in opposite directions. These gamma photons are detected outside the body using a ring of PET detectors. These PET detectors are typically scintillators, converting the 511 keV gamma photons to a high number of optical photons, which are detected by underlying photosensitive detectors.

The goal of the measurement is to determine the three-dimensional distribution of activity inside the patient. The two detected positions of the two gammas form a line of response (LOR), somewhere along which the original positron annihilation must have occurred. The problem of determining the most likely activity distribution from all measured coincident gamma photons is called image reconstruction. Most modern PET image reconstruction methods use Maximum Likelihood Expectation Maximization (MLEM) or one of its variants to fit expected simulated data to the measurement.

One of the challenges specific to an integrated PET-MRI system is correcting for photon attenuation in the patient body without the availability of an attenuation coefficient map (μ-map) from a computed tomography (CT) or a 511 keV transmission scan. One of the proposed methods to address this challenge, with promising results reported in literature, is to calculate a μ-map from a so-called pseudo-CT image, which is generated based on the MRI data. In our department, a method was developed to construct pseudo-CT images from standard MRI sequences by employing deep learning neural networks. The pseudo-CT images generated by this method visually resemble real CT images, but it is currently unclear whether the quantitative accuracy is good enough for PET attenuation correction.

The goal of this project is to evaluate the use of the deep learning algorithm, developed in our department, to generate pseudo-CT images for attenuation correction of PET-MRI image reconstruction. In this context, you will validate the deep learning pseudo-CTs against real CT scans of patients. Possible next steps are to determine and further explore the challenges faced when implementing this method of attenuation correction in the prototype PET/MRI system developed at our department, to study the influence of image co-registration errors or specific types of misclassifications in the training set, to further develop the deep learning algorithm, and to write a scientific paper describing the results of the evaluation.

The preferred project start date is in November 2020, and the duration should be at least 9 months. For this project, experience with programming/scripting (Python, C++) or the desire to learn this skill is appreciated. In this project, you will need to learn about the working principle of PET-MRI systems, PET image reconstruction with attenuation correction, deep learning neural networks, and the appearance of various human anatomical structures on PET, MRI and CT. You will be supported by our group consisting of researchers and students from different disciplines: physics, biomedical engineering, computer science and medicine. This project is performed in close collaboration with industry (Philips, MRIguidance) and researchers from the UMCU department of Radiotherapy.

Fig. 1: Example of a commercial combined PET-MRI system (Siemens Biograph mMR)

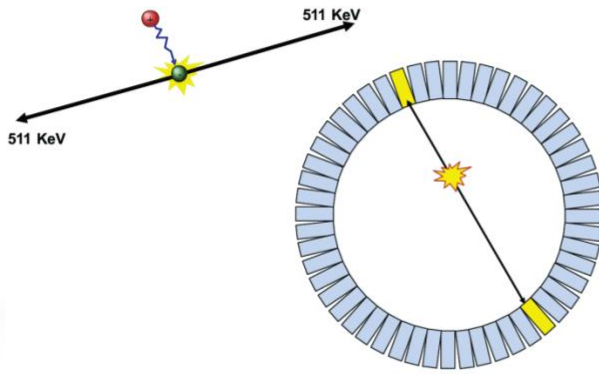

Fig. 2: In PET, two 511 keV gamma photons from a positron electron annihilation have to be detected and correlated.