PhD in Signal Processing for Multiplexed Long Axial Field-of-View Positron Emission Tomography

Announcement

The University Hospitals of Brest and Nantes, in collaboration with Siemens Healthineers, are seeking a talented and highly motivated student for a PhD CIFRE position. The PhD project focuses on signal processing in positron emission tomography (PET) imaging specifically in the context of multiplexed long axial field-of-view (LAFOV) acquisitions.

Keywords: inverse problems, medical imaging, positron emission tomography, multiplexed PET, dual-tracer, unmixing, kinetic modeling, LAFOV, total body.

Context and objectives

Positron emission tomography (PET) is a quantitative nuclear imaging modality widely used in oncology for cancer staging and therapeutic response assessment. A small amount of radiotracer emitting positrons is administered to the patient. Emissions resulting from the positrons annihilations are detected by the PET scanner. Tomographic reconstruction algorithms are then used to generate images representing the spatial distribution of the radiotracer within the body. The radiotracer is a radiopharmaceutical targeting a specific biological process in the body. Consequently, the comprehensive evaluation of certain diseases may require the use of two (or more) radiotracers providing complementary information. In such cases, patients typically undergo separate PET acquisitions for each radiotracer scheduled several days apart, leading to multiple trips to the hospital. In addition, images of the different radiotracers are not taken in the same physiological conditions and require elastic registration to be interpretable by the nuclear physician.

Our team has recently developed a generic method for enabling multiplexed PET acquisitions in clinical routine [1]: using multiple radiotracers in a single PET acquisition. This would overcome all the aforementioned limitations. A dynamic acquisition is performed with a small delay between radiotracer injections. The separation of radiotracer signals is then based on a generic pharmacokinetic model. A clinical research protocol named "ELMIRA" is currently ongoing, led by the University Hospital of Nantes, France, and mainly funded by the RHU

OPERANDI (with Siemens Healthineers as an industrial partner). This protocol evaluates the interest of the multiplexed PET method in two different pathologies: hepato-cellular carcinoma with [^{18}F]-FDG and [^{18}F]-FCholine, and neuro-endocrine tumors with [^{18}F]-FDG and [^{68}Ga]-DOTATOC radiotracers. The majority of PET scans included in ELMIRA protocol will be performed on the Siemens Vision 600 PET/CT scanner with a standard axial field-of-view (SAFOV) of 26.3 cm. Due to the need for a full dynamic acquisition, multiplexed PET imaging is restricted to the axial coverage of the PET scanner. Thus, a couple of PET scans will also be performed on the LAFOV Siemens Quadra PET/CT scanner (106 cm) recently installed at the University Hospital of Brest, France. This will allow performing multiplexed PET imaging from top of head to thigh.

The current preferred method for image separation is *indirect* and works in two separated steps: dynamic images of the multiplexed acquisition are first reconstructed and the separated images are obtained by fitting the dynamic model separately on each voxel afterwards. By using the *direct* method embedding the pharmacokinetic model within the tomographic reconstruction, separated images with improved quality can be obtained in a single step [2, 3]. However, the direct method is subject to bias propagation: any misfit of the pharmacokinetic model causing bias will propagate to neighboring voxels during the iterative reconstruction due to the tomographic aspect of PET image reconstruction. Bias propagation is particularly problematic in dynamic LAFOV PET because the images cover a large part of the body including a wide diversity of radiotracer kinetic behaviors.

The global aim of this PhD thesis is to develop new methods of signal processing dedicated to multiplexed LAFOV PET and apply them to a forthcoming clinical research protocol on lymphoma conducted by the University Hospital of Brest. [^{18}F]-FDG PET remains currently the clinical standard for lymphoma staging and treatment response assessment. CXCR4-targeted imaging (*e.g.* using [^{68}Ga]-Pentixafor) represents a more recent and emerging concept, targeting the chemokine receptor involved in tumor progression and microenvironment interactions. The integration of CXCR4 into multiplexed PET imaging could therefore provide additional biological insights beyond standard metabolic imaging.

The following strategies may be considered as initial directions for methodological developments. The indirect method can be improved by adding a regularization term penalizing differences of kinetic parameters in neighboring voxels. This resembles regularization strategies included in the tomographic reconstruction problem as used in clinics [4]. The direct method can be improved by mitigating the bias propagation problem. In a standard single-tracer PET acquisition, this can be done by using adaptive residual modeling [5]. This method could form the basis for adapting it to multiplexed acquisitions.

Requirements

The candidate must hold a master degree (or an equivalent) in Applied Mathematics, Com-

puter or Data Science or any related field. He/she should enjoy working in a multidisciplinary environment with physicists, physicians and numerical scientists. Good programming skills, knowledge of inverse problems and/or medical physics are a definite plus.

Host partners

- University Hospital of Brest, Nuclear Medicine Department, France,
- GETBO, UMR 1304, Brest, France,
- University Hospital of Nantes, Nuclear Medicine Department, France,
- CRCI2NA, UMR 1307, Nuclear Oncology Team, Nantes, France,
- Siemens Healthineers, France.

Supervision

- Pr Ronan Abgral (ronan.abgral@chu-brest.fr)
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Practical information

- Start fall 2026, 3 years duration
- The student will spend a part of his/her PhD in Nantes and the other part in Brest
- Gross annual salary: 37k€

References

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