Artificial intelligence based 3-gamma PET image reconstruction

Thesis Location: Laboratory of Medical Information Processing (LaTIM), French Institute of Health and Medical Research (INSERM UMR 1101), Brest, France (https://latim.univ-brest.fr/)

Period: 3 years, starting on September 2021

3-gamma medical imaging is a novel nuclear imaging modality that relies on the acquisition of 3 gamma photons coming from a b+ and gamma emitter such as Scandium 44 (Sc-44). The development of this approach is motivated by the possibility of utilising the information of the third gamma photon, which can help localise the annihilation site; this information can improve overall image quality but also allow for potential dose reduction and high speed dynamic imaging. Within the context of this imaging paradigm the development of new fast image reconstruction techniques is crucial.

The objective of this thesis is to develop new image reconstruction techniques for 3-gamma PET imaging. This imaging is based on the utilisation of the coincidence photons to define a line of response (LOR) and on the detection of the emitted third photon to derive a Compton cone that can help in localising the annihilation position on the LOR. Over the last few years artificial intelligence (AI) has been massively employed in medical image analysis [1] and has more recently been also considered in the field of image reconstruction [2]. A potential advantage of these methods include the incorporation of physical processes without deriving a precise physical model and a reduced computational burden once the algorithm is trained. The hypothesis of this work is that AI-based localisation of the third gamma will enhance both qualitative and quantitative accuracy of static and dynamic PET imaging using the proposed approach.

Two distinct stages can be identified in the proposed thesis work. The first will focus on the implementation of a reconstruction algorithm for 3-gamma imaging based on AI. Within this context two scenarios will be considered. The first will be based on the use of AI approaches for estimating the coordinates of the cone-LOR intersection within the "pseudo-TOF" approach we have previously proposed for 3-gamma reconstruction [3]. The alternative will be the application of approaches such as classical convolutional neural networks (CNNs) and generative adversarial networks (GANs) for direct 3-gamma reconstruction (direct transfer from raw data to 3D images). The AI based approaches will be trained using simulated datasets based on validated scanner models already available but also on future imaging system designs. The second part of the thesis will consist of a performance comparison between the algorithms developed in the first step with those of (i). a "pseudo-TOF" algorithm as well as with (ii). a standard iterative PET image reconstruction using the CASToR platform [4]. The evaluation performed on acquired datasets will concern both performance in terms of sensitivity (according to the level of activity injected) but also in terms of image quality (signal-to-noise ratio, spatial resolution) and computation times. Finally, we will focus on the performance of the developed reconstruction approaches in the context of dynamic imaging.

Education: Master degree in physics, computer science, applied mathematics or equivalent and have a background / experience in deep learning / machine learning and image analysis

Scientific Interests: Machine learning/deep learning, image reconstruction, medical imaging
Programming Skills: Python, R, C/C++
Languages: English, French optional
Contact: Send before the 10th of May (at the latest) your CV, cover letter, grades/marks (Master, License/Bachelor) and a reference letter by e-mail to: visvikis@univ-brest.fr

References:

[1] Geert Litjens et al ; A survey on deep learning in medical image analysis; Medical Image 42, 60-88, 2017
[2] Reader A et al; Deep Learning for PET image reconstruction; IEEE Transactions on Radiation and Plasma Medical Sciences, 5(1), 1-25, 2021
[3] Giovagnoli D et al ; A Pseudo-TOF Image Reconstruction Approach for Three-Gamma Small Animal Imaging; IEEE Transactions on Radiation and Plasma Medical Sciences, 2020, doi: 10.1109/TRPMS.2020.3046409
[4] https://castor-project.org