Training School @ PSMR-TBP
Introduction

Kris Thielemans
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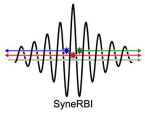
on behalf of the
Collaborative Computational Projects on Synergistic Reconstruction for Biomedical Imaging (CCP SyneRBI)

http://www.ccpsynerbi.ac.uk



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Overview

- Training school aims and structure
- SIRF and CIL description
- Practicalities
  - Schedule
  - Where to find information

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AIMS AND STRUCTURE

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Aims

For you to gain

- basic understanding of imaging
  - physics processes behind MR, PET and SPECT
  - the image formation process and in particular image reconstruction methods
- hands-on experience
  - SIRF and CIL software
    - use and evaluate existing algorithms
    - Implement your own, or combine existing ones
  - modern data-processing tools and resources
    Python, Jupyter, Zenodo, HackMD (markdown), GitHub and git,…

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Additional aims

- Join/grow a community of researchers improving image quality and willing to *share* experience and software
  - sharing between modalities as well as fields (medical and material science)
  - international
- Accelerate research and translation into practice

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How to do all of that in one day?

Introductory lectures

Pointers to material for self-teaching

Hands-on project work in groups

- *Solve some challenges together with our help*
- *Use provided cloud computing platform*

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Schedule for today

- Introduction
  Kris Thielemans & Christoph Kolbitsch
- Demonstration of tools used
  Edoardo Pasca
- **Basic principles** of PET & SPECT, MR, TotalBody PET and Reconstruction using Deep Learning
- Project descriptions

Lunch break

- Hands-on Projects

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SIRF AND CIL DESCRIPTION

- Project background
- Software overview
- Example results

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Background: what are CPPs?

Collaborative Computational Projects (CCPs) are UK-funded networking grants with Research Software Engineering support

Engineering and Physical Sciences Research Council

CoSeC

Timelines

- CCP in Synergistic PET-MR Reconstruction 2015-2020
- CCP in Synergistic Reconstruction for Biomedical Imaging (SyneRBI) 2020-2025

http://www.ccpsynerbi.ac.uk

- CCP in Tomographic Imaging 2010-2025

http://www.ccpi.ac.uk

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SyneRBI Aims

- Networking and community:
  - Bringing together expertise: improve communication between researchers and initiatives to advance the understanding of multi-modal imaging data, algorithms and scope for synergy.
  - Training the next generation: target young researchers, from Masters, to PhDs and postdocs to develop the future leaders in the field.
- Expanding open source software (OSS) infrastructure:
  - enable researchers to use a high-quality common framework for cross-modality algorithm development.
- Translation towards biomedical research:
  - create validated comprehensive pipelines for raw-data-to-end-result in clinical research studies,
  - train end-users in advanced synergistic image reconstruction methods to enable proof-of-concept studies.

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Synergistic Image Reconstruction Framework

- Aims
  - ***powerful*** enough to handle real data,
  - ***simple*** enough to be used for training and fast prototyping
  - ***robust*** enough to be incorporated into real-word pipelines
- Open source
  - Apache 2.0 license
    Actual distribution is GPL due to use of FFTW

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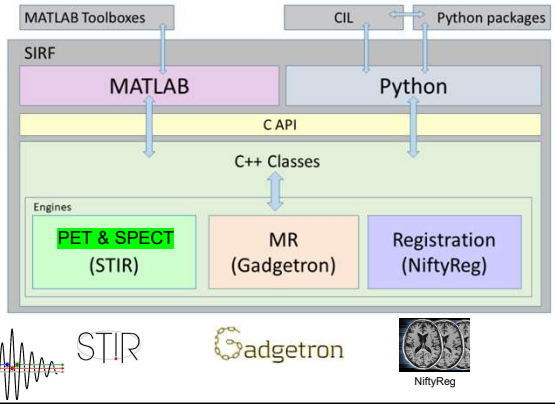
SIRF Software Architecture



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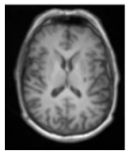
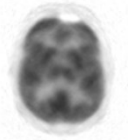
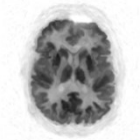
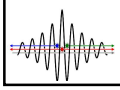
Example SIRF reconstructions
(epilepsy study, PET-FDG)


T1-weighted MR


OSEM


Uniform-weighted quadratic MAP


Bowsher-weighted quadratic MAP



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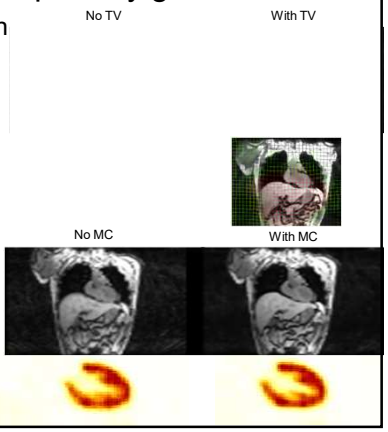
Siemens mMR: respiratory gated PET/MR

