CCP SyneRBI Steering Panel
Wednesday 9th February 2022 – 14:00-16:00

Attendees- Andrew Reader, Anna Barnes, Ciprian Catana, Daniel Lesnic, David Atkinson, Edo Pasca, Evangelos Papoutsellis, Evgueni Ovtchinnikov, Gemma Fardell, Harry Tsoumpas, Julian Matthews, Martin Turner, Matthias Ehrhardt, Kris Thielemans, Ross Maxwell, Simon Doran, William Hallett

Apologies- Alex Frangi, Amy Barker, Brian Hutton, Edwin J.R. van Beek, Geoff Parker, Jakob Sauer Jorgensen, Jamie McClelland, Jeff Fessler, Jennifer Steeden, Jose de Arcos Rodriguez, Paul Marsden, Robert Aykroyd, Ronald Boellaard, Simon Rit

Approval of minutes of previous meeting 17Sep2021
Minutes approved – no comments.

Brief status report since last SP meeting (activities, software, funding)
Previous Activities
Claire Delplancke organised a hackathon in Bath with Matthias Ehrhardt. This hackathon was hybrid where the focus was on stochastic optimisation algorithms using subsets and variance reduction. A separate group looked at how to make this possible efficiently in the SIRF stir interface. After the hackathon there was progress on implementing a lot of the algorithms and there will be a follow-up to evaluate the algorithms on real data and release a paper to describe the various different algorithms and methods.

CoSeC Impact Award- This is organised by STFC CoSeC group to award cases where CoSeC resources were used. Joint 3rd place awarded to Palak Wadhwa (Leeds), work based on TOF-PET for GE Signa PET/MR. Congratulations to Palak + team. SCD CoSeC Impact Award 2021: Case Studies (stfc.ac.uk)

Software
SIRF 3.1 was released before the previous SP meeting. We've now been working on SIRF 3.2 with the aim to publish end of Feb/March 2022. The main change is new capabilities for MR acquisition's using 2D non-cartesian encoding and 3D stack-of-stars. Maintenance includes: MR data sorting, upgrades of dependencies, fixes for Ubuntu 20.04 and Python 3, versioning and CMake import support.

Funding
5-year grant funding (April 2020-March 2025) – we have now completed 2 years. There is a £230K budget for networking activities and a 1.8 FTE at CoSeC. Previously discussed, EPSRC forced CoSeC to have around a 10% cut in the overall effort on CCPs in the past year. This is likely to continue (see "prioritisation" item below). The CCP budget itself is not affected.

CCPi

There was a CCPi Exec meeting recently. Plans include creation of simple recon pipeline for non-expert users (pre-processing / reconstruction / GUI). The target is reconstruction for 2k^3 datasets which is the industry standard. There is a launch of the Digital Volume Correlation app in the pipeline. CCPi also agreed to prioritise the joint activity with SyneRBI e.g. hackathons.

Current plans for activities
SyneRBI Planned Activities
- Christoph Kolbitch is organising a hackathon in Berlin – 17th-19th March. One of 5 projects is SIRF+CIL for MR reconstruction using Machine Learning.
- Hackathon during the first week of April 2022 on stochastic subset algorithms: evaluation. Joint with PET++ and CCPi.
- Training day at PSMR-TBP conference on 28th May 2022 – Italy and will take place in-person.
- Phantom meeting – no updates
- Kris has been involved in preparations for a meeting on establishing a standard and open file format for PET raw data, that has come out of a publication on AI on PET with manufacturers perspective. All the manufacturers seem to be on board to make this happen.
- We plan to organise a reconstruction challenge. There have been two meetings so far (organisation team: Matthias, Christoph, Kris & Harry). Currently identifying main aims and operational procedures.
  - Simple and fixed - given acquisition model and data – implement / compare algorithm performance for both PET and MR reconstruction, without having to be synergistic (but it could be advantageous)
  - If speed criterium is included, reference hardware will be used e.g. cloud
  - The aim is to set-up hackathons to prepare simple examples, building on current material from training schools
  - Data: Siemens and GE are the main data to be used. It would be ideal to have PET/MRI on the same phantom. The disadvantage is that GE MR has not been tested with SIRF as of yet.
  - The ranking has not yet been identified
  - Announcement – 2022 seems too soon. Potential announcement time: 2023 – IEEE MIC, PSMR and ISMRM?

Discussion on prioritisation of network and CoSeC efforts
Context
Software progress is made with CoSeC support 1.6 FTE (reduced from 1.8) (maintain software, carrying tests and implement new features) and community contributions. There are community building exercises ensuring individuals are motivated, this is completed by meetings, hackathons etc. Training schools are organised, and awards are given to those who have made a significant contribution.

How to make SIRF+CIL useful
There are two reasons why individuals want software. To do a specific task they find difficult or enable them to do new research. There are a number of reasons stopping individuals:
- Difficult installation

- Not enough real-world examples
- Documentation beyond SIRF-exercises and demos is not clear
- Lacking various features
- Computation speed
- Inconsistent conventions in places
- Bugs

Current capabilities

We currently have a common framework for PET and MR image reconstruction, registration and basic manipulation of images. Current C++ interface is not very friendly and not so much intended for other people to work with. Most individuals are currently using Python. Training schools are with Python. MATLAB is lagging behind.

