

## Report from CCPETMR for the Period 01/04/19 to 30/09/19

Kris Thielemans, CCP PET-MR Chair

Evgueni Ovtchinnikov, CCP PET-MR Project Manager

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### 1. Background

Positron Emission Tomography and Magnetic Resonance (PET-MR) is a recent combined modality for medical imaging. The CCP PET-MR project established in 2015 aims at bringing together the best of the UK's PET-MR imaging expertise. Recent research shows that the use of MRI intermediate results can improve PET imaging quality and vice versa, and latest scanners can acquire MR and PET data simultaneously. Our CCP is dedicated to exploiting exciting new capabilities that the synergy of MR and PET imaging can deliver. The main deliverable of the project will be an open source PET-MR reconstruction software framework we named SIRC (Synergistic Image Reconstruction Framework). SIRC is intended to be simple enough in use for educational and research purposes, thus reducing the "barrier for entry" for new contributors to PET-MR imaging research and development, and at the same time powerful enough to process real scanner data.

### 2. Highlights for the Current Reporting Period

In the reported period, we have made major advances to our Open Source software suit SIRC (Synergistic Image Reconstruction Framework) and its underpinning PET reconstruction package STIR (Software for Tomographic Image Reconstruction). SIRC 2.0 released in May 2019 has gained image registration capabilities (interfacing to a well-known registration package NiftyReg) via our Flagship. STIR has had major work on supporting Time-Of-Flight (TOF) PET and the hybrid kernel synergistic reconstruction method (via contributions from our network). The latter feature is in the imminent STIR 4.0 and SIRC 2.1 and the former will be added to STIR in the next reporting period. We have also progressed with integration between SIRC and the CCPi Core Imaging Library (CIL). CIL contains advanced regularisation techniques and recent algorithms for optimisation of non-smooth objective functions. CIL largely adapted SIRC terminology and Python class structure, with some aliases now introduced into SIRC. This joint effort of CCP PETMR and CCPi was facilitated by joint CoSeC staff between the two projects.

Major highlights of this reporting period were our next two CCP PET-MR Hackathons. Hackathon 3 was held at University of Hull 24-26 July 2019, and it was attended by 10 developers from KCL, UCL, Leeds, Hull and STFC, including CCPi developers. The hackathon was organised around four themes: (i) try to use the SIRC in an HPC cluster SCARF, (ii) image registration, (iii) denoising images, and (iv) GPU projector in STIR and Gadgetron GPU gadgets. Participants were divided in the 5 groups (two groups for (iv)), with occasional cross-checks and CoSeC staff and the PI floating between groups. We had good interaction with CCPi, and the feedback from the participants was excellent. Hackathon 4 was held at University of Bath 23-24 Sep 2019, and it was attended by 10 developers from UCL, Bath, Manchester, Leeds, NPL and STFC, including two CoSeC staff. The Hackathon started with a half-day training for new SIRC users, and then proceeded to working on 3 themes: (i) try to reconstruct PET dataset with CIL implementation of FISTA algorithm, (ii) finalise adding CIL in SIRC-SuperBuild, (iii) incorporate Hybrid Kernel algorithm from STIR into SIRC, and (iv) get basic synergistic functionality up and running and prepare demos for the training in November. Attendees' feedback was overall very positive.

We have 2 submitted journal papers that received reviews with very minor revisions in this period:

1. E. Ovtchinnikov, R. Brown, et al., *SIRF: Synergistic Image Reconstruction Framework*, Computer Physics Communications 2019
2. P. Wadhwa, et al., PET Image Reconstruction Using Physical and Mathematical Modelling For Time of Flight PET-MR Scanners in STIR Library, Methods

We have had 4 contributions to several major international conferences (ISMRM Annual Meeting, 2 at PSMR, Fully3D) directly related to the software output of this CCP. We also have an accepted oral (A. Gillman, et al) at IEEE-MIC 2019, Manchester, UK as output of one of our funded exchanges.

### 3. Workshops and New Opportunities

Our main outreach activities during the reported period continued to be our regular (every 6 weeks) Software Framework meetings, where we discussed our development progress with our potential developers and users from PET-MR research community (KCL, Leeds, Manchester and other Universities' researchers) and representatives of major imaging scanner manufacturers, including Siemens and GE.

CCP PET-MR organised the one day PET-MRI School for students and early stage researchers at PSMR 2019, 8th Conference on PET/MR and SPECT/MR, 15–17 April 2019, Munich, Germany (28 participants) with a hands-on PET-MR software training session using SIRF. CoSeC staff helped in developing the training material and one joined the school for assistance on site. The school was very well received, with the hands-on sessions using Jupyter notebooks very much appreciated.

The hackathons mentioned above also contained a large component of training.

A large amount of work during this reporting period has been to prepare a Symposium on Synergistic Image Reconstruction (<http://synergimrecon.org/>) that was held in Chester, November 2019, jointly organised between CCP PETMR and CCPi. We had about 100 attendees for the 2 day symposium and 40 for the subsequent 2 day training school. More detail will be provided in the next reporting period.

### 4. Issues and Problems

Our main stumbling block remains the installation of SIRF and its pre-requisites under various Operating Systems. In particular, we have not yet succeeded in the Windows installation of Gadgetron. In order to run our SIRF MR scripts under Windows we employ our Virtual Machine running pre-installed Gadgetron as a Gadgetron server. In our SIRF training sessions we also use Microsoft Azure cloud computing service and Jupyter notebooks.

We have not been able to make much progress with our PET-MR phantom group. We do have now a Zenodo community <https://zenodo.org/communities/ccp-petmr> but with few contributions of data