# Report of the CCP PETMR Exchange

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*Exchange with* Institute of Nuclear Medicine, University College London, London, UK
*and* LIGHT Laboratory, University of Leeds, Leeds, UK

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## Summary

Due to the distance travelled for this exchange, it was decided that the exchange should take place between multiple host facilities and over a longer period of time, in this case two months, than typical CCP PETMR Exchanges. Additionally, due to the extra cost, the exchange was funded by CSIRO, CCP PETMR and University of Queensland. The project was originally divided between two projects, which became four projects during the exchange. These were: implementing HKEM into STIR and SIRF; developing a motion modelling technique to capture discontinuous lung motion; developing PET data-driven head motion estimation techniques; and implementing geometrical awareness and consistency into STIR and SIRF. Due to the increased scope of work and limited time, all projects require some additional work for completion. However, this was a worthwhile trade-off, as the benefit from the short time on exchange was maximised.

## University of Leeds

### Activities

Initially, effort was focused on learning the Hybrid Kernel Expectation Maximisation (HKEM) method and its implementation in STIR. Daniel Deidda explained the HKEM method, and the hybrid explanation, and provided a preprint version of the paper outlining the algorithm. Initially, the algorithm was implemented in STIR as a new Objective Function. After discussion between Daniel, Harry Tsoumpas, Kris Thielemans and myself, we agreed that implementation as a Reconstruction class would provide both a more natural and more flexible implementation. Daniel and myself re-implemented the method into this architecture.

I applied the technique to neurological FDG data acquired in Brisbane on the Herston Imaging Research Facility's (HIRF's) Siemens mMR. Some difficulty was encountered in attempting to resample the MR prior and MRAC u-map using the PETMR-rd-tools, due to different acquisition parameters. Despite difficulties, I was able to reconstruct the data with OSMAPOSL and kernelised OSMAPOSL, both with and without PSF.

In addition, I presented a summary of my previous work during my PhD to the LIGHT laboratory.

## Results

The HKEM reconstructions for neuro-FDG were subjectively determined to be superior to regular OSMAPOSL, and to vendor reconstructions. However, a bug with the particular implementation of PSF within STIR was found, which caused the intensities to be greatly increased globally. A GitHub Issue has been raised, and the issue is under investigation.

HKEM has been implemented as a kernelised OSMAPOSL Reconstruction in STIR, and a pull request (PR) has been submitted to STIR.

This method was presented at the 2018 STIR Users' and Developers' Meeting.

## Future Work

Some further refactoring is required before the STIR PR can be merged. Additionally, a SIRF wrapper for the class is still intended to be produced.

Upon completion of this work, we are hoping to apply the technique to the full dataset acquired at HIRF, and to be able to publish an analysis of the technique on a clinical dataset.

# University College London

## Activities

Work with UCL originally focused on developing a motion modelling technique capable of modelling discontinuous lung motion. First, I spent time with Ben Thomas and Oliver Kiersnowski understanding UCL's existing methodology for lung motion correction, developed originally by Richard Manber. The proposed algorithm for motion modelling can be used in lieu of registration motion modelling used within this methodology.

Two weeks were dedicated to implementing a draft of the proposed algorithm, which uses block matching for correspondence matching, with a stochastic update schema. It explicitly enforces a temporal model per voxel for regularisation, and relaxes spatial regularisation seen in normal registration algorithms.

Upon discussions with Alaleh Rashidnasab and Kris, it became apparent that we were also both working on similar approaches on extending PET data-driven head motion tracking techniques to be able to provide full motion estimation. We dedicated some of the time during the exchange to first explain and understand each of our respective approaches to the problem. Rather than competing, we decided to combine our approaches into a single approach to near-continuous data-driven motion estimation, using regression against a multidimensional PCA-derived motion surrogate.

All work thus far was hindered by the fact that STIR reconstructions are in a different physical coordinate system to the vendor reconstructions: resampling issues for u-map and priors with the HKEM project, and motion field/parameter alignment in the lung and head motion modelling projects. This issue is sought to be solved as part of the Geometry project of the first CCP PETMR Hackathon. Hence, a portion of the time with UCL was also dedicated to solving the STIR and

SIRF portions of the Hackathon project, under co-supervision with David Atkinson. As a part of this work, a protocol for a PET/MR phantom acquisition has also been developed, and an evening was dedicated with Ben Thomas to acquire this phantom data on the Siemens mMR at UCLH.

I was also able to spend time with Richard Brown, and understand some of his work on parametric, MCIR (motion-corrected) reconstructions implemented within SIRF. I hope to work with Richard to implement this pipeline within Python in the future. It was also beneficial to spend time with Johannes Mayer, and learn about his framework for PET/MR simulation.

Finally, I had the opportunity to present a summary of my previous work during my PhD to UCL INM at the beginning of the collaboration.

## Results

Progress on the proposed block matching algorithm show promising results, and that the algorithm is worth perusing. However, the results are not yet developed enough to be able to be applied for lung motion correction: required changes are outlined in the following section.

Preliminary results for the head motion tracking are very promising. A publication is planned to be published, outlining the technique. Further collaboration on extending this technique is also planned.

A framework for STIR to reconstruct images with the vendor's origin has been developed. A number of PRs are open and many merged to implement these changes. Additionally, required changes to SIRF have been proposed and implemented, and are currently in a PR to the project. Some of the work was presented at the 2018 STIR Users' and Developers' Meeting.

## Future Work

The current implementation of the discontinuous motion modelling is too reliant on the patch similarity metric, and thus unrealistic motion is often captured in regions with little contrast and features due to coincidental matches. In order to improve results, it is hypothesised that the distance metric must be modified to be penalised by some form of spatial regularisation.

A completely novel technique for data-driven PET motion tracking has also been envisaged and discussed. We hope to be able to develop the technique over the coming months in collaboration.

The number of STIR changes still require merging. Additionally, an alternative, simpler implementation of the ray tracing matrix projector has been suggested. Other projectors, specifically interpolation-based projectors, also are required to be modified.

# Additional Activities

In addition to the planned activities outlined above, I conducted a number of other collaborative activities during the exchange.

Whilst in Leeds, I visited the Leeds Cancer Centre at St. James University Hospital. There, I gave a presentation on my work throughout my PhD and current collaboration, highlighting the work of

CSIRO, CCP PETMR and UQ. Additionally, I was given a tour of the facilities and an outline of some of the centre's research work by Richard Speight.

I was able to attend the first CCP PETMR Hackathon at Rutherford Appleton Laboratory of the Science and Technology Facilities Council. There is participated in the Geometry challenge, proposing a class to add to SIRF containing the required information to express an image's location in a patient-based physical coordinate system. Additionally, I was able to meet CCP PETMR collaborators from a large number of organisations, and tour the Diamond Light Source.

I also visited Nicholas Dowson, one of my PhD supervisors, in Oxford. There, I was able to meet members of Optellum, a start-up working in early interception of lung disease. At Optellum, I gave a presentation on my work throughout my PhD and current collaboration, highlighting the work of CSIRO, CCP PETMR and UQ.

Finally, I attended the 22$^{nd}$ CCP PETMR software meeting at the end of the collaboration, returning to Leeds. There I presented an update of progress at and following the hackathon on the Geometry project. I plan to present the implemented results of this project at the upcoming 2018 STIR Users and Developers Meeting held at the 2018 MIC in Sydney. I have also been invited to aid in instruction at the STIR short course at the same conference.