<u>MR</u>
- Acquisition models (well-validated, including adjoint operations)
  -fully/under sampled, parallel imaging
  -2D and 3D cartesian
  -Golden-angle radial phase encoding (RPE)
  -2D radial, 3D stack of stars
- Coil sensitivity modelling and estimation
- Sorting of data, subset selection
- "canned" Gadgetron reconstructions (GRAPPA, SENSE)
- Demonstrated with MCIR, FISTA-GTV
- ISMRMRD input, but only tested with Siemens data

<u>PET</u>
- Acquisition models (well-validated, including adjoint operations)
  -2D and 3D PET acquisitions, non-TOF (TOF not validated properly therefore not yet merged)
  -Multiple ray tracing (CPU) or Joseph (CPU or GPU)
  -"Corrections"
    - *Capability to use scanner normalisation (Siemens mMR and GE RDF9)*
    - *Non-TOF scatter estimation*
    - *Randoms estimation (ML from delayed (Siemens) or RFS (GE))*
- *"Canned" STIR reconstructions and priors*
  -OS-EM, OS-OSL, OS-SPS, OS-(H)KEM
  -Priors: quadratic, log-cosh, RDP
- Demonstrated with "RRA" motion correction (but gating is not yet in SIRF) and MCIR (pdhg)

<u>CIL (for SIRF)</u>
- Optimisation algorithms, algorithms that were used on SIRF data:
  -Gradient descent (with Lipschitz)
  -FISTA
  -(s)pdhg

Limitations

MR
- o Gated data – we can extract gated data, however; some components e.g. self-gating signal, are not yet into SIRF. No test data available (validated with patient data).
- o No quantitative MR processing (T1 mapping, fingerprinting, DCE) (WIP@PTB)
- o No B0 non-uniformity modelling
- o Gadgetron version is out-of-date (PR nearly ready)

PET
- o Cylindrical scanner approximation (STIR PR on Block/generic geometry nearly ready)
- o No TOF (STIR PR is re-activated)
- o No dead-time modelling
- o Units are "proportional counts" (need duration, decay, branching ratios and calibration factor, most of this is now in place in STIR)
- o GE data:
  -RDF9 only (already outdated)
  -known bug in image orientation
- o Image geometry (gantry alignment and bed position ignored)
- o Not easy to handle gated or dynamic data

Framework
- o Struggle with dependency management
- o C++ layer
  -Few abstract classes to ensure consistency
  -Different API than Python/MATLAB
  -Limited documentation
- o Handcrafted interfacing to Python/MATLAB
- o Difficult to track what is happening and where
- o CIL and handling of complex numbers (WIP)

Possible Improvements

- o Make installation procedures easier. A fair amount of work has been completed on this, one of the avenues we want to open up is Conda (allows you to do version management of dependencies). Many people on the Python side are using Conda.
- o Framework
  -clean-up on the C++ side and making interfaces to allow us to speak to other engines
  -Handcrafted interfaces to Python/MATLAB could constructed almost automatically via SWIG
  -Code re-organisation for speed
- o MATLAB catch-up (~10% FTE CoSeC). *There are some difficulties with MATLAB catch-up:*
  - ▪ *Specific compilers needed on Linux, which generates conflicts with dependencies.*
  - ▪ *MATLAB comes with own libraries which generates conflicts*
  - ▪ *Not on VM, docker nor conda*

- o Image geometry
  -Ensure the orientations fit with what is appropriate/patient data
  -3-month CoSeC FTE (writing tests, curating data)
  -Experts required for debugging
  -Community to provide test data and feedback

- o Gated data – on the MR we can complete this. More work needed on the PET-side. For instance, at the moment there are no data structures for gated data, so the user needs to manage this by-hand.

- o In the grant proposal, we promised to make automatic pipelines for clinical data: input: a certain prescribed format/set of files; output: PET/MR data images reconstructed with advanced image reconstruction algorithms. Aim is to integrate these pipelines into XNAT database for using in clinical research studies/trials.

Comments from SP

Harry:

1. *other projects: Simulator interface, Continuous bed motion*
2. *Who are our primary users: algorithmic vs evaluation on practical images?*
3. *Competitors? E7tools and Duetto might be sufficient for many*

Ross: enlarge user base for parts of the software

Andrew: basics installation for undergraduates etc, simpler is good, PyTorch

Julian: installation important, and it should work

Ross: would be good to get more clarity on sub-tasks needed to complete a project

Julian: MATLAB: benefits with existing community using SPM etc.

Will: MATLAB used by modellers. Installation is crucial. Would prefer quantitative PET.

Ciprian: simple-to-use, quantification, AI algorithms, enable multi-centre trials

Look into Duetto/e7tools wrapper?

Conclusion: Exec Committee will take these comments on board and suggest updated plan at next SP meeting.

A.O.B.
We are almost half-way through the project. We therefore plan to 'refresh' the SP membership.