Master internship 2023 in Lyon, France.

Optimization of Compton camera system design for nuclear medicine applications.

This work is a collaboration between researchers from CREATIS and IP2I laboratories

In the last years, there has been a growing interest in the use of Compton cameras for nuclear medicine applications due to their high detection efficiency and their ability to simultaneously detect multi energy gamma-ray emitting radioisotopes. Even if several prototypes have been built [Tashima 2022], the high-performance requirements in terms of energy, time and spatial resolution for clinical medical applications have not yet been met. These imaging devices need to be further investigated and optimized to reach the clinical standards for which accurate Monte Carlo simulations are required. To this end, the Compton camera module (CCMod, [Etxebeste 2020]) developed within GATE/Geant4 [Sarrut 2021] Monte Carlo simulation toolkit will be employed. This module facilitates the investigation of CC systems and the comparison between different prototypes in an environment that allows to simulate realistically medical applications The quality of the image generally reconstructed by means of iterative reconstruction (CoReSi software in CREATIS [Maxim 2016]) is the final endpoint. A preliminary comparison of a CC prototype (CLaRyS prototype) and a commercial gamma camera (collimated camera) has been recently performed with promising results for an energy range comprised between 140 and 511 keV.

The first objective of this internship consists in completing this preliminary study to quantify the gain on Compton cameras in terms of e.g. acquisition time for a given image quality. Then, the student will optimize the design of a Compton camera for an energy range comprised between 140 and 511 keV, with special interest in assessing the ability to estimate the 3D distribution of Technetium-99m (^{99m}Tc) which is the most widely used radiotracer for diagnostics. To this end, different geometric configurations such as single-layer and multi-layer systems will be studied based on different detector technologies considering recent advances on instrumentation. In particular, CZT semiconductor detector technology will be investigated within a collaboration with experts in gamma-ray imaging of CEA-LETI that have already developed Compton cameras [Montémont 2016] based on this technology for environmental radiation monitoring.

Keywords: Nuclear Medicine, Compton cameras, CZT detectors, Monte Carlo simulations

Tasks of the master internship.

1. Finalize the comparison of the CLaRyS CC prototype with a commercial gamma camera
2. Model Compton camera prototypes based on recent advances on instrumentation
3. Simulate Compton camera acquisitions based on different configurations, single and multi-layer systems
4. Compare performance of different detector technologies with simple source distributions

5. Evaluate reconstructed image quality with a single and multiple Compton camera prototypes rotating around the subject of study
6. Assess the ability of different selected prototypes to image the distribution of ^{99m}Tc in a realistic situation

Environment. The student will work in a multidisciplinary team composed of researchers in inverse problems, tomography, imaging for radio-therapy and Monte Carlo simulations of CREATIS and IP2I laboratories.

Expected skills and other information

- Expected skills: medical physics, computer sciences, image processing
- Technical skills: Python is required, experience with GATE would be an asset
- English and French
- Location: IP2I, Lyon, France

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