COLLEGE DOCTORAL BRETAGNE SCIENCES DE LA VIE ET DE LA SANTE

Year 20 /23

THESIS TOPIC

Subject N° (to be completed by the ED):	**FUNDING:** ☒ **Requested** ☐ **Acquired**	**Funding origin:**
Thesis title: **Deep learning for PET/CT synergistic reconstruction**		3 keywords: PET/CT, Image synergistic reconstruction, Deep Learning
Unit / team: **LaTIM, U1101, team ACTION**		
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Socio-economic and scientific context (approximately 10 lines):

The aim of dose reduction in medical imaging is to offer the possibility of performing more scans without harming the patient.

Over the last decades, new methodologies have pushed towards less noisy reconstructions with lower patient dose. "Noise-controlling" reconstruction methods have beendeveloped since the 80's; starting with model-based image reconstruction (MBIR) iterative techniques (maximum-likelihood) that account for the measurement statistics such as the expectation-maximization (EM) algorithm, then including a penalty term (regularizer) to control the noise while preserving image edges. More recently, compressed sensing techniques utilize the sparsity to solve underdetermined systems; these techniques are nowadays used for sparse-view and low-dose CT reconstruction, with total variation regularizers. Recent artificial intelligence (AI) techniques for image reconstruction have pushed this principle further by learning adapted representations instead of using "fixed" representations.

Today, the aim of medical image scientists is to reduce the dose to a minimum level in order to allow screening and monitoring.

Working hypothesis and aims (approximately 8 lines):

Conventional image regularizers—i.e., non AI-based—have been extended to multimodal imaging. When the different channels share some structural information, a coupled regularization is indeed highly beneficial for the multichannel image. This is the case in PET/CT and PET/MRI as each modality depends on the same underlying anatomy. These methods utilize hand-crafted objective functions that may not reflect the natural dependencies between the modalities.

Optimal image coupling models can be learned with AI techniques such as multimodal machine learning. These techniques are utilized to learn abstract models that can process and relate information from multiple modalities, unlike conventional techniques where dependencies between modalities are imposed by a given analytical model. Dependencies across modalities will be learned by the model—as opposed to previous work in which multi-modal structural similarities were imposed by the model—and could be extended beyond simple geometric similarities, e.g., with the possibility of learning joint textural and temporal information.

Thanks to the noise reduction allowed by the exploitation of the dependencies between the images, a reduction of the patient dose and of the acquisition time can be foreseen.

Main milestones of the thesis (approximately 12 lines):

To date, there are no AI-based models for multimodal reconstruction. Our project will therefore focus on the following two methodological issues: (i) the development of such models and (ii) their incorporation into reconstruction algorithms.

The project will focus on PET/CT and PET/MRI imaging. The methods to be proposed will include two modules :

- **a "physical model" module that will exploit the scanner data**
- **an AI module that will exploit trained multimodal models,**

We will use generative models such as GAN and multi-channel VAE to generate multiple images from a single latent variable. These networks will form the basis of the AI module. The reconstruction architecture will be based on an unrolling model, which is currently the most successful model in the scientific literature.

The methods developed will then be integrated into the CASToR platform, which is developed by our laboratory. CASToR will form the basis of the "physical model" module. The methods will first be tested on simulated Monte Carlo data, which will allow us to evaluate their performance based on ground truth. Subsequently, they will be tested on patient data.

Scientific and technical skills required by the candidate (2 lines):

Deep learning, Optimization, Computer Science, medical physics

3 publications from the team related to the topic (last 5 years):

V. S. S. Kandarpa, A. Perelli, A. Bousse, and D. Visvikis, “LRR-CED: Low-resolution reconstruction-aware convolutional encoder-decoder network for direct sparse-view CT image reconstruction,” Physics in Medicine & Biology, vol. 67, no. 15, p. 155 007, 2022. DOI: 10.1088/1361-6560/ac7bce.

F. Lamare, A. Bousse, K. Thielemans, C. Liu, T. Merlin, H. Fayad, and D. Visvikis, “PET respiratory motion correction: Quo vadis?” Physics in Medicine & Biology, vol. 67, no. 3, 03TR02, 2022. DOI: 10.1088/1361-6560/ac43fc.

B. Laurent, A. Bousse, T. Merlin, S. Nekolla, and D. Visvikis, “PET scatter estimation using deep learning U-Net architecture,” Physics in Medicine & Biology, 2022. DOI: 10.1088/1361-6560/ac9a97.

National and international collaborations:

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