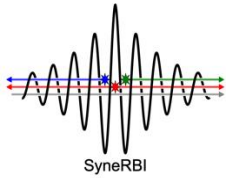
SIRF / CIL online training

11/12/25

Training team



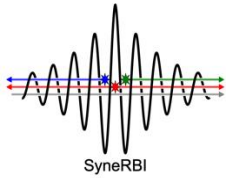
Speakers

Nikos Efthymiou	UMGC, Groningen, The Netherlands
Edoardo Pasca	Scientific Computing STFC, UK
Margaret Duff	Scientific Computing STFC, UK
Kris Thielemans	UCL, London UK

Support during the training

Casper da Costa-Luis	Scientific Computing STFC, UK
Evgueni Ovtchinnikov	Scientific Computing STFC, UK

Aims



For you to gain

- basic understanding of PET image formation in imaging
- Basics of image reconstruction and optimisation

Hands-on experience

- SIRF and CIL software
- use and start to evaluate existing algorithms
- Implement your own, or combine existing ones
- modern data-processing tools and resources
  Python, Jupyter, pytorch …

Aims

- Join/grow a community of researchers improving image quality and willing to *share* experience and software
  - sharing between modalities
  - international
- Accelerate research and translation into practice

Join SyneRBI SIRF Discord Server

https://discord.gg/9jsMfSDSdM

#sirf-training-2025

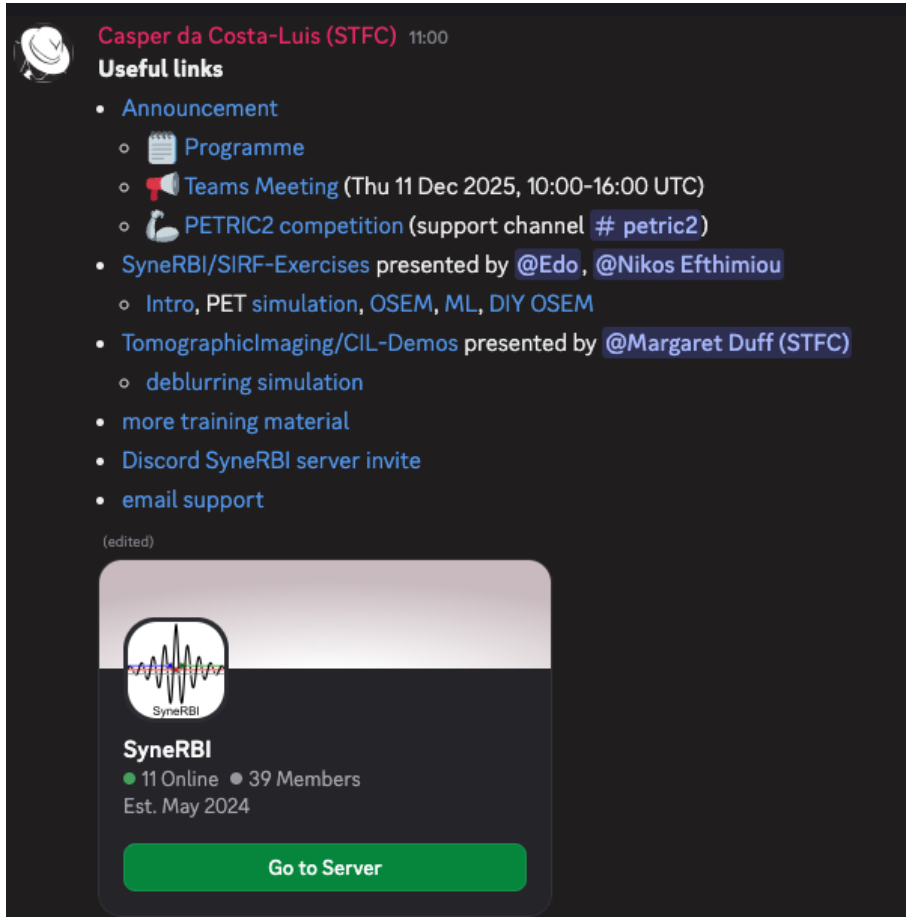
Materials

Brief introductory lectures

Pointers to material for self-teaching (https://www.ccpsynerbi.ac.uk/events/sirf-cil-training-school-11-dec-2025/)

Hands-on project work in groups

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



Program

Morning

10:00- 10:30

Basics of PET Imaging

10:30 – 11:00

to show how to create image data objects for MR, CT and PET and how to work with them.

11:00 – 11:40

how to use SIRF to create images and forward project them with and without attenuation.

11:40 – 12:20

implement Ordered Subsets Expectation Maximization (OSEM) in SIRF

12:20 – 13:00

Lunch Break

Afternoon

13:00-13:40

monitor progress of a SIRF reconstructor (currently using OSEM as an example) and implement a (simplistic) gradient-ascent algorithm using SIRF

13:40-14:20

implement Maximum Likelihood Expectation Maximization (MLEM) and OSEM in SIRF yourself using SIRF functionality.

14:20-15:00

brief introduction in optimisation in inverse problems with CIL

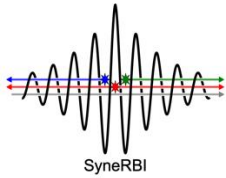
15:00 – 15:30

What is PETRIC2 and how to participate? (Kris)

