Postdoc in Monte Carlo modeling for positron emission tomography (PET) applications @ BioMaps (Orsay, France)

Integration of electronic response models and uncertainty assessment for Monte Carlo simulation applied to positron emission tomography (PET)

Context

The BioMaps laboratory [1] aims to design methods, instruments and agents for biomedical imaging of different imaging modalities and their transfer to clinical applications in neurology and oncology. In this context, scientific computing is a cornerstone of the device since it allows i) to articulate the imaging modalities between them, ii) to extract and analyze the relevant information from the images. To do this, the massive use of simulation and numerical modeling are essential in the overall methodological approach.

The GATE [2-3-4] simulation platform is an open source software, designed to allow researchers and engineers to perform a wide range of Monte Carlo simulations in the field of medical physics. This simulation code, developed in C++, has been present in the research landscape for more than 20 years and widely used internationally. It is made up of approximately 1000 classes to 1/ simulate the entire process from the creation of elementary particles (electrons, positrons, photons, protons etc.) used in medical physics, 2/ model the tracking of particles in different media, and 3/ integrating the interactions with this medium until the modeling of the expected final signal.

Job Description

We are looking for a qualified postdoc to join our laboratory as part of the FOCUS-EJN project (Digital Experimentation and Digital Twins). This project is directly linked to an ongoing thesis on the development of a Digital Twin (DT) applied to Positron Emission Tomography (PET). The third milestone of this thesis consists in evaluating the clinical performance of a new generation PET system equipped with detectors under development at the Institute for Research on the Fundamental Laws of the Universe (Irfu) of the CEA. As part of this project, the postdoc will participate in the development of electronic signal models of the detector and their integration into GATE. In parallel, AI models have been developed to analyze the signals and reconstruct the properties of the interactions in the detector (in particular their positions). The postdoc will study the effects of the predictive uncertainties of these AI models on the clinical images and the evaluation of the simulation uncertainties as such of the DT.

More specifically, the candidate will work on:

1. Integration into the collaborative developments of the GATE simulation platform of electronic response models specific to PET detectors. This approach will make it possible to get close enough to clinical systems and prototypes and therefore to real experience.

2. Integration into the PET simulation platform of AI models to increase detection performance by predicting gamma interaction parameters. These models come from the results [5] which are based on the use of a neural network associating an uncertainty with the predictions through the estimation of a probability density function on the predicted parameters. The new DT will thus make it possible to study the effects of these predictive uncertainties of AI on clinical images.
3. Evaluation of DT simulation uncertainties using the URANIE uncertainties platform [6] developed by the CEA

As a postdoc, you will work in close collaboration with multidisciplinary research teams, doctoral students and PET experts. You will actively contribute to the advancement of knowledge in the field of PET by developing advanced simulation tools and evaluating the performance of the Digital Twin.

Profile required

- Education: PhD in particle physics, nuclear, medical, AI etc..
- Skills in programming and data analysis
- Knowledge of C/C++, ROOT, Geant4
- Knowledge in particle physics and radiation/matter interactions
- Notions of detector electronics
- Notions/knowledge of Python, AI
- Ability to work independently
- Knowledge of tools such as GATE and URANIE would be a plus
- Ability to work in a team and communicate effectively

Practical Information

- Address: BioMaps/SHFJ, 4 place de Général Leclerc, Orsay, France
- Duration: 1 year + 1 year renewable
- Start of contract: from November/December 2023
- Employer: The French Atomic Energy and Alternative Energy Commission (CEA, Commissariat à l'énergie atomique et aux énergies alternatives)

Please send your **CV**, your **cover letter** and the **contact** details of **two people** who can serve **as references** to Dr. Olga Kochebina olga.kochebina@cea.fr and Dr. Sébastien Jan sebastien.jan@cea.fr

---

[1] https://www.biomaps.universite-paris-saclay.fr/
[2] http://www.opengatecollaboration.org/
[3] Jan S. et al. GATE: a simulation toolkit for PET and SPECT. Phys Med Biol. 2004 49(19):4543-61. doi: 10.1088/0031-9155/49/19/007. PMID: 15552416; PMCID: PMC3267383.
[4] Sarrut D. et al. The OpenGATE ecosystem for Monte Carlo simulation in medical physics. Phys Med Biol. 2022 67(18):184001. doi: 10.1088/1361-6560/ac8c83
[5] Daniel G. et al., "Deep Learning reconstruction with uncertainty estimation for γ photon interaction in fast scintillator detector", 2023, soumise à Engineering Applications of Artificial Intelligence le 1/06/23
[6] Blanchard JB et al, "The Uranie platform: an open-source software for optimisation, meta-modelling and uncertainty analysis", 2019, EPJ Nuclear Sci. Technol. 5 4, doi: 10.1051/epjn/2018050