Report of the fifth CCP PETMR hackathon

Logistics

Date: 27-29 January 2020

Location: STFC Cosener's House, Abingdon

Attendees: Richard Brown (UCL), Evgueni Ovtchinnikov (STFC), Kris Thielemans (UCL), Edoardo Pasca (STFC), Eric Einspänner (MLU), Evangelos Papoutsellis (Manchester, remote), Johannes Mayer (PTB), Christoph Kolbitsch (PTB), Alexander Whitehead (UCL)

Aims

Implementing Motion Compensation Reconstruction

Topics

Group 1 Edoardo, Vaggelis

The aim of this group was to try to set up a MCIR PET reconstruction dataset with CIL. Data was simulated starting from the brain slice phantom,

- 4 arbitrary know affine transformations have been created and
- AcquisitionModel have been convolved with resampler, thanks to OperatorComposition available in CIL
- data have been forward projected.
- The PDHG algorithm has been used, with KullbackLeibler fidelity term and TV regularisation, from CCPi regularisation toolkit.
- The optimisation problem can be set up within the CIL block framework.
- Initial reconstruction taking care of motion and not were done showing the benefit of MCIR
- Follow-up work with Richard has been taken forward and 3D data from brainweb phantom have been used for PET. A few memory leaks have been identified and fixed for the MR. Work in progress

Group 2 Christoph, Johannes, Richard, Evgueni

The aim of this group was to get a proof of principle MCIR MR reconstruction working with a dataset simulated by Johannes (3D T1-weighted MR scan of the thorax with respiratory motion)

- **Splitting of MR k-space data into different motion states.** A new method was implemented which allowed for the creation of an empty MR AcquisitionData object which could then be filled with individual acquisitions. Different AcquisitionData objects could be created corresponding to different motion states
- **Reconstruction of different motions states.** The MR AcquisitionModel expects certain flags (first_in_slice, last_in_slice) which were not available anymore if the data had been split into different motion states. Workaround: Add acquisitions with flags first_in_slice and last_in_slice to every motion states. Another problem was that if a k-space point was acquired multiple times, then the AcquisitionModel just used one of it rather than averaging the information.
- **Transformation of different motion states.** There were several problems when trying to use a NiftyResample to warp the MR images to different motion states, because they are complex float and because they have a different orientation of the coordination system. A workaround was found by

using asarray() and fill() methods, saving images to file and loading them again (fixed some missing orientation information), transforming imaginary and real part separately and hard-coding the necessary transformation to ensure correct image orientation.

- **MCIR MR.** A backward and forward operator for MCIR MR was created and a simple conjugate gradient based iterative MCIR reconstruction could be carried out.
- **Follow up work.** Richard has solved many of the above workarounds for the image transformation. Together with Edoardo also the possibility of combining the MR AcquisitionModel and the ImageTransformation has been demonstrated. Johannes has completed a new MR AcquisitionModel which will also solve the problems for the "Reconstruction of different motion states".

Group 3 Richard, Johannes

The aim of this group was to get the simulation framework close to a pull request.

- **MR Acquisition Model**: Since the simulation framework is intended to sample motion-robust trajectories in k-space the corresponding backward and forward models must be . The interface of how to pass trajectory information was conceptualised. We found that a pre-processing step of the MR acquisition data was useful to fill the respective trajectory data structure in the ISMRMRD::Acquisition with the information needed in the reconstruction.
  We started to implement a Fourier-Encoding model that would replace the backward() and forward() methods in the current MRAcquisition model, such that
  - the coil-combining and coil-application steps could be separated from the fourier transforms
  - The coilmap computation would not need its own implementation of a backwards transform, which will make the whole MR reconstruction more modular and reduce the number of code.
- **Branch Merging:** Johannes' simulation branch was merged with the master branch to bring it up to date and prepare the merge of the pull request.
- **Follow up work:** The MR reconstruction will be revised to include a data-specific encoding model. Also the k-space will receive sorting prior to reconstruction to