The CCPi Core Imaging Library
Versatile software for Tomographic Imaging

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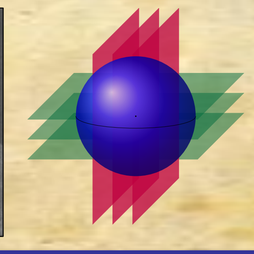
A Brief History of Tomography

W.C.Röntgen

1895

Nobel Prize in Physics, 1901. First X-ray image of his wife hand

J. Radon



1917

"Radon Transform" Mathematical formula to determine an object from its line integrals.

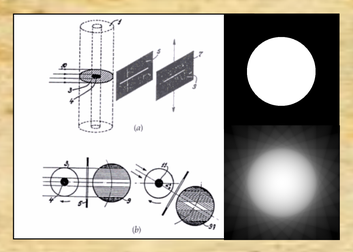
E. W. Twining

" … Planigraphy, Stratigraphy and Tomography are the names given to those methods of radiography … … Tomography is the best name for the method … "

1937

Adopts the Greek word "Tomography" Τέμνω (to cut) + Γράφω (to draw).

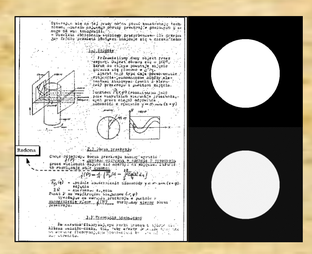
G. Frank



1940

"BackProjection" Patents the first reconstruction method.

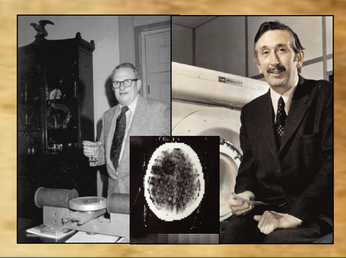
J. Wloka



1953

"Filtered BackProjection Algorithm" First use of Radon's inversion formula.

A. M. Cormack
G. N. Hounsfield



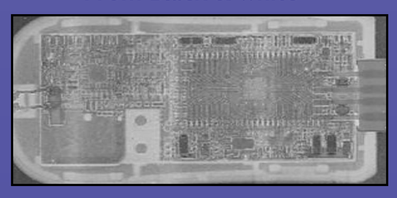
1979

Nobel Prize in Medicine for the development of computed tomography.

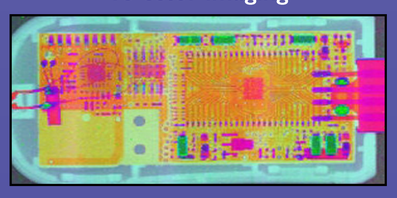
Overview & Goal

- The Collaborative Computational Project in Tomographic Imaging (CCPi) aims to provide the UK tomography community with a software toolbox of algorithms that increases the quality and level of information extracted by computed tomography.
- Moving beyond traditional black and white tomography, we unlock the full power of spectral imaging and exploit Multi-Channel Tomography modalities towards chemical imaging, structure and material decomposition.

From Black & white



To color imaging



USB X-ray spectral imaging where each colour represents a different material.

Principles of Tomography

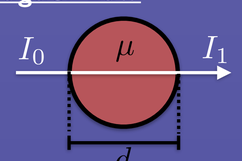
P. Bouguer (1729)

" … Loss of light intensity passes through a medium is directly proportional to the intensity and path length …"

