Report from CCP_PETMR for the Period 01/10/18 to 31/03/19

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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 SIRF (Synergistic Image Reconstruction Framework). SIRF 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.

http://www.ccppetmr.ac.uk/
https://github.com/CCPPETMR/

Highlights for the Current Reporting Period

In the reported period, we have made major advances to our Open Source software suit SIRF (Synergistic Image Reconstruction Framework) and its underpinning PET reconstruction package STIR (Software for Tomographic Image Reconstruction). SIRF 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 PET and the hybrid kernel synergistic reconstruction method (via contributions from our network). These 2 features were published in major peer-reviewed journals and will be merged into STIR master in the next reporting period. We have also progressed with integration between SIRF and the CCPi Core Imaging Library (CIL). CIL contains advanced regularisation techniques and recent algorithms for optimisation of non-smooth objective functions. CIL was written to largely adapt SIRF terminology and (Python) class structure, with some aliases now introduced into SIRF. This joint effort of CCP PETMR and CCPi was facilitated by joint CoSeC staff between the 2 projects.

We used STIR for hands-on training in a 1 day Short Course on Image Reconstruction for PET and SPECT at the IEEE Medical Imaging Conference, Sydney (Australia) in October 2018. The course had about 60 participants. The hands-on sessions received excellent feedback.

The second Hackathon was held at St Thomas' Hospital in London 17-19 Dec 2018, and it was attended by 12 developers from UCL, KCL, Manchester and STFC, including 2 CoSeC staff. The Hackathon started with a half-day training for new SIRF users, and then proceeded to working on 3 themes: (i) Porting of a synergistic algorithm to SIRF, (ii) Resolving various issues with processing mMR data and (iii) Working on SIRF image registration functionality. Attendees' feedback was overall very positive. During the hackathon we created a new repository for user contributions using SIRF (https://github.com/CCPPETMR/SIRF-Contribs/) where part (i) of the output of the hackathon is now available (other parts were merged directly into SIRF itself). This serves as an example for non-experts how to implement a synergistic algorithm in SIRF (Python) and test it on real data.

We have had 2 international experts visiting and giving seminars broadcasted to the community. This included a presentation by Dr Simon Stute (CEA, Orsay, France) on CasTOR, an alternative PET

reconstruction package. The CasTOR developers are interested in joining the SIRF effort but available resources are limited. Discussions on how to proceed will start soon.

Papers:

1. Nikos Efthimiou, Elise Emond, Palak Wadhwa, Christopher Cawthorne, Charalampos Tsoumpas, Kris Thielemans,*" Implementation and validation of time-of-flight PET image reconstruction module for listmode and sinogram projection data in the STIR library", Phys. Med. Biol.* **64** 035004, doi: 10.1088/1361-6560/aaf9b9
2. D Deidda, N Karakatsanis, P Robson, YJ Tsai, N Efthimiou, K Thielemans, Z Fayad, R Aykroyd, C Tsoumpas, "*Hybrid PET-MR List-Mode Kernelized Expectation Maximization Reconstruction*", Inverse Problems, 2019/1/21, doi:10.1088/1361-6420/ab013f

Conferences:

1. Richard Brown, Benjamin A. Thomas, Alaleh Rashidnasab, Kjell Erlandsson, Evgueni Ovtchinnikov, Edoardo Pasca, Andrew Reader, Julian Matthews, Charalampos Tsoumpas and Kris Thielemans, "*Motion-Corrected Reconstruction of Parametric Images from Dynamic PET Data with the Synergistic Image Reconstruction Framework (SIRF)*", IEEE NSS/MIC, 2018.
2. P. Wadhwa, K. Thielemans, O. Bertolli, N. Efthimiou, E. Emond, B. A. Thomas, M. Tohme, G. Delso, W. Hallett, R. Gunn, D. Buckley, C. Tsoumpas, "*Implementation and Validation of Image Reconstruction for PET Data From GE SIGNA PET/MR Scanners In the STIR Library*", IEEE NSS/MIC, 2018.

Workshops and New Opportunities

We plan to continue with our regular meetings: Working Group meetings every 6 months, bi-monthly Executive Group meetings, Software Framework meetings every 6 weeks and bi-weekly brainstorming tele-conferences.
SIRF v2.0 will be released in May 2019. We will continue our joint CCPPETMR-CCPi effort on sharing reconstruction/analytics algorithms across the modalities and CCPs. A first software release with this integration (v2.1) is scheduled for the next reporting period.
We are gearing up towards using SIRF at a 1 day Training School on PET-MR image reconstruction that we organise at the PET SPECT and MR (PSMR) conference in May 2019.
The third CCPPETMR Hackathon will take place in the summer 2019 In Hull.
A journal paper on SIRF is in preparation.

We have started planning a joint CCP PETMR-CCPi symposium on synergistic image reconstruction, fall 2019.

Issues and Problems.

As before, we are experiencing some delays in the software development due to two main reasons: targeting of C++, Python and MATLAB, and development for multiple operating systems (OS) and environments. Both of these are requirements decided by our Working Group and confirmed by our User Survey. Some of our development time is going towards bug fixing of the tools and packages we depend on, but we do contribute those bug fixes upstream.