Stochastic Optimisation Can Increase Algorithm Efficiency

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CIL
CORE IMAGING LIBRARY

The Core imaging library (CIL) is designed for both imaging scientists and the inverse problems and optimisation mathematical community. Combining **mathematical building blocks** and the **modular design** of CIL enable users to **rapidly implement and experiment** with new reconstruction algorithms and compare them against existing **state-of-the-art methods.**

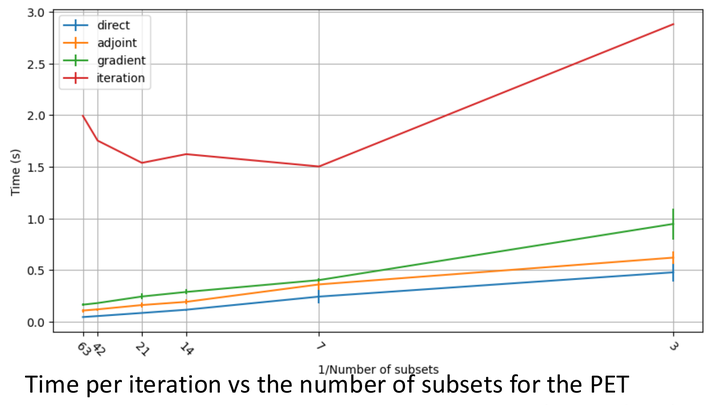
Stochastic Optimisation

Model Based Image Reconstruction can tackle problems where data is sparse, noisy, reduced at the cost of increased computational burden.
Stochastic optimization algorithms[1] process only part of the data at each iteration, thereby **reducing the computational complexity** of the problem and leading to faster convergence.
However, in tomography given the data size, fractionating the data to be processed may lead to longer overhead time due to memory transfers.

Speedup of the MCIR reconstruction in terms of wall clock time

	6MS	30MS	60MS
PDHG time	1 h 10 min	5 h 29 min	10 h 50 min
Stochastic PDHG time	42 min	1 h 22 min	2 h 27 min
Stochastic PDHG speedup to convergence	1.65	3.98	4.43
SPDHG/PDHG time per epoch	115%	125%	135%

[1] A guide to stochastic optimisation for large-scale inverse problems Ehrhardt M et al *Inverse Problems* **41** 053001 (2025)



Time per iteration vs the number of subsets for the PET reconstruction. Despite certain operations can be sped up by increased number of subsets, the whole algorithm's performance suffers from loss of performance.

This poster demonstrates the potential of stochastic optimization on three different applications: MRI Motion Compensated Image Reconstruction, Rapid PET image reconstruction and battery X-ray CT.

Further work needs to be done to assess the carbon footprint of these methods

Stochastic CIL – Accelerating reconstruction with stochastic optimisation in CIL

Plugging stochastic gradients into deterministic algorithms leads to stochastic algorithms e.g.

Optimization of the form

$$F(x) = \min_x \sum_{i=1}^{n} f_i(x)$$

Can be solved by gradient descent

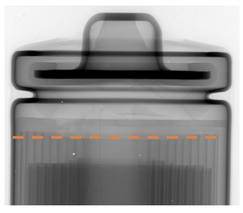
$$x_{k+1} = x_k - \gamma \nabla F(x_k)$$

Replacing the gradient ∇F by the gradient of just one sampled function f_i gives stochastic gradient descent

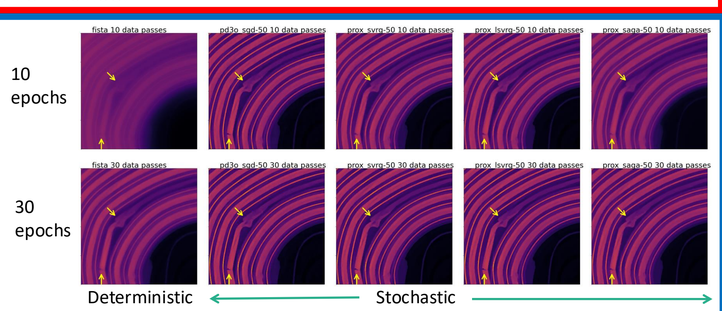
$$\tilde{\nabla} F(x_k) := \nabla f_{i_k}(x_k)$$

