Title: Total Body PET/CT Reconstruction with Optimised CT Dose by Combined Utilisation of Emission and Transmission Data

1 Research Context

Positron emission tomography (PET) combined with X-ray computerised tomography (CT) provides a visual representation—in the form of a radioactivity image—of functional processes such as metabolism, O_2 consumption and myocardial perfusion. In addition to providing anatomical information, CT imaging is also used to correct PET images for attenuation, thus allowing the reconstruction to achieve absolute quantification.

The CT dose for the patient (and to some extend for the clinician) should be minimal, without affecting the image quality (signal to noise ratio). This requires an optimisation of the CT raw data utilisation, and suggests the utilisation of emission data as a complementary source of information for the CT. This idea is not new, and several methodologies have already been proposed [1, 2].

The introduction of time-of-flight (TOF) PET has allowed for great progress in this field, and it has been demonstrated TOF-PET emission data determines both activity and attenuation images "*up to a constant*" [3]. Thenceforth, many algorithms such *maximum-likelihood activity and attenuation* (MLAA) [4, 5] were published. However, their utilisation is generally limited to PET/MRI systems, where the MRI-derived attenuation map in incomplete.

The emergence of *total body* (TB) PET/CT may revive the interest in MLAA types of approach, for 2 main reasons: (i) TB-PET requires a full attenuation map of the patient, therefore higher CT dose, and (ii) the large number of TB-PET lines of response may provide the required additional information for the reconstruction of the attenuation map.

2 Proposed Approach

The objective of this work to explore the possibilities offered by the joint utilisation of raw PET and CT data, i.e., CT projection data and list-mode PET, and to establish an joint image reconstruction methodology for TB-PET/CT, in order to optimise the utilisation of the CT and to reduce the dose. This methodology can be considered as an extension of MLAA [1, 4]. The following research directions will be investigated:

1. *Reconstruction Algorithms:* The first task, which will establish the foundations of this work, will consist in developing novel algorithms for simultaneous activity and attenuation

images from raw PET/CT projection data, with a possible integration to the tomographic reconstruction platform CASToR [6].

2. *CT Dose Optimisation:* The second task is the theoretical analysis of the reconstructed images (activity and attenuation) stochastic properties (bias and variance), in order to predict to image quality as a function of the CT dose and of the PET counts. These prediction will provide the required tools for CT dose optimisation, as well as a better understanding of the impact of each modality on the image quality. The theoretical models will then be validated with realistic Monte-Carlo simulations.

3. *Incorporation of Respiratory Motion*: Respiratory motion is a source of inconsistencies between PET and CT raw data, and produces attenuation artifacts. This problem was partially solved in previous work [7]. More specifically, is has been demonstrated that PET/CT allows automatic registration of the PET activity image to the attenuation map, provided that the motion and the PET image are estimated simultaneously (e.g., by joint maximum-likelihood) [8]. In order to minimise the CT dose and to maximise the quantity of useable information, this work will extend this methodology to joint PET/CT reconstruction with motion estimation, using the entire raw PET list-mode data and CT projection across the respiratory cycle.

4. *Possible Extensions:* Kinetic modelling, respiratory motion models, motion estimation from raw data using deep-learning techniques, Bayesian models for PET/CT.

3 Required Profile

Master in

- Applied Mathematics
- Signal/Image Processing
- Any other relevant field.

(non-exhaustive list).
Good grades required. **Knowledge of French language <u>not</u> required**.

4 Supervision

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