15:30 – 16:00

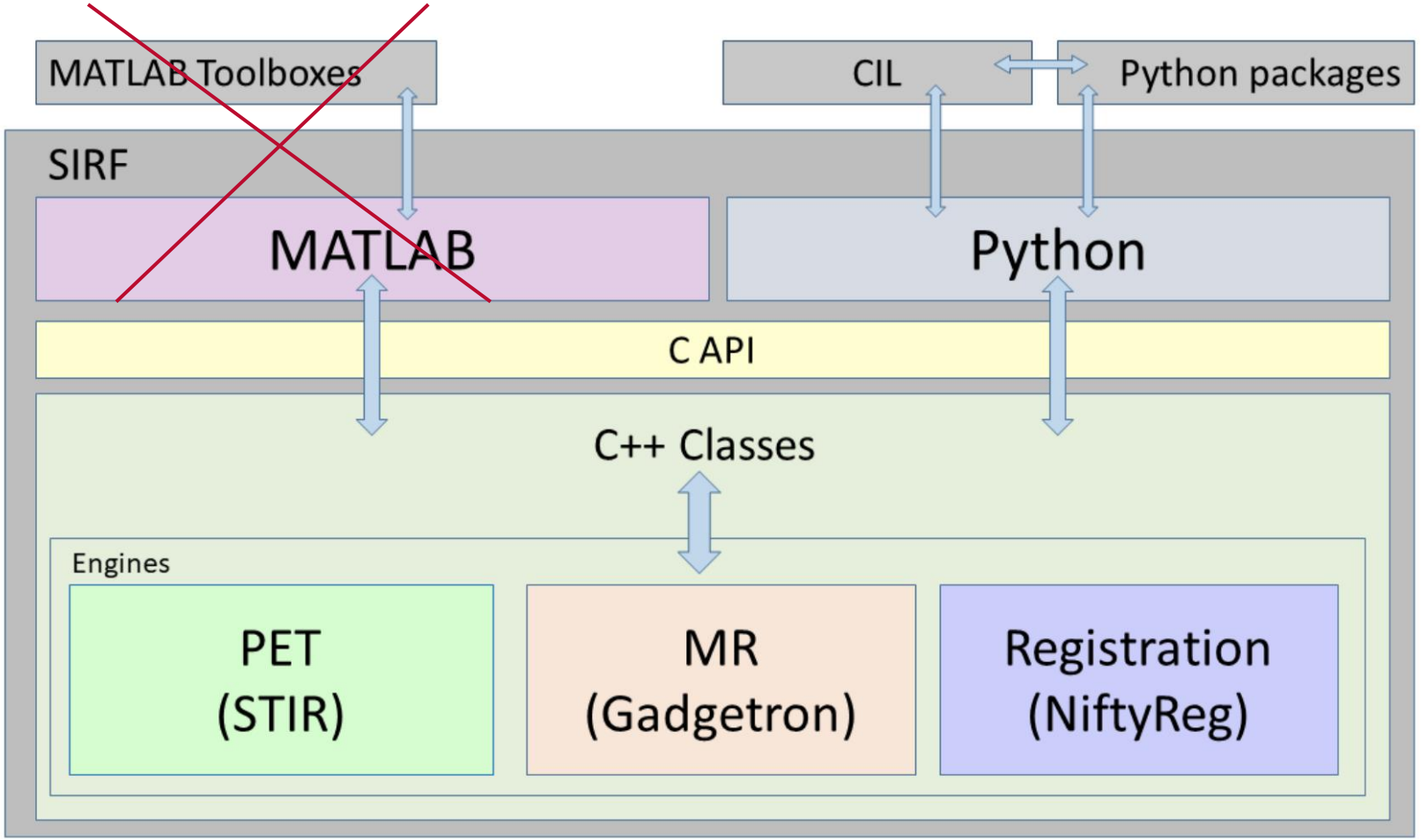
Feedback and closing

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

Synergistic Image Reconstruction Framework



Ovtchinnikov et al. Computer Physics Communications
Volume 249, April 2020, 107087

STIR

Gadgetron

NiftyReg

Core Imaging Library

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:

X-Ray Tomography non clinical

Optimisation software

CIL
CORE IMAGING LIBRARY

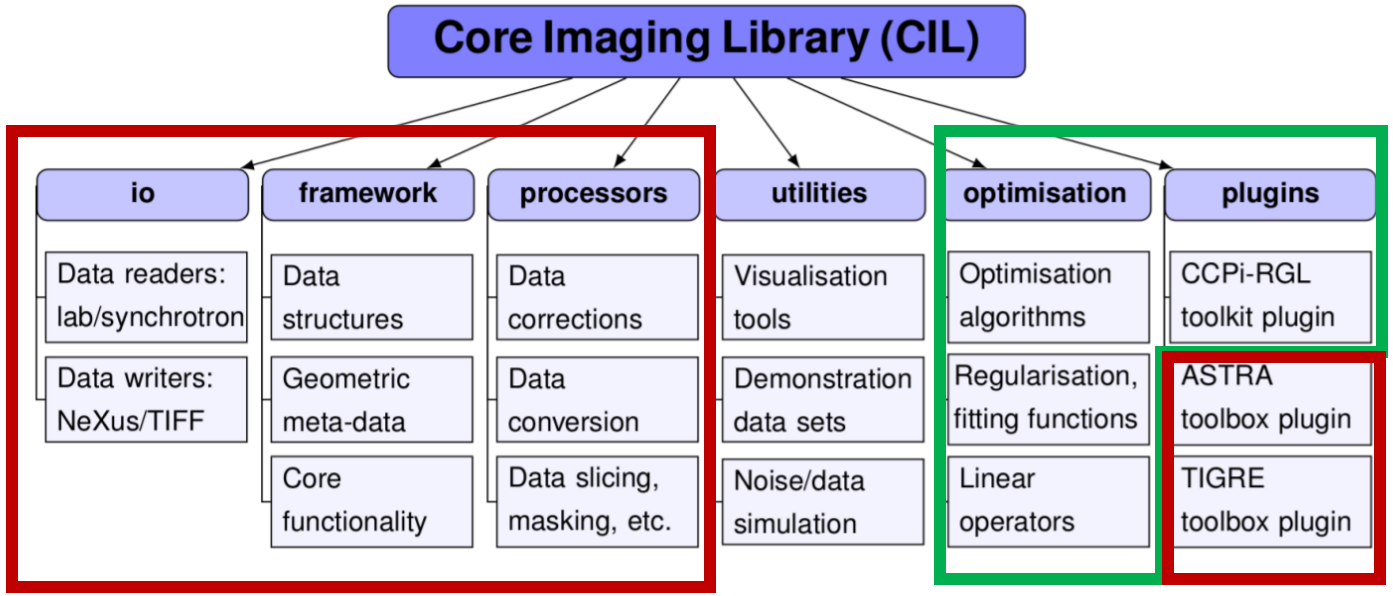


Figure 1: Overview of CIL module structure and contents. The **cil.plugins** module contains wrapper code for other software and third-party libraries that need to be installed separately to be used by CIL.