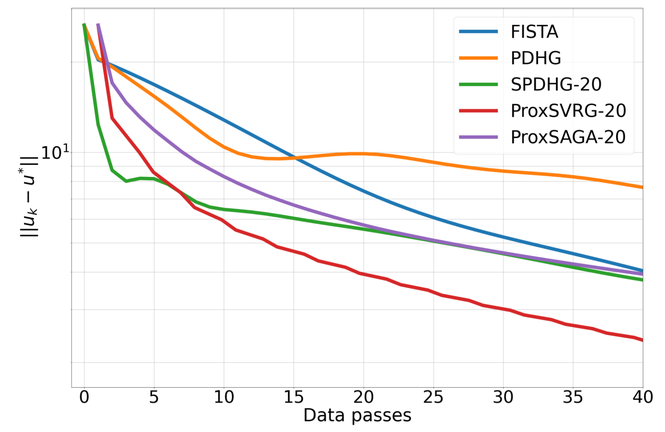
Similarly other approximations can give variance reduced algorithms e.g. SAG, SAGA, SVRG and LSVRG.

https://arxiv.org/abs/2603.21230



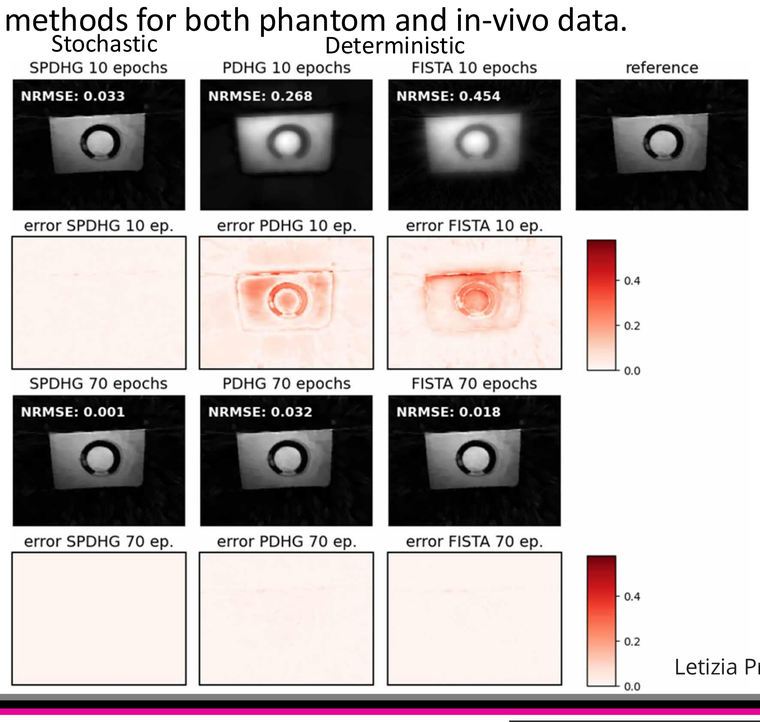
Radiograph of a AAA battery, a cross section of which is shown in the reconstructions above.