Beer-Lambert-Bouguer Law

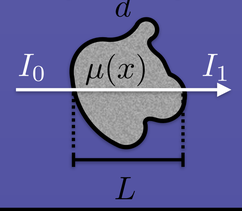
- Homogeneous

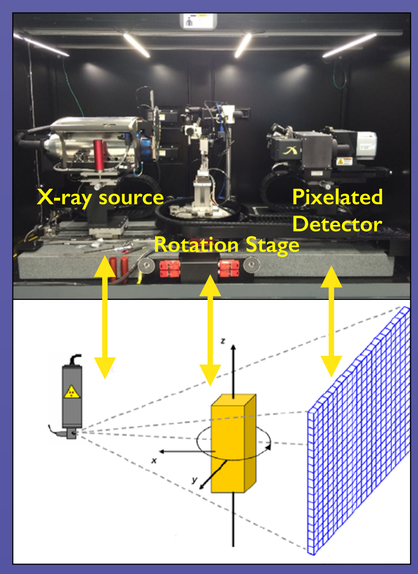
$$\frac{I_1}{I_0} = e^{-\mu d}$$



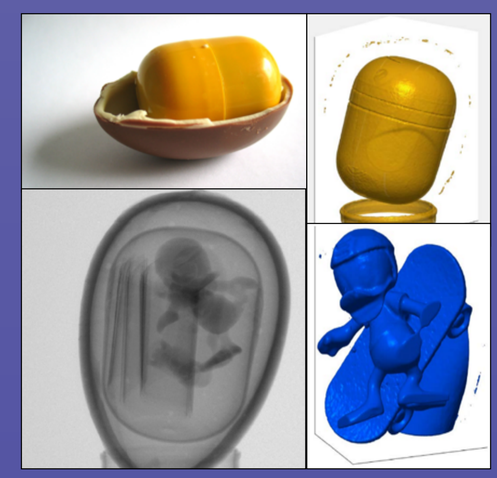
- Non - Homogenous

$$\frac{I_1}{I_0} = e^{-\int_L \mu(x)dx}$$





So …. what is inside a Kinder Egg?
We can break it or X-ray it



Core Imaging Library

- Open-source object-oriented software written in the Python programming language.
- Design for Tomography image processing including:
  - Data loading, Pre - processing
  - Reconstruction, Segmentation
  - Post - processing, Visualisation
- Plethora of customised algorithms to be constructed by the user for different imaging modalities. Direct translation from mathematical expressions to Python code.

Mathematical Optimisation

Minimisation Problem
Tomography Reconstruction

$$\min_x \mathcal{F}(Kx) + \mathcal{G}(x)$$

FBP

$$u \approx A^*(v * g)$$

CGLS

$$\min_u \frac{1}{2}\|Au - g\|^2$$

Total Variation

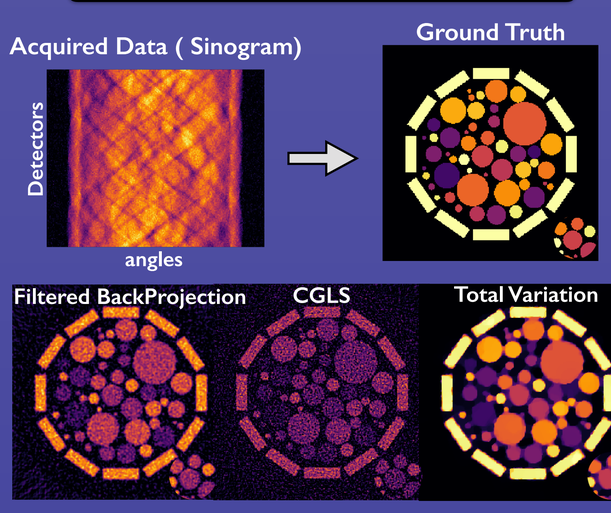
$$\min_u \frac{1}{2}\|Au - g\|^2 + \alpha\|\nabla u\|_{2,1}$$

```
# Setup and run Filtered BackProjection
fbp = FBP( ig,  ag,  filter_type = 'hann')
fbp.set_input(g)
fbp_recon = fbp.get_output()

# Setup and run Conjugate Gradient Least Squares
cgls = CGLS (x_init = x_init, operator = A,
             data = g, max_iteration = 50)
cgls.run()

# Total variation regularisation Primal-Dual Hybrid
algorithm (PDHG)
F = BlockFunction(alpha * MixedL21Norm(),
                  0.5 * L2NormSquared(g))
G = IndicatorBox(lower=0)
K = BlockOperator(Gradient, A)
pdhg = PDHG( f = F,  g = G, operator = K,
             max_iteration = 100)
pdhg.run()
```