Jørgensen et al, (2021)
Phil. Trans. R. Soc. A. 379: 20200192.

Program

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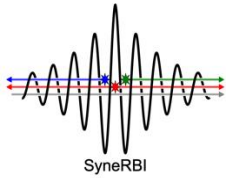
Feedback and closing

Use our online training platform



- Login information should have been sent by email
- https://sirfXX.tomography.stfc.ac.uk
- Password and VM address via chat
- Exercises 30 min each (TBC) Notebook time + 5/10 min recap = 40 min
- Hands-on project work in groups
  - Solve some challenges together with our help
  - Use provided cloud computing platform

10:30 – 11:00 GMT

Walk through

SIRF-Exercises/notebooks/Introductory/introduction.ipynb

to show how to create image data objects for MR, CT and PET and how to work with them.

11:00 – 11:40 GMT

SIRF notebook

SIRF-Exercises/notebooks/PET/image_creation_and simulation.ipynb

shows how to use SIRF to create images via geometric shapes and forward project them with and without attenuation. Exercises extending the simulation to include noise and other parts of the PET model are suggested.

11:40 – 12:20 GMT

SIRF notebook

SIRF-Exercises/notebooks/PET/OSEM_reconstruction.ipynb

shows how to implement Ordered Subsets Expectation Maximization (OSEM) in SIRF and suggests some exercises for reconstruction with and without attenuation etc.

12:20 – 13:00 GMT

Lunch break (self provided)

13:00 – 13:40 GMT

SIRF notebook

SIRF-Exercises/notebooks/PET/ML_reconstruction.ipynb

shows how to monitor progress of a SIRF reconstructor (currently using OSEM as an example) and implement a (simplistic) gradient-ascent algorithm using SIRF. This notebook can be extended to use regularized reconstruction as well.