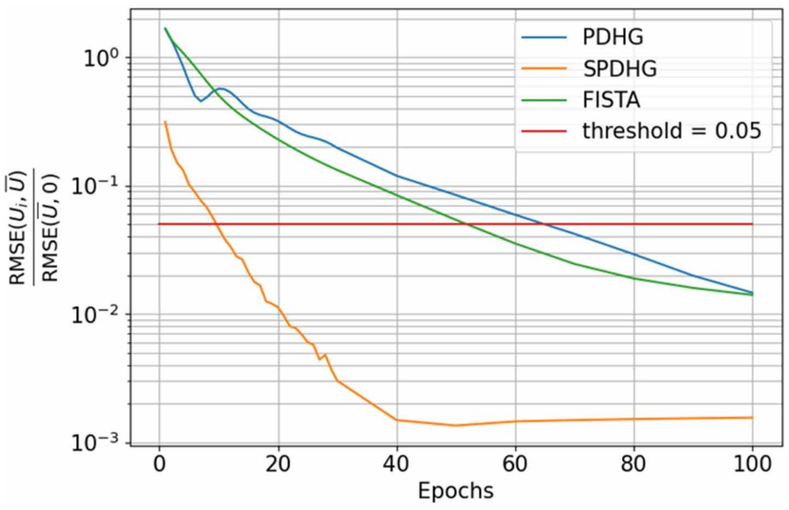




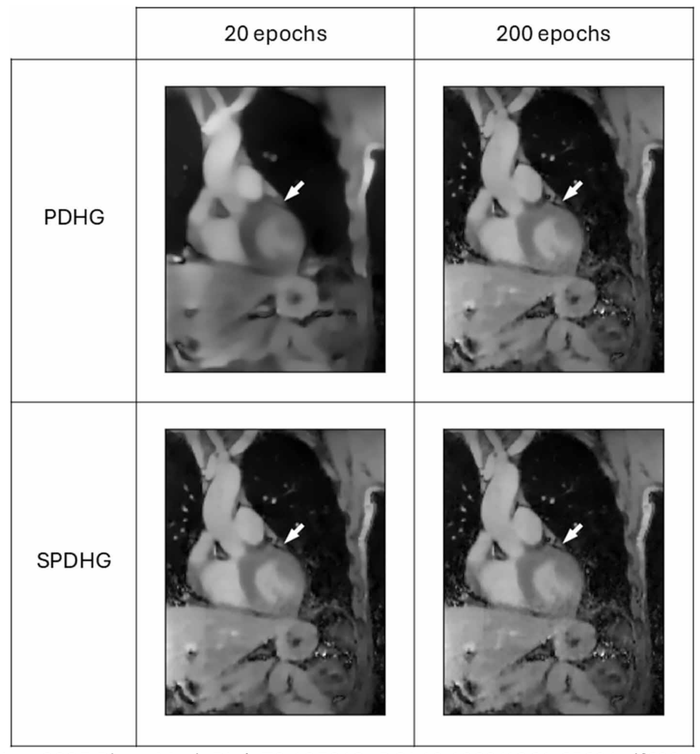
Motion Compensated Image Reconstruction for Magnetic Resonance Imaging

These plots show how the stochastic SPDHG algorithm converges to a reference solution in fewer epochs than deterministic methods for both phantom and in-vivo data.





For the phantom data, we plot normalized root mean squared error against epochs to quantitatively measure convergence.



Letizia Protopapa et al *Efficient motion-corrected image reconstruction for 3D cardiac MRI through stochastic optimisation* 2025 Phys. Med. Biol. 70 185012. *DOI 10.1088/1361-6560/adf609*

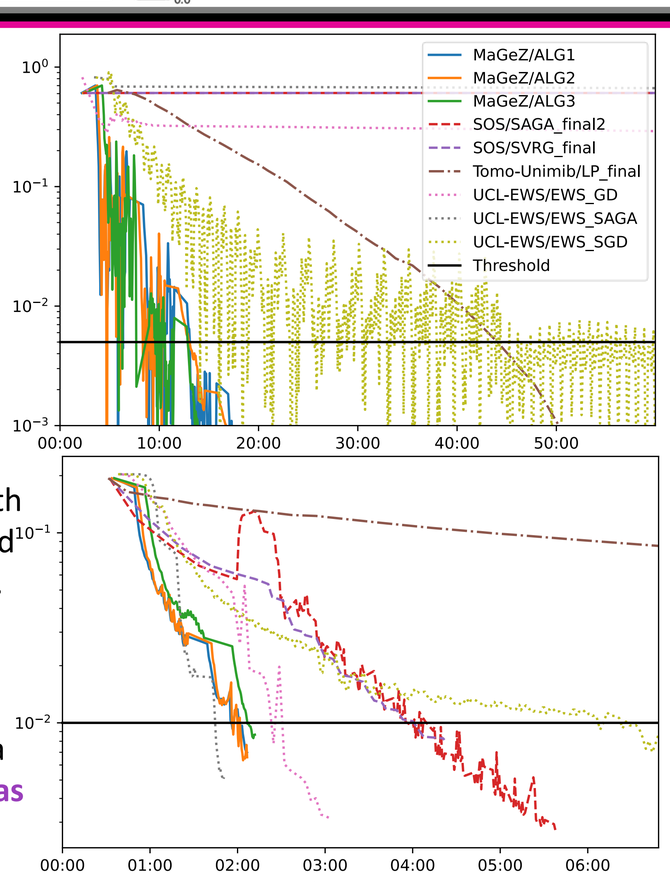
PETRIC Challenge

The **PET Rapid Image Reconstruction Challenge (PETRIC)** aimed to accelerate development of PET image reconstruction algorithms for real-world applications.

