Building Core Strength for a Better Image

CoSeC
Computational Science Centre for Research Communities

At the time of gaining third place for the CoSeC Impact Award, Dr. Evangelos Papoutsellis (a.k.a. Vaggelis) was a postdoctoral researcher in the Henry Moseley X-ray Imaging facility of the University of Manchester, where his role within the Collaborative Computational Project in Tomographic Imaging (CCPi) was to develop the Core Imaging Library (CIL). Expanding on the pre-existing software, Vaggelis extended CIL's functionality across a range of imaging problems, providing an open source software toolbox. This is a vital resource in the processing of images produced by scanners such as positron emission tomography – PET, magnetic resonance imaging –MRI, and many others.

Background

In addition to medicine, many other disciplines use tomographic imaging e.g., materials science, archaeology, geophysics etc., with the common aim of understanding the structure and composition of the imaged material.

Tomography literally means 'to write or describe slices or sections' and involves radioactive waves (e.g. X-Rays) penetrating a material (e.g. a human body) to produce a three-dimensional, reconstructed image. On passing through a rotating material the transmitted waves are detected and converted into a two-dimensional 'map'. Using a mathematical algorithm on these 2-D maps leads to the reconstruction of a 3-D tomographic image of the scanned object.

The tomographic image is an imperfect representation of the original material because it often contains different types of defects: noise i.e., random variations of brightness of colour; blur i.e., loss of sharpness; missing regions i.e., unphysical empty spaces.

The aim of the developers of the Core Imaging Library is to develop tools that enable highly efficient imaging processing and to reconstruct high quality images.

Particular emphasis is on putting together a variety of optimisation (or 'test') problems for reconstruction with plug & play components. The intention is to enable users to employ existing methods or create their own prototype model with flexible and user friendly tools. To achieve this, the developers must first overcome several challenges.

Challenges

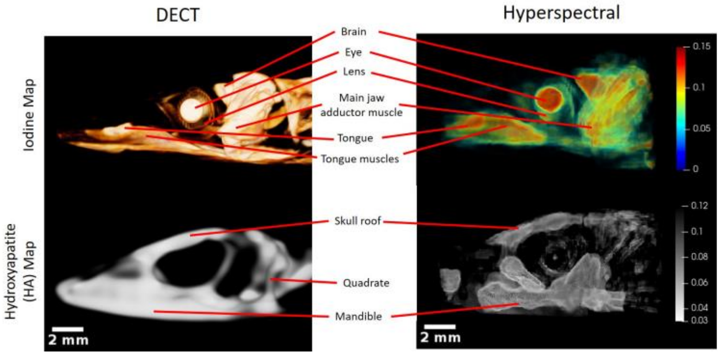
The first major challenge is that the CIL should provide simple tools to allow the user to express different mathematical problems for reconstruction. Using a variety of *Functions, Operators* and *Algorithms*, several tomography tasks can be configured with a few lines of code. Moreover, the CIL should be generic and applicable to different tomographic setups such as: X-ray Computed Tomography (CT); Dynamic X-ray CT; Hyperspectral CT; PET and MRI, and produce advanced reconstruction methods compared to the conventional analytic methods.

The second challenge lay in the quantity of data produced from scanning – it is often extremely large. This makes it difficult to process, leads to inefficiencies in reconstruction, and reduces the quality of the final image.

Therefore, it is essential that CIL is multi-functional, flexible, dynamic, and able to grow in potential and proficiency.

Vaggelis' role in addressing the challenges

Dr. Papoutsellis expanded previous CIL tools with a plethora of functions and operators along with their corresponding algebra. This upgrade enabled CIL to handle different imaging tasks, such as de-noising, de-blurring, in-painting (i.e. filling in blank spaces) and tomography reconstruction. In addition, Vaggelis and the development team enabled certain features from the CIL to be incorporated in the S*ynergistic Image Reconstruction Framework* (SIRF) from the *Collaborative Computational Project in Synergistic Reconstruction for Biomedical Imaging (CCP SyneRBI),* suitable for PET and MRI reconstruction. Vaggelis also equipped the library with tools necessary to process extremely large amounts of data received from a scanner; they speed up reconstruction of the final image by slicing the data into very small chunks. He also developed pre-processing tools capable of preventing unwanted artefacts appearing in the final image.



Lizard head segmentation comparison for dual-energy CT (DECT) - non CIL - and hyperspectral imaging using advanced CIL reconstruction methods. Images courtesy of Stephan Handschuh

Vaggelis is leading on-going development of CIL, and tomographic imaging communities are literally seeing the impact of his work in the processing, production and quality of reconstructed tomographic images. This enables them in their own disciplines, from diagnosing patients' diseases to identifying the microstructures within fossilized relics.

CoSeC's Impact

"Through CoSeC I've worked alongside Drs. Edoardo Pasca and Gemma Fardell, (STFC Research Software Engineers) gaining massively from their expertise. I've improved my own skills in writing code - it's now better structured and higher quality and has helped me overcome the main image processing challenges. I've also been able to work with end-users, who have helped me 'de-math' my code and make it much more user-friendly. And last but not least, being a part of the CoSeC community network has helped me gain direct employment with STFC, and I'm very happy about that!"

Dr. Evangelos Papoutsellis

CoSeC's network of supported communities enables invaluable opportunities to work across CCPs. For example, Vaggelis worked with CCP-SyneRBI, which lead to developing CIL with tools that are useful to both CCPi and CCP SyneRBI. These two communities held a joint, 2-day Synergistic Symposium where training was split between PET-MR and CIL software ,and received some great feedback from participants from both communities.

https://www.scd.stfc.ac.uk/Pages/CoSeC-Case-Studies.aspx

@CoSeC_community

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Further information: In November 2020 five articles were submitted for publication demonstrating the Core Imaging Library (CIL) in specific tomography applications. Two describe CIL and its main building blocks used to read, load, pre-process, reconstruct, visualise and analyse tomographic data for conventional X-ray CT; different geometric setups – parallel, cone-beam and laminography; how to use CIL to process data; and setup optimisation problems for Dynamic, Hyperspectral CT as well as Positron Emission Tomography. The other three present novel reconstruction methods for specific applications such as lab-based Hyperspectral CT, Neutron tomography and motion correction/estimation for PET. See: https://www.ccpi.ac.uk/ and https://github.com/vais-ral/CIL-Demos. Contact: *https://epapoutsellis.github.io/*

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CCPi Tomographic Imaging

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