The Multi-Modal Australian ScienceS Imaging and Visualisation Environment (MASSIVE) for Near Realtime CT Reconstruction using XLI

Wojtek J Goscinski[1], Timur E. Gureyev[2]
[1]Monash University, Australia, wojtek.goscinski@monash.edu
[2]CSIRO, Australia, tim.gureyev@csiro.au

INTRODUCTION

The Multi-modal Australian ScienceS Imaging and Visualisation Environment (MASSIVE)[1] is a specialised Australian high performance computing facility for computational imaging and visualisation. This facility has been formed to provide researchers with the hardware, software and expertise to drive research in the characterization, biomedical science, materials research, engineering, and geoscience communities, and stimulate advanced imaging research that will be exploited across a range of imaging modalities, including synchrotron imaging, neuroimaging, electron microscopy and optical microscopy. The MASSIVE facility provides the hardware, software and expertise help for scientists to apply advanced imaging and visualisation techniques across a wide range of scientific fields and provides scientists with an unprecedented view of captured data and simulated models by providing the capability to view full resolution datasets.

This presentation will introduce the MASSIVE project, and present early research that it has supported. In particular, it will present a MASSIVE usecase