Two years post-doctoral position, starting Sept 2021 in Lyon, France

Artificial Intelligence and Monte Carlo simulations in medical physics: investigating Angular Response Functions for SPECT image simulation with neural network

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This work is a collaboration between researchers from CREATIS lab and the nuclear medicine department of the Léon Bérard cancer center (Lyon, France). It is funded by the European project POPEYE.

Scientific context. Monte Carlo simulations of nuclear-based imaging systems (SPECT, PET, Compton Camera) are a key tool to design, control and test instrumentation or to perform research in image reconstruction. They are used by industrials and researchers all over the world. Monte Carlo however requires lot of computation time, in particular for SPECT image systems simulation.

Recently, our group proposed the use of AI methods to replace the simulation of a SPECT detector head by a fast neural-network predicting the detector output [1]. This method is based on the Angular Response Function (ARF) concept. Neural network (NN) is learnt from the output of a dedicated simulation. While efficient, this approach rises 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 detected gammas generated by the NN? How to improve/guarantee the optimization of the NN? Moreover, the NN is trained to predict the detection probability of all particles impinging onto the detector in given energy windows. This means the training process must be repeated if any parameter of the camera is modified, in particular when energy window settings are modified. Is it possible to develop and train a different NN that predicts the energy spectrum of incoming particles? In that case, it would be possible to select the energy window in a post-processing step after the prediction; thus, a single learning process will be sufficient for any choice of energy windows. Of course, other ideas could be proposed to improve the general approach.

Medical context. In nuclear medicine during last ten years, cancer treatment by Molecular Radionuclide Therapy (MRT) has been growing rapidly. As an example, peptide receptor radionuclide therapy (PRRT) has been shown to be an alternative treatment for neuroendocrine tumors (NETs) when surgery is not indicated [2]. MRT consists in intravenous administration of a molecular vector labeled with a radionuclide. The vector's goal is to accumulate the compound in target organs while β or α-emitting radionuclide provides cytotoxic effects. Lutetium 177 is one of the most used radionuclides. In addition to β particles, it also emits γ rays that allow to quantify the radionuclide concentration in the tumors and healthy organs with SPECT/CT images acquisitions repeated at different point-times after treatment injection.

Patient-personalized dosimetry [3], [4] is a key notion that allows to optimize tumor control by administering the highest possible activity in target volume while limiting irradiation complications to organs at risk. The principle is to estimate the biodistribution and the pharmacokinetic of the activity inside the patient from SPECT/CT images. This image-based estimation is however impaired by numerous effects (attenuation, scatter, breathing motion…) that must be corrected or accounted for [5]–[7] and Monte Carlo simulation is a key approach for that task.

Monte Carlo simulation of SPECT imaging systems consists in building a virtual model of the imaging process in the most accurate way possible [8], [9] which allows to optimize the acquisition parameters, to calibrate the images and to estimate the dose distribution. This is the main goal of our task in the POPEYE European project, grouping researchers from Patras University (Greece), LATIM (Brest, France) and our group (CREATIS, Lyon, France). The previously described Monte Carlo task could hence be applied in this medical context to the newly acquired SPECT system, called VERITON, for which a Monte Carlo model will have to be developed and validated.

Objectives of the post-doctoral position.

1. Investigate AI-based ARF concept to better understand the statistical properties and limitations in order to improve the already developed approach.
2. Implement the improved approach in the OpenGate simulation software.
3. Apply and validate the approach against a real SPECT imaging system, such as the VERITON.

Environment. The recruited person 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 PhD in (either): AI, medical physics, computer sciences, image processing
- Technical skills: PyTorch, Python, C++ (Geant4, Gate)
- English and French
- Funded by the POPEYE EU project
- Expected start: September 2021
- Location : Léon Bérard Cancer Center, Lyon, France
- **Send application with this website: https://bit.ly/31ARTA3**
- Questions: David.Sarrut@creatis.insa-lyon.fr and ane.etxebeste@creatis.insa-lyon.fr

References

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