PhD position in Lyon, France

Monte Carlo simulations guided by artificial intelligence for medical physics and nuclear medicine. Study of GANs to model phase spaces.

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This work is a collaboration between researchers from CREATIS, LATIM and LIRIS laboratories and the nuclear medicine department of the Léon Bérard cancer center (Lyon, France). It is funded by the MoCaMed *ANR project (2021-2025).*

Context. Monte Carlo simulations of nuclear imaging systems (SPECT, PET, Compton Camera) represent a key tool for studying and optimizing the design of such imagers, as well as for conducting research in image reconstruction. Monte Carlo simulations of such imagers [1], [2] thus make it possible to optimize acquisition parameters, calibrate images, estimate dose distribution and improve detection systems. These simulations are used by industrials and researchers around the world[3], [4].

However, they require very high computation times. Even though many variance reduction (VRT) techniques have been proposed in the past and recently, the growing need for detailed simulations of the physical phenomena involved in imaging detectors still results in long simulation times. Although some dedicated simulators (GPUs), such as those in some Treatment Planning System (TPS), can be very fast [5]–[7], the generic codes that are the basis of medical physics research are still slow.

Artificial Intelligence. The ambition of the MoCaMed project is to investigate the value of Quasi-Monte Carlo and Artificial Intelligence approaches within Monte Carlo simulations of medical physics. Thus, one way of reducing these computation times consists in dividing the simulation into different parts, in particular separating the monitoring of particles in the patient from the monitoring in the detectors. Recently, our group proposed [8], [9] the use of artificial intelligence methods to replace bulky and inconvenient phase space files with compact Generative Adversarial Networks (GANs). A GAN [10], [11] models the probability distribution of particles represented by phase space and can then be used as a source of particles in simulations. These first approaches constituted the proof of the concept but raised a number of theoretical and practical questions, such as: how to optimize the size of the learning dataset? What are the statistical properties of the particles generated by the GAN? Is it possible to train a GAN to generate all the characteristics of the probability distribution of the particles leaving the imaged patient (or an object)? In the mentioned works, GAN has been applied for modeling linear accelerator beams as well as for SPECT. Now, we are looking to study how to apply these approaches for simulations of PET systems and more generally of other imaging systems.

Objectives of the PhD

The main goal is to investigate and propose novel methods to model large and complex phase-spaces with deep learning approaches such as GAN. In particular, several starting tasks can be proposed:
1. Perform bibliographic review of GAN concept, with application to Monte Carlo simulations.
2. Investigate current methods to model phase-spaces with GAN ; perform profiling ; study advantages, limitation and associated uncertainty.
3. Investigate the potential interest of conditional GAN and transfer learning to model family of phase-spaces.
4. Investigate the various applications in the field of Monte Carlo nuclear imaging simulation that may benefit from such modelling.

At the end of the PhD, we should have a better knowledge about interests and limitations of GAN for phase-spaces.

Environment. The student will work in a multidisciplinary team composed of nuclear physicians, medical physicists, researchers and computer scientists of CREATIS laboratory and Leon-Bérard Cancer Center.

Expected skills and other information

- Expected skills: AI, medical physics, computer sciences, image processing
- Technical skills: PyTorch, Python, C++ (Geant4, Gate)
- English and French
- Expected start: 2021
- Location: Lyon, Léon Bérard Cancer Center, France
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References

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