PhD position in medical image processing, Orsay, France

The *In-Vivo* Molecular Imaging Lab at CEA is seeking a talented and highly-motivated candidate for a PhD engagement in the EU Horizon 2020 funded project "HYBRID" (www.hybrid2020.eu).

Modelling and reconstruction of a 3-D whole-body parametric map in hybrid PET-MRI pharmacological imaging.

The objective of the PhD project is the development and evaluation of a new data processing algorithm for the estimation of a tri-dimensional (3-D) *in vivo* map of a pharmacological parameter over the whole body of the patient. The data will be acquired during a dynamic whole-body Positron Emission Tomography (PET) scan with a tracer probing the pharmacological parameter of interest. Magnetic Resonance (MR) images will be acquired simultaneously to the PET data thanks to an integrated PET-MR imaging system. These complementary MR images will guide the estimation of the pharmacological parametric map. The patient data collection and the evaluation of the processing algorithm will be part of two biomedical research protocols, aiming at better understanding and predicting the therapeutic effect of pharmaceutical drugs.

Methodology

At first, a pharmacokinetic model linking the data acquired during the dynamic PET scan to the pharmacological parameter of interest will be defined. Then, an optimisation algorithm will be derived to invert the pharmacokinetic model and reconstruct the parametric map directly from the PET data.

This inverse problem faces three major difficulties:

1) The problem is intrinsically ill-posed (projection tomography), hence very sensitive to the stochastic noise (Poisson process) in the PET data.
2) The high dimensionality of the problem: a few tens of millions of parameters to be estimated for a few hundreds of millions of recorded events.
3) Missing data: because of the limited axial aperture of the integrated PET-MR system, the whole body cannot be scanned simultaneously. The majority of the dynamic data are not recorded.

The novelty of the research project is threefold:

1) The direct estimation of the pharmacological parameter of interest from the acquired data. Usually, it is a twostep process. First, a series of dynamic images of the PET tracer distribution within the body is reconstructed. Then, the pharmacological parameter is estimated from these dynamic images. The goal of the PhD project is to merge these two steps into a single one.
2) The estimation of the pharmacological parameter of interest over the entire human body. Usually, this estimation is limited to a single anatomical localisation entirely covered by the scanner field-of-view. Thus, there are no missing dynamic data.
3) The use of simultaneous MR data to help in the estimation of the pharmacological parameter of interest. Usually, PET data only are used.

Environment

The successful candidate (Master degree in Applied Mathematics, Signal and Image Processing, or Physics) will benefit from being part of the biomedical physics and engineering community at the Paris Saclay University (EOBE doctoral school) and conduct his research at the *In-Vivo* Molecular Imaging Lab of the French Alternative Energies and Atomic Energy Commission (IMIV/CEA) in Orsay, France. The student will enjoy working in a large, international and cross-specialty research and training network within the framework of a European Innovative Training Network, called HYBRID, dedicated to dual-modality and multi-parametric non-invasive medical imaging methods (www.hybrid2020.eu). The student will spend several weeks abroad with academic and industrial partners, and benefit from regular network training with the other PhD students enrolled in the HYBRID project.

Keywords: Inverse problem / Algebraic modelling of complex systems / Optimization algorithms / Intensive computing / Medical application / Tomographic image reconstruction

Eligibility

- The candidate must not have resided or carried out their main activity (work, studies, etc.) in France for more than 12 months in the 3 years immediately prior to its recruitment
- Applicants should have less than 4 years of postgraduate research experience

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Context

Positron Emission Tomography (PET) and hybrid PET/Magnetic Resonance Imaging (MRI) are able to provide whole-body image information of patients in the context of cancer imaging and screening for metastatic disease. Standard clinical PET and PET/MRI protocols entail the computation of relative quantification parameters (e.g. SUV in PET), based on simplifying assumptions, and derived from a single pass whole-body acquisition. However, these assumptions are not always valid and several studies have shown the benefit of using absolute quantitation for the prediction and assessment of response to therapy. The computation of these quantitative parameters with a direct physiological interpretation is based on a pharmacokinetic analysis of the PET data and is usually limited by the axial field-of-view, and, thus, to a single localisation (e.g. the primary tumour). Input data for the pharmacokinetic analysis are derived from a dynamic PET acquisition over this single "bed position". However, a more complete re-/staging of cancer patients would benefit from applying such a pharmacokinetic analysis to the whole-body.

First pilot studies point to the feasibility and benefit of whole-body parametric PET imaging, but a number of methodological challenges remain to be addressed. It includes the estimation of the arterial input function needed by the pharmacokinetic analysis and the image blurring introduced by the patient motions between whole-body passes. Therefore, further work is needed to derive and establish clinically viable schemes for whole-body data acquisition, image reconstruction and quantification protocols to produce whole-body parametric images for whole-body tumour characterization. Hybrid PET/MR imaging brings a unique opportunity to address these methodological challenges. Complementary MR data can be used to guide image-based arterial input function estimation and to detect and compensate for patient motions.

The objective of the PhD project is to expand parametric imaging to whole-body PET/MRI for improved assessment of response to therapy in oncology patients by addressing unmet methodological challenges, including the development of a dynamic PET image reconstruction optimized for whole-body imaging and addressing the discontinuous and non-uniform time sampling of dynamic whole-body acquisitions. Complementary MR data will be used to (1) guide image-based arterial input function estimation, and (2) detect and compensate for motion occurring within and between time samples. Pending the practical implementation, an added value of whole-body parametric PET imaging for predicting/assessing therapy response in patients non-small cell lung cancer (NSCLC) treated with a tyrosine kinase inhibitor (TKI) shall be evaluated within the framework of the CONcEPT research protocol.

Expected results: This project will result in a novel acquisition protocol and PET image algorithm producing dynamic data suitable for quantitative whole-body parametric imaging. Further, it will yield dedicated quantification methods using the dynamic whole-body PET data and MR-guided image-derived input function estimates. A comparison of conventional whole-body PET (e.g. SUV) and MR images with the resulting whole-body parametric images will be performed for NSCLC patients treated with a TKI.