- Motion compensation to reduce artefacts and noise
- Workflow:
  1. Gated MR recon (FISTA+TV)
  2. Image registration
  3. MCIR of gated MR with GTV
  4. MCIR of gated PET (OSSPS)



MCIR = Motion Compensated Image Reconstruction

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CIL https://github.com/TomographicImaging/CIL

Open Source Python framework for tomographic imaging with emphasis on challenging datasets where conventional filtered back-projection fail.
Apache 2.0 license

CIL aims to combine the best of the two worlds of:

Tomography **Optimisation software**

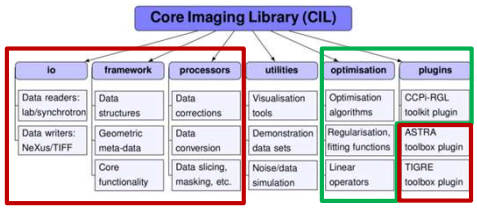

Figure 1: Overview of CIL module structure and contents. The **cil.plugins** module contains wrapper code for other software and third-party libraries that need to be installed separately to be used by CIL.

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STIR

Software for Tomographic Image Reconstruction

http://stir.sourceforge.net
https://github.com/UCL/STIR

Main publication:
Thielemans, Tsoumpas, *et al* (2012) STIR: Software for Tomographic Image Reconstruction Release 2, *Physics in Medicine and Biology*, 57(4):867-83.

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Massachusetts General Hospital

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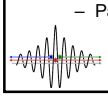
STIR 1-slide overview

- Development started in 1997, open source from 2000, Apache 2.0 since STIR 4.1.0.
- Covers PET and SPECT
- Aims to provide start-to-end quantitative image reconstruction
- Capabilities
  - Estimation of parts of the acquisition model
  - Image reconstruction
  - Motion-compensated reconstruction
  - Parametric imaging (for dynamic data)



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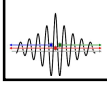
Current PET scanner support (STIR 4.1)

- Siemens mMR and older Siemens scanners
  PET raw data · SyneRBI/SIRF Wiki (github.com)
- GE Signa PET/MR and any GE PET/CT that uses RDF 9
  (SIRF supported is preliminary)

Warning: Time-of-Flight branch of STIR should work via SIRF but has not been tested very well yet.



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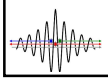
Some sirf.STIR pecularities

- To do simulations, you need to start from "template" AcquisitionData
  - Read one from file
  - Construct one based on a particular scanner (together with some extra parameters)
- Note that the sinogram-data in this "template" will not be used for the simulation (or even not exist!)



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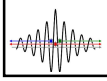
- sirf.STIR image dimensions are restricted for a scanner:
  - axial spacing and number of slices is fixed
  - "in-place" spacing and number of pixels is arbitrary
- Exercises are set-up such that images and acquisition data are compatible.
- You can create an ImageData from an AcquisitionData that works.



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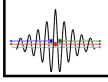
- STIR writes diagnostic output by default to the terminal but this is hidden when using Jupyter notebools.
- If you are stuck, you can redirect it to files (as illustrated in some notebooks)

```
msg_red = pet.MessageRedirector('info.txt',
'warnings.txt', 'errors.txt')
```



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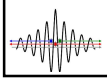
How to get/install the software?

- STFC Cloud: https://training.jupyter.stfc.ac.uk/
- ~~Your own installation:~~
  - ~~Virtual Machine~~
  - ~~Docker~~
  - ~~(self-built)~~

More detail on the HackMD site



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Acknowledgements

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  - **Kris Thielemans** (UCL)
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  - **Edoardo Pasca** (STFC)

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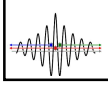
  - **Nikos Efthimiou** (MGH)



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Acknowledgements

- **CCP SyneRBI and CCPi Executive Committees**
  - **Kris Thielemans** (UCL)
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  - **Evangelos Papoutselis**
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  sites: Bath, CSIRO Brisbane, KCL, Manchester, PTB Berlin, UCL, …
  - **Christoph Kolbitsch** (PTB)
  - **Johannes Mayer** (PTB)
- **Underlying open source projects**
  - Gadgetron, STIR, NiftyReg, Astra
  - CMake, Jupyter, python, gcc …
- **Funding**
  - CCP SyneRBI (EP/T026693/1).
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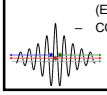
  - CCPi (EP/P02226X/1, EP/V007742/1, EP/M022498/, EP/T026677/1



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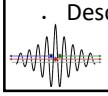
Schedule for this morning

- Kris+Edo+Christoph: introduction on school including software
- Kris: Principles of PET and SPECT image reconstruction

~10:30-11:00: coffee break

- Nikos: TotalBody PET challenges
- Christoph: Principles of MR image reconstruction
- Andrew: PyTorch principles for deep-learned iterative PET image reconstruction
- Descriptions of projects to be tackled in groups



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