PhD Thesis Title: Hybrid Kernelised Expectation Maximisation Reconstruction Algorithms for Quantitative Positron Emission Tomography
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Abstract:

Positron emission tomography (PET) imaging is commonly used in the clinical practice to diagnose different diseases. However, the limited spatial resolution sometimes prevents the desired diagnostic accuracy. This work examines some of the issues related to PET image reconstruction in the context of PET-magnetic resonance (MR) imaging, and proposes a novel PET iterative reconstruction algorithm, hybrid kernelised expectation maximisation (HKEM), to overcome these issues by exploiting synergistic information from PET and MR images. When the number of detected events is low, the reconstructed images are often biased and noisy. Anatomically-guided PET image reconstruction techniques have been demonstrated to reduce partial volume effect (PVE), noise, and improve quantification, but, they have also been shown to rely on the accurate registration between the anatomical image and the PET image, otherwise they may suppress important PET information that may lead to false negative detection of disease. The aim of the HKEM algorithm is to maintain the benefits of the anatomically-guided methods and overcome their limitations by incorporating synergistic information iteratively.

The findings obtained using simulated and real datasets, by performing region of interest (ROI) analysis and voxel-wise analysis are as follows: first, anatomically-guided techniques provide reduced PVE and higher contrast compared to standard techniques, and HKEM provides even higher contrast in almost all the cases; second, the absolute bias and the noise affecting low-count datasets is reduced; third, HKEM reduces PET unique features suppression due to PET-MR spatial inconsistency.

This thesis, therefore argues that using synergistic information, via the kernel method, increases the accuracy and precision of the PET clinical diagnostic examination. The promising quantitative features of the HKEM method give the opportunity to explore many possible clinical applications, such as cancer and inflammation.

References to author publications that relate specifically to the dissertation:

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2. **Daniel Deidda**, Nicolas A. Karakatsanis, Nikos Efthimiou, Philip M. Robson, Zahi A. Fayad, Robert G. Aykroyd, and Charalampos Tsoumpas. *Effect of PET-MR Inconsistency in the Kernel Image Reconstruction Method*. IEEE Transactions on Radiation and Plasma Medical Sciences DOI: 10.1109/TRPMS.2018.2884176.

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4. **Daniel Deidda**, Robert G. Aykroyd, and Charalampos Tsoumpas. *Assessment of Maximum A Posteriori Image Estimation Algorithms for Reduced Acquisition Time Medical Positron Emission Tomography Data*. Recent Studies on Risk Analysis and Statistical Modelling. Springer, 2018. DOI: 10.1007/978-3-319-76605-8_1

5. **Daniel Deidda**, Nikos Efthimiou, Richard Manber, Kris Thielemans, Pawel Markiewicz, Robert G. Aykroyd, and Charalampos Tsoumpas. *Comparative Evaluation of Image Reconstruction Methods for the Siemens PET-MR Scanner Using the STIR Library*. Nuclear Science Symposium and Medical Imaging Conference Record, pages 1-6. IEEE, 2016, DOI: 1109/NSSMIC.2016.8069615.

6. **Daniel Deidda**, Nicolas A. Karakatsanis, Philip M. Robson, Nikos Efthimiou, Zahi A. Fayad, Robert G. Aykroyd, and Charalampos Tsoumpas. *Hybrid PET-MR list-mode kernel expectation maximization reconstruction for quantitative PET images of the carotid arteries*. Nuclear Science Symposium and Medical Imaging Conference Record. IEEE, 2017, DOI: 1109/NSSMIC.2017.8532641.