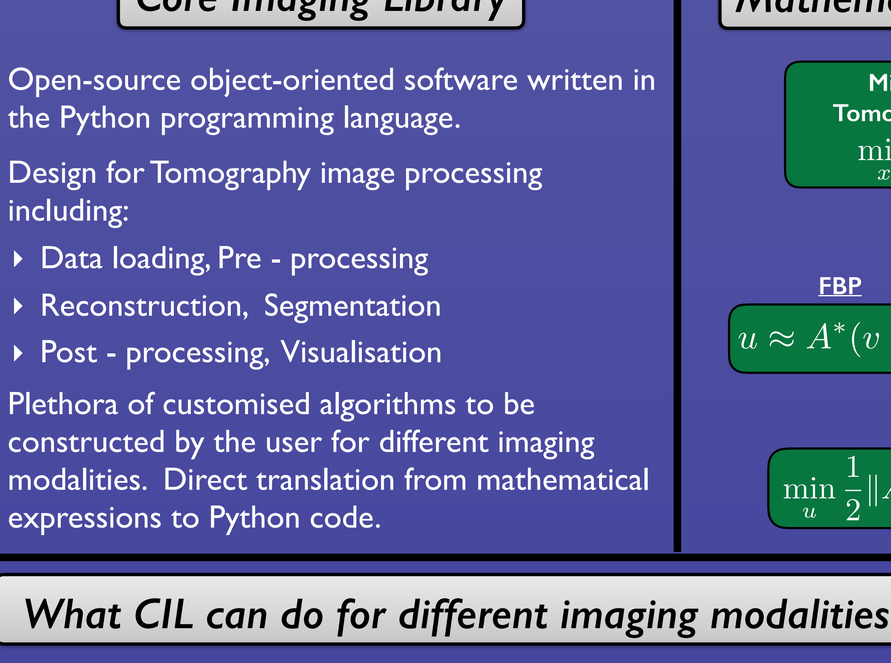
Tomography Reconstruction



What CIL can do for different imaging modalities?

(a) Neutron Tomography at ISIS Neutron and Muon Source, Science and Technology Facilities Council

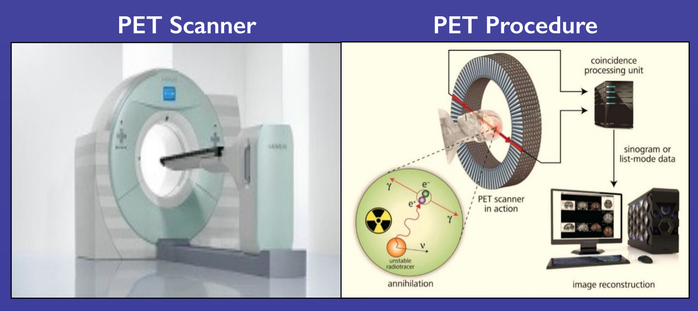
Identify different materials using neutron imaging

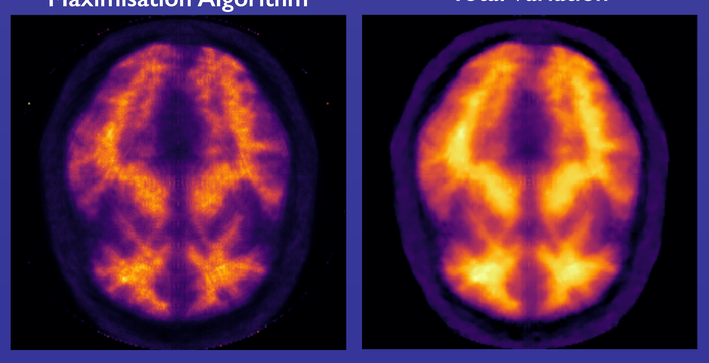


Parallel 4D energy channel reconstruction can depict chemical differences for different materials.

(b) Positron Emission Tomography Collaboration of CCP-PET/MR & CIL

Identify radio-tracer distribution inside the brain

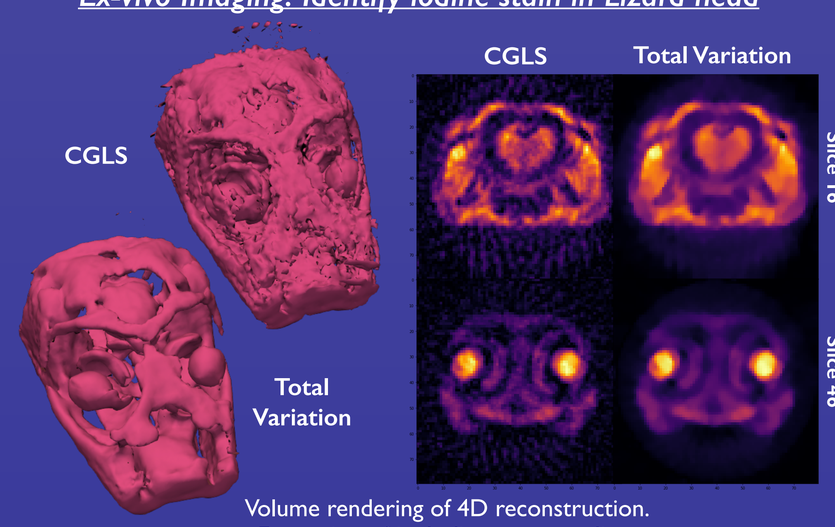




Different reconstruction algorithms can highlight specific radio-tracer distribution.

(c) X-ray Multi-spectral Tomography at Henry Moseley X-ray Imaging Facility, University of Manchester

Ex-vivo Imaging: Identify iodine stain in Lizard head



Volume rendering of 4D reconstruction. Extraction of its Iodine map per slice.

Conclusion

The Core Imaging Library of CCPi is a universal software for different imaging tasks and different tomographic modalities. Designed not only for academic purposes but also for industrial companies across UK that focus on tomographic applications in materials, biology and medical imaging.

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