Postdoctoral position, Lyon, France

Monte Carlo simulations of Compton camera and PGPI imaging in hadrontherapy and nuclear medicine

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The CREATIS and IPNL laboratories open in collaboration with LPSC a 2-year postdoc position in the field of simulations in biomedical imaging. The position is funded by the Labex Primes.

Scientific background

There is currently a consensus in the community of medical physicists about the need for ion-range verification in hadrontherapy. Twelve years after the original presentation of the idea, Prompt gamma (PG) detection seems a very good candidate to perform such a verification during treatments. The various approaches followed to tackle this issue can be classified in three categories [Krimmer 2017a]:

- PG imaging (PGI) with passive collimation (mutli-slit cameras [Pinto 2014, Min 2012]; knife-edge camera [Richter 2016]) and active collimation (Compton camera [Krimmer 2015, Solevi 2016]),
- Collimated scintillator with spectroscopy: Prompt Gamma Spectroscopy (PGS) [Verburg 2014],
- Scintillator with time-of-flight (TOF) measurement (with no collimation): monitoring of the ion range from the characteristics of the TOF spectrum corresponding to PG coming from the patient: either the position and the width of the spectrum (Prompt Gamma Timing (PGT) [Golnik 2014]) or the integral (Prompt Gamma Peak Integral (PGPI) [Krimmer 2016, Krimmer 2017b].

The present project deals with both Compton camera (CC) and PGPI.

Several applications of Compton cameras (CC) are actually foreseen: hadrontherapy monitoring, nuclear imaging with high energy radiotracers or Targeted Radionuclide Therapy (TRT) monitoring where most radionuclides emit high energy gammas allowing per-treatment images. CC have the potential to provide images of high-energy radiotracers with sensitivity at least 2 orders of magnitude larger than the one of conventional SPECT cameras [Han 2008, Fontana 2017] which could be a major breakthrough. A CC prototype is under development within the CLaRyS collaboration gathering several French laboratories [Krimmer 2015]. First tests of the prototype are planned by the end of 2018. . Dedicated reconstruction algorithms have been developed and quantification aspects are currently under investigation.
All these studies require input data from Monte Carlo (MC) simulations. At present, a few ad-hoc Monte Carlo simulations have been developed, either based on the Megalib package or the Geant4 platform. However, the former is not medical oriented, and the latter is difficult to use and maintained. The OpenGate collaboration already developed powerful PET and SPECT modules allowing precise simulations of clinical devices. Here, the purpose of this post-doctoral position is to develop an additional Gate module for the simulations of Compton Camera devices, both usable in nuclear medicine and hadrontherapy.

Regarding PGPI, a feasibility study has been carried out within a 2-year project (“Physique Cancer”) that led to the construction of a demonstrator with 3 detectors readout by a data acquisition board and the associated acquisition software. One of the main outcomes of this study is the sensitivity of the technique to any type of deviations: ion ranges, numbers of incident ions, patient positioning and morphological changes. Most of these parameters are strongly correlated but ion range is the most important quantity. Therefore, the combination of signals from various detectors - such as averages and ratios - has been studied, and they provide, during the treatment, information on the energy deposited in the patient (and thus the ion range) and its spatial distribution. A patent application has been submitted in July 2016 (n° FR1656378).

Tasks:
The tasks of the recruited person will be to:

- Compton camera
  - Determine the main components of a CC and define a convenient parametrization
  - Test by comparison with experimental data

- Investigate the possibility of variance reduction technique
- Design and implementation of a tool to make the direct connection between MC and reconstruction

- PGPI
  - Optimize the detection device with treatment plans and the fast simulation tool of PG emission developed within the GATE platform [Huisman 2016]
  - Assess the performances of the technique with a few relevant clinical cases.

Profile

- The candidate must hold a PhD in medical physics, physics or image processing.
- Scientific interests: Monte Carlo simulations, computer sciences (medical image processing), x-ray and particle physics,
- Programming skills: high level in C++ required.
- Language: French, English
- Location: Centre Léon Bérard, Lyon, France.
- Period: 1 year (renewable for 1 additional year) starting from end 2017/early 2018.

Contacts

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