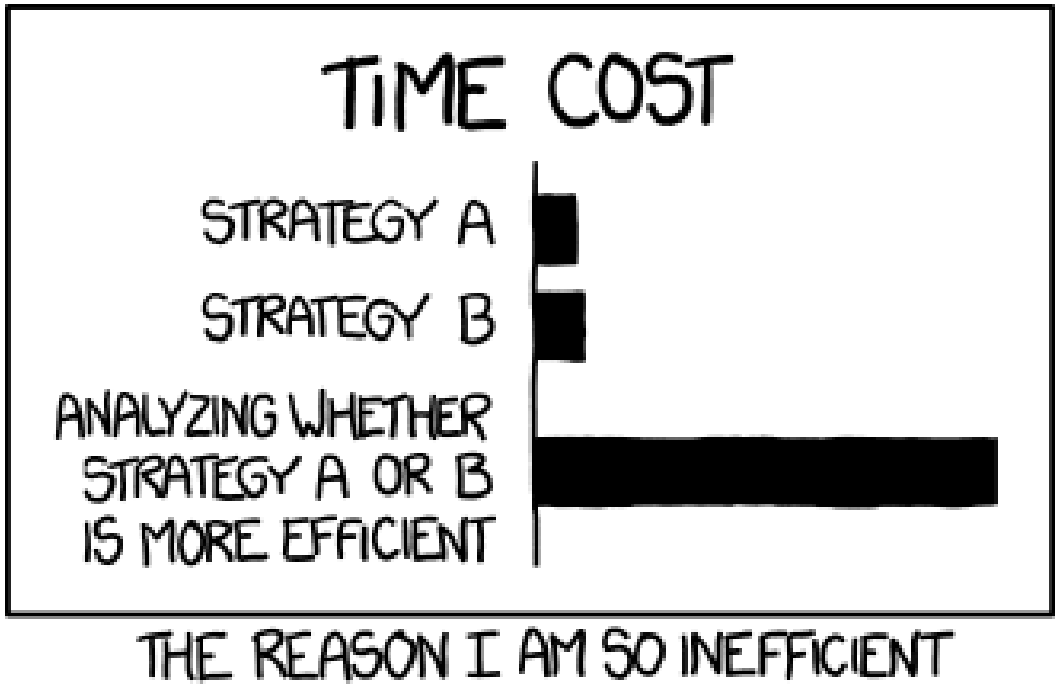
13:40 – 14:20 GMT

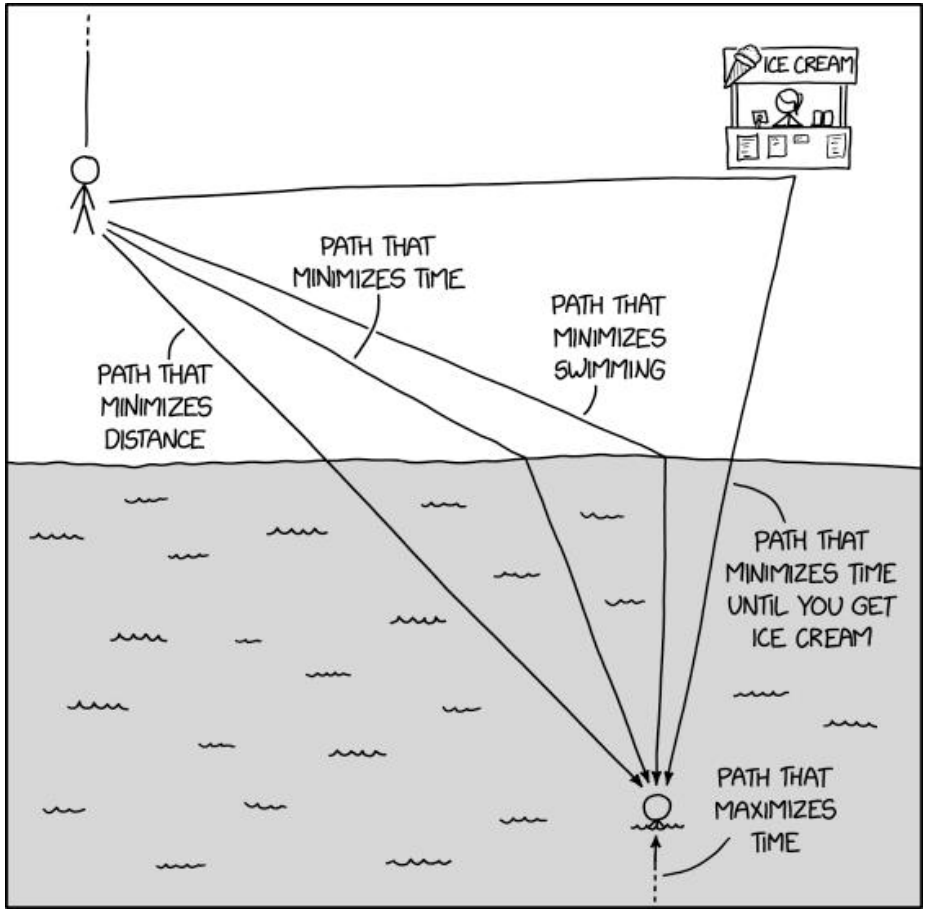
SIRF notebook

SIRF-Exercises/notebooks/PET/DIY_OSEM.ipynb

invites you to implement Maximum Likelihood Expectation Maximization (MLEM) and OSEM in SIRF yourself using SIRF functionality.

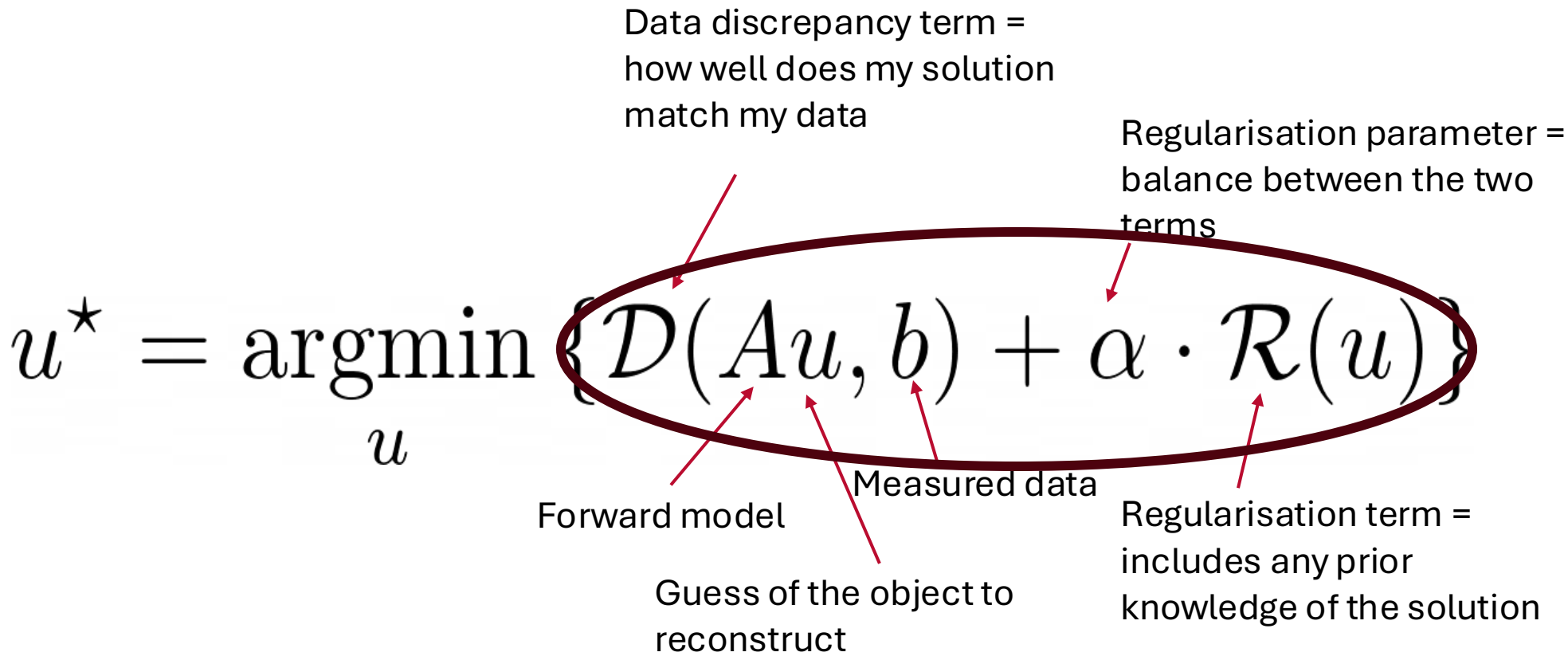
14:20 – 15:00 GMT Optimisation and Inverse Problems with CIL