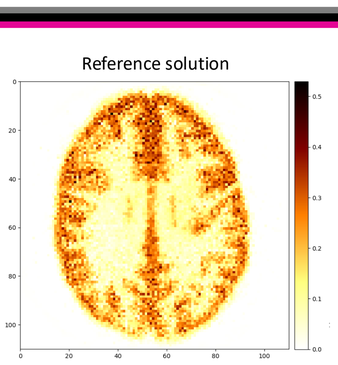
Participants were provided with a set of phantom data acquired on a range of clinical scanners.

Objective: Achieve a reconstructed image close to a reference converged solution **as quickly as possible**, measured by computation time.

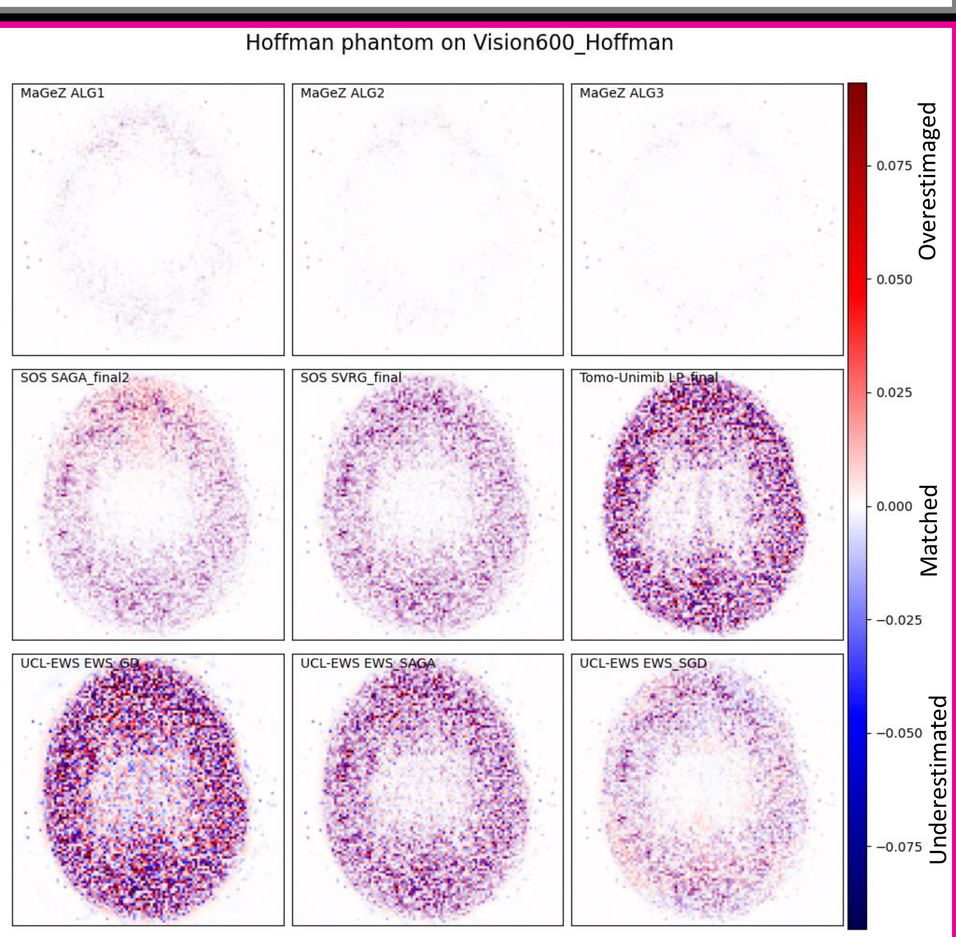
Da Costa-Luis et al 2026
10.3389/fnume.2026.1770002



Metric of convergence of the algorithms on 2 different phantoms vs clock time shows a variety of performance of the algorithms



Difference between each algorithm's solution and the reference image was measured when the winning algorithm reached the threshold distance



Four teams submitted a total of nine algorithms, all using Stochastic Optimisation with a range of preconditioning and step size rules.
https://www.ccpsynerbi.ac.uk/petric/

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