Deep-learning enhanced Compton camera imaging for nuclear medicine SPECT applications

Title:	**Deep-learning enhanced Compton camera imaging for nuclear medicine SPECT applications**
Position:	PhD fellowship
Topics:	Medical image reconstruction, inverse problems, deep-learning, Monte Carlo simulations
Institutes:	CREATIS, CNRS UMR 5220 – INSERM UMR 1294, INSA, Lyon, France
Supervisors:	Voichita Maxim — voichita.maxim@creatis.insa-lyon.fr
	Ane Etxebeste — ane.etxebeste@creatis.insa-lyon.fr

Scientific Context

Compton cameras, due to the absence of a mechanical collimator, can provide better sensitivity than Anger cameras which are the standard detector employed in nuclear medicine for SPECT scans. This results in a reduced patient dose or a faster acquisition. Their application in nuclear medicine was first proposed by ([1]). Since then, the interest in Compton cameras has steadily grown. Recently, the application of these systems for targeted radiotherapy ([2], [3]) or as multimodal PET / Pinhole / Compton camera systems ([4], [5]) has been considered. However, the uncertainties in measurements caused by physical effect, such as detector geometry or Doppler broadening, demand strong requirements on both instrumentation and reconstruction, especially at low photon energies of clinical interest.

PhD fellowship project

In this project, we will focus on reaching the technological requirements for nuclear medicine applications by implementing optimized data processing and enhanced tomographic reconstruction algorithms for systems based on different detector technologies considering recent advances on instrumentation. In this context, we have developed a ML-EM reconstruction algorithm based on precise physics modeling which includes Total variation (TV) prior and Point Spread Function (PSF) corrections for image quality enhancement ([6], [7]). PSF correction leads to noisy images with artifacts, especially for low doses. One of the aims of this project is to develop blind deconvolution techniques using neural networks, specific to detector technologies and robust for low doses. In order to train the network and evaluate the performance of the reconstruction algorithm, accurate modeling of the response of Compton camera systems is essential ([7].) To this end, the Compton camera module (CCMod, [8]) developed within GATE/Geant4 ([9]) Monte Carlo simulation toolkit will be employed. The developed model of a scintillation detector based Compton camera prototype for the validation of the module against experimental data (MACACO, [10]) in the framework of a collaboration between CREATIS and IRIS groups, will be a starting point for modeling the response of different technologies. Finally, in this project we will study the application of these imaging systems for the monitoring of thyroid cancer, which is one of the most common cancers in young women. The proof of concept will be made on simulated data. Preliminary tests could be made on real data obtained within the framework of collaborations.

Objective and tasks

The goal of this PhD fellowship is to study and evaluate the ability of deep learning to improve the quality of Compton camera imaging based on different detector technologies with respect to standard techniques, in thyroid cancer monitoring.

- Model Compton camera systems based on scintillators
- Simulate Compton camera acquisition data using CCMod
- Prepare and optimize the training data set
- Develop and evaluate blind deconvolution techniques using neural networks robust for low dosis
- Evaluate the performance of these cameras equipped with an advanced reconstruction algorithm for thyroid cancer monitoring in realistic conditions
- Repeat each step for Compton cameras based on semiconductor detectors
- Compare performance of different detector technologies in the studied clinical case

Thesis supervision

The PhD candidate will be recruited at CREATIS and INSA Lyon and will be co-supervised by Voichita Maxim and Ane Etxebeste. He/she will work in the Tomoradio team in a stimulating environment composed of researchers in inverse problems, tomography, imaging for radio-therapy and Monte Carlo simulation. This work will be done in a strong collaboration with physicists from IP2I Lyon and LPSC Grenoble.

Profile Required

We are looking for enthusiastic and autonomous students with strong motivation and interest in multidisciplinary research.

- **Education**: Master in Applied or Pure Mathematics, Computer Science, Signal and Image processing, Biomedical Physics or engineering degree in related fields.
- **Scientific interests**: computer sciences, deep-learning, medical applications, applied mathematics, Monte Carlo simulations.
- **Programming skills**: Python, Tensorflow.
- **Languages**: English required, French optional.

How to apply?

Send your resume, a brief statement of interest and your transcript of records, to:
voichita.maxim@creatis.insa-lyon.fr and ane.etxebeste@creatis.insa-lyon.fr
Deadline for application is 30th of April 2022.

References

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