Credit to xkcd for both comics

Variational Regularisation



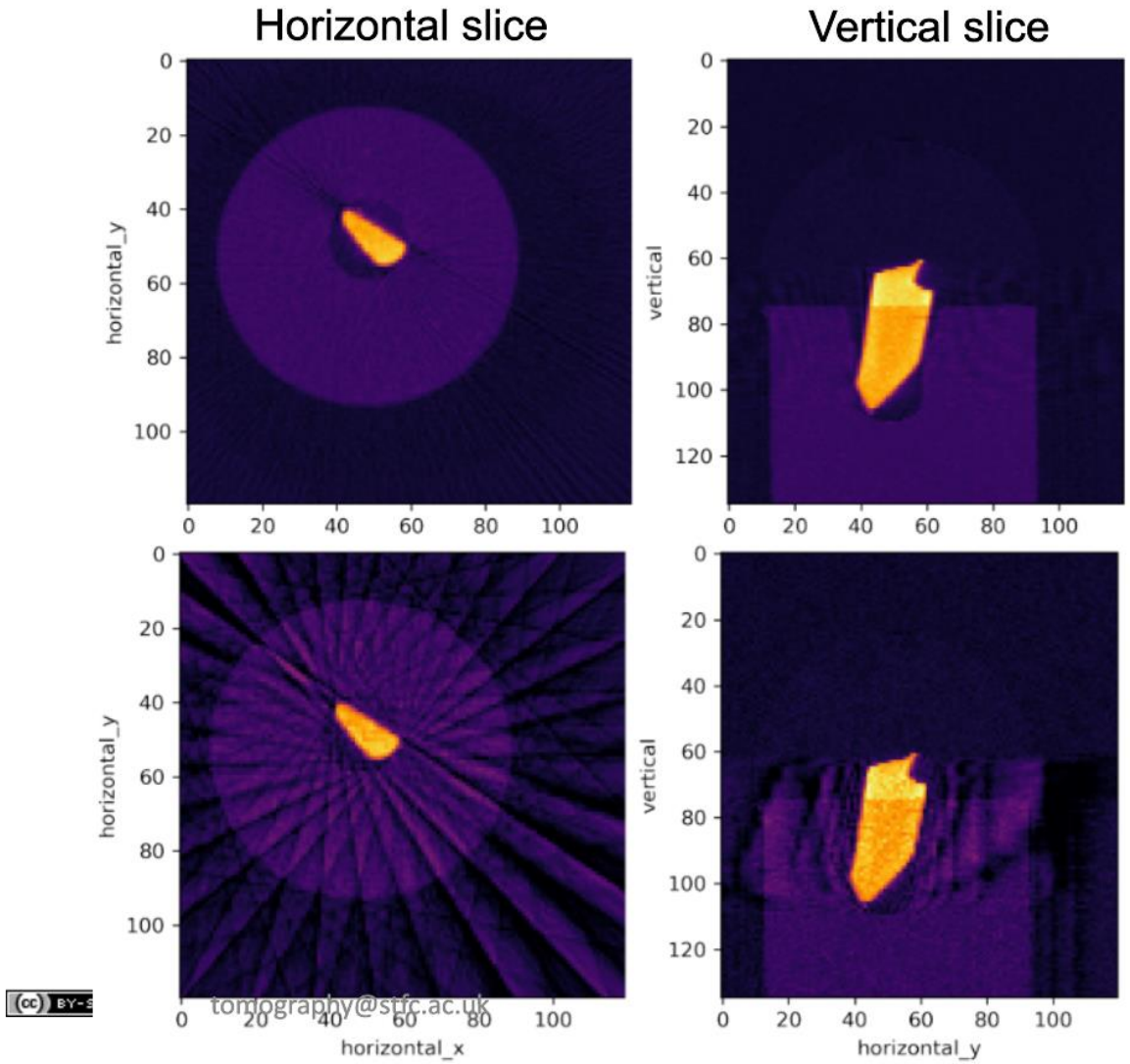
Objective function

name	description
BlockFunction	separable sum of multiple functions
ConstantFunction	
OperatorCompositionFun	
IndicatorBox	
KullbackLeibler	
L1Norm	
L2NormSquared	
LeastSquares	
MixedL21Norm	
SmoothMixedL21Norm	
WeightedL2NormSquare	
TotalVariation	

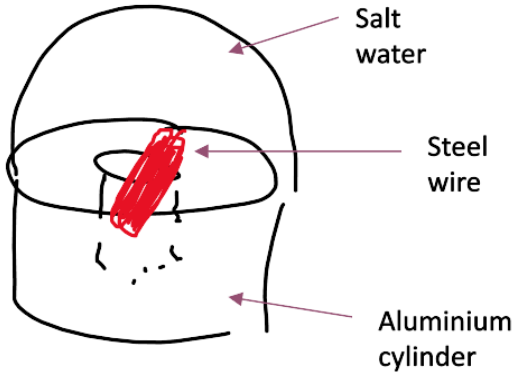
name	description
BlockOperator	form block (array) operator from multiple operators
BlurringOperator	apply point spread function to blur an image
ChannelwiseOperator	apply the same operator to all channels
DiagonalOperator	form a diagonal operator from image/acquisition data
FiniteDifferenceOperator	apply finite differences in selected dimension
GradientOperator	apply finite difference to multiple/all dimensions
IdentityOperator	apply identity operator, i.e. return input
MaskOperator	from binary input, keep selected entries, mask out rest
SymmetrisedGradientOperator	apply symmetrized gradient, used in TGV
ZeroOperator	operator of all zeroes
ProjectionOperator	tomography forward/back-projection from ASTRA
ProjectionOperator	tomography forward/back-projection from TIGRE

90 projections

15 projections



Jørgensen et al.: *Core Imaging Library - Part I: a versatile Python framework for tomographic imaging* Phil. Trans. R. Soc. A. **379** 20200192 (2021) DOI: 10.1098/rsta.2020.0192



Tikhonov regularisation

Data fidelity

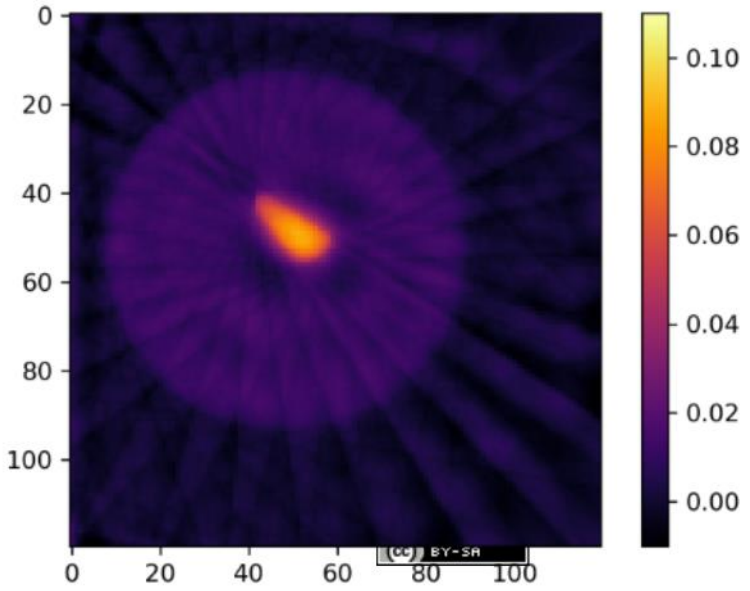
Regulariser

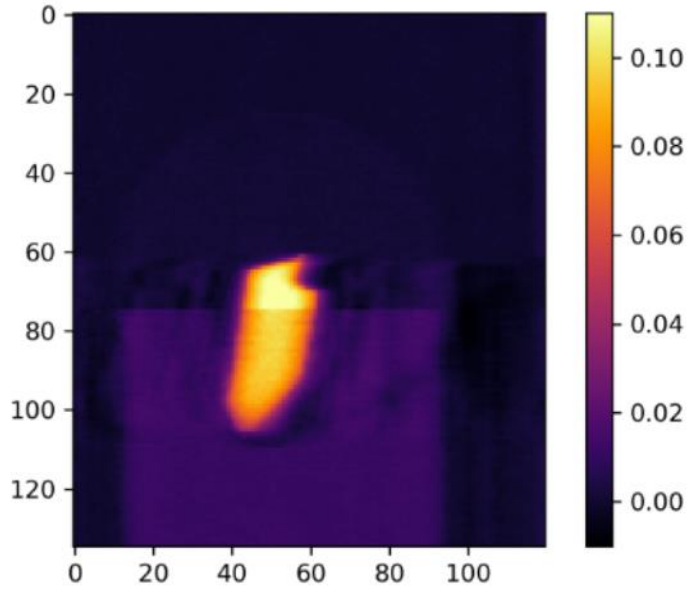
$$u^\star = \arg\min_u \left\{ \|Au - b\|_2^2 + \alpha^2 \|Lu\|_2^2 \right\}$$

Minimiser: Solution image

Unknown image TBD

Regularisation parameter





73

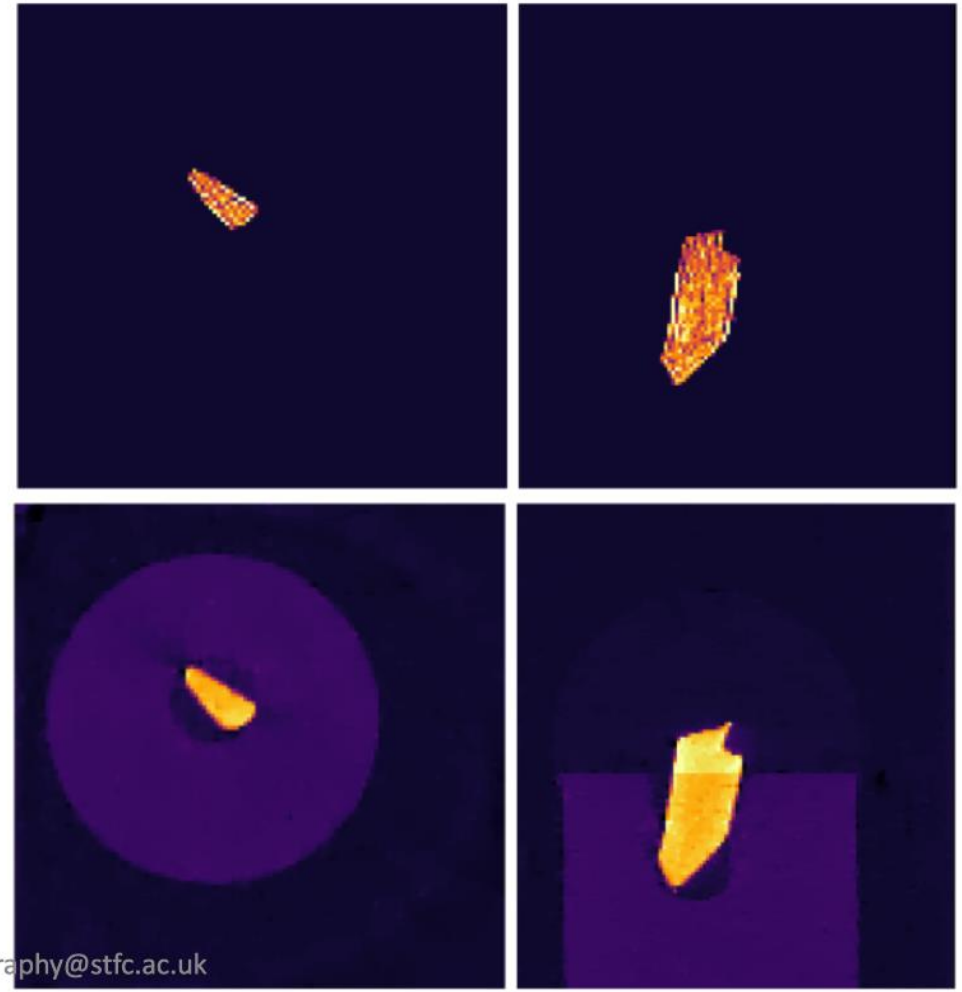
Sparsity and Total Variation Regularisation

L1-norm regularisation:

$$\|u\|_1 = \sum_j |u_j|$$

Total variation regularisation:

$$\sum_j \|D_j u\|_2$$

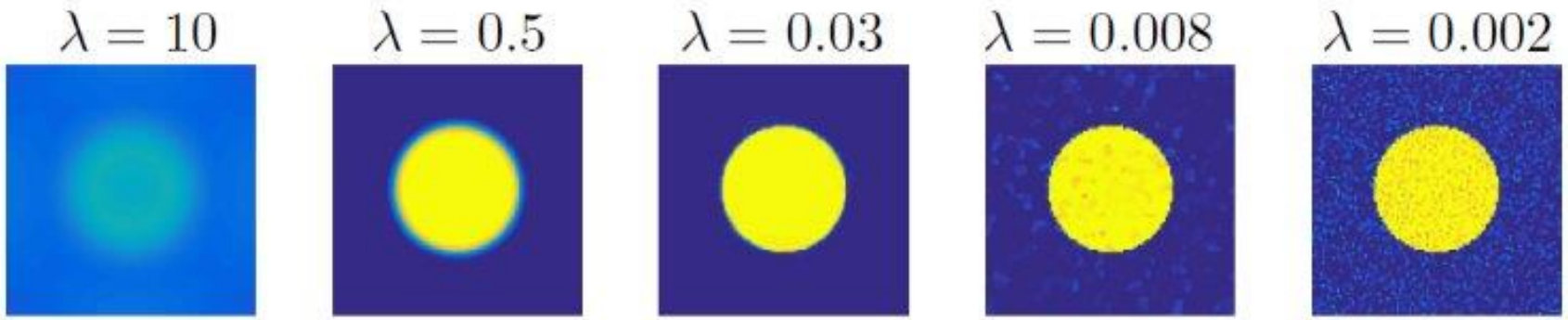


tomography@stfc.ac.uk

Effect of the Regularisation Parameter

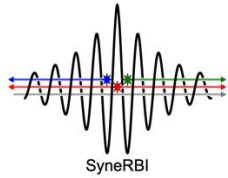
Total variation regularization:

$$\min_u \|Au - b\|_2^2 + \lambda \cdot \mathrm{TV}(u)$$



- Large λ: Almost only effect of regularizer. TV $\rightarrow$ Constant.
- Small λ: Almost just least-squares solution.
- Best trade-off?

Variational Regularisation



Data discrepancy term = how well does my solution match my data

Regularisation parameter = balance between the two terms

$$u^\star = \underset{u}{\operatorname{argmin}} \{\mathcal{D}(Au, b) + \alpha \cdot \mathcal{R}(u)\}$$

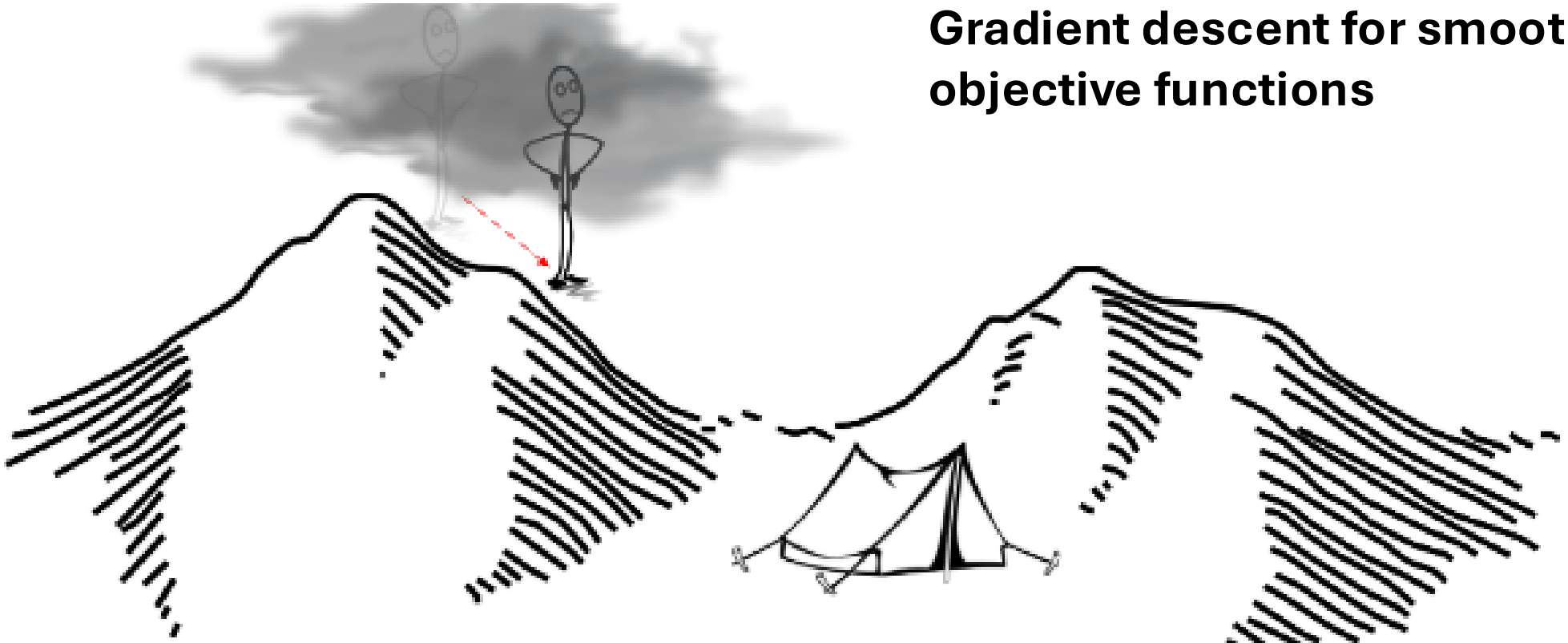
Forward model

Measured data

Guess of the object to reconstruct

Regularisation term = includes any prior knowledge of the solution

Different Objectives require different strategies



Gradient descent for smooth objective functions

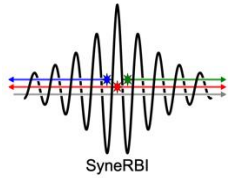
$$u_{k+1} = u_k - \beta \nabla \mathrm{L}(\mathrm{u_k})$$

Different Objectives require different strategies

Non-smooth objective functions need a different strategy

Gradient Descent (GD)	When your objective is convex and differentiable $\min f(x)$
Conjugate Gradient Least Squares (CGLS)	For minimising a least squares problem $\|Ax - b\|_2^2$
Simultaneous Iterative Reconstruction Technique (SIRT)	To solve problems of the form $Ax = b$ with optional constraints
Iterative Shrinkage-Thresholding Algorithm (ISTA)	To solve problems of the form $\min f(x) + g(x)$ where f is convex and differentiable and g is convex with a simple proximal operator
Fast Iterative Shrinkage-Thresholding Algorithm (FISTA)	Like ISTA but accelerated
Primal Dual Hybrid Gradient (PDHG)	To solve problems of the form $\min f(Ax) + g(x)$ where is f convex and has a "simple" proximal method of its conjugate and is g convex with a "simple" proximal.
Stochastic Primal Dual Hybrid Gradient (SPDHG)	Similar to PDHG but where can be written as a separable sum
Linearized Alternating Direction Method of Multipliers (LADMM)	To solve problems of the form $\min f(Ax) + g(x)$ where both and are convex and have "simple" proximals.
Stochastic algorithms…	Stochastic versions of gradient descent (everything is differentiable) and proximal gradient descent (one term can be non-differentiable with a simple proximal)

Your turn to have a play...



CIL notebook

CIL-Demos/binder/PyData22_deblurring.ipynb

gives a brief introduction in optimisation in inverse problems with CIL with an example of image deblurring.

Extension: Can you tweak the regularisation parameters to get better results than we have in the notebook?

Extension Extension: Look in https://github.com/TomographicImaging/CIL-User-Showcase especially numbers 13, 9, 7 and 4 for other examples of using the CIL optimisation toolkit

Summary

- CIL has a range of functions and operators that you can use to build up custom objective functions
- CIL has a range of algorithms suitable for different objective functions

- SIRF acquisition models and functions can be used in CIL *almost* seamlessly
- For more information and support on CIL please join the discord, add issues and contribute on github and email tomography@stfc.ac.uk

- CIL user meeting 27th –30th January 2026 at Rutherford Appleton Laboratory – free registration https://ccpi.ac.uk/events/cil-um-26/

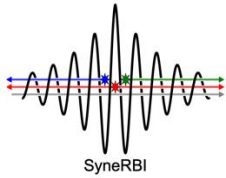
CIL Discord

CIL GitHub

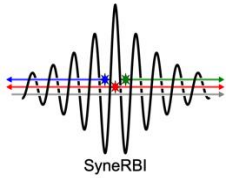
15:00 – 15:30 GMT

What is PETRIC2 and how to participate? (Kris)

Conclusions



Example with real data

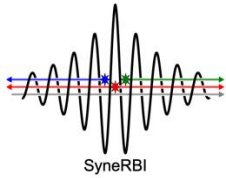


SIRF notebook

SIRF-Exercises/notebooks/PET/reconstruct_measured_data.ipynb

implements OSEM on Siemens mMR data, incorporating various aspects of the acquisition model (normalisation, attenuation, randoms, scatter).

More material: SIRF-Exercises



- Deep_Learning_PET
- Deep_Learning_listmode_PET
- Geometry
- Introductory
- MR
- PET
- Reg
- SPECT
- Synergistic
- synergistic_deconvolution

CIL User Meeting ‘26

- 🎤 Inspiring talks from the CIL community
- 🛠️ Hands-on training for both new and advanced users
- 💻 Interactive hackathon to collaborate on exciting topics
- 🤝 Poster session and networking opportunities
- 🔬 Tours of some world-leading facilities at the Rutherford Appleton Laboratory
- 💬 A chance to give your feedback and influence the future of CIL

https://ccpi.ac.uk/events/cil-um-26/

January 27, 2026

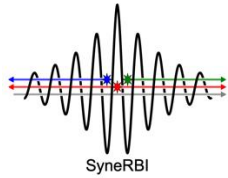
9:00 am

January 30, 2026

5:00 pm

Rutherford Appleton Laboratory, Oxfordshire
UK

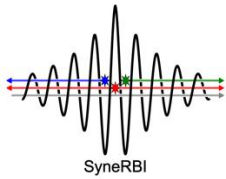
STIR Hackathon 2026



This year is the 25th anniversary of STIR and we are happy to announce a STIR hackathon in London, UK. This hackathon is intended for existing users of STIR who are interested in expanding their knowledge and even becoming STIR developers. We anticipate to cover the following themes:

- Reconstructing measured PET and SPECT data with STIR
- Using PET Monte Carlo software (GATE, SimSET, Simind) with STIR
- Improving GPU performance
- Thu 5 March - Fri 6 March 2026
- https://stir.sourceforge.net/2026Hackathon/

Symposium on AI and Reconstruction for Biomedical Imaging



This symposium featuring invited internationally-leading researchers covering recent advances in AI and image reconstruction for biomedical imaging,

is intended to enhance UK and international networking, research progress and education in this important area.

https://www.ccpsynerbi.ac.uk/airbi/

March 9, 2026

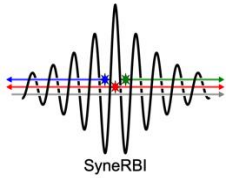
9:00 am

March 10, 2026

6:00 pm

London Institute of Healthcare Engineering (LIHE)

Hackathon on Software for Machine Learning Approaches for Reconstruction in Biomedical Imaging



hackathon on software for machine learning (ML) approaches in biomedical imaging with specific emphasis on SIRF. We will work on:

- integration of ML into SIRF
- implement promising approaches in SIRF
- connection to ML toolboxes like DeepInverse

https://www.ccpsynerbi.ac.uk/events/airbi-hackathon/

March 11, 2026

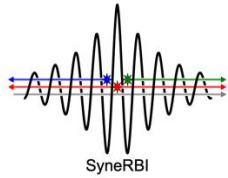
9:00 am

March 12, 2026

6:00 pm

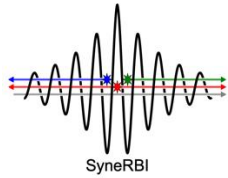
London Institute of Healthcare Engineering (LIHE)

More information



- PETRIC2
  https://github.com/SyneRBI/PETRIC2/
- CCP SyneRBI
  https://www.ccpsynerbi.ac.uk/
- Synergistic Image Reconstruction Framework
  https://github.com/SyneRBI/SIRF/wiki
  includes install instructions
- Core Imaging Library
  https://github.com/TomographicImaging/CIL
- Software for Tomographic Image Reconstruction
  https://github.com/UCL/STIR/

Finally



- Servers will be deleted by Wednesday 17th
- Take all your notebooks

How do I use this at home?

- VirtualBox : https://zenodo.org/records/15631621
- `docker pull ghcr.io/synerbi/sirf:edge-gpu`
- GitHub CodeSpaces

Feedback

https://forms.office.com/e/bcZT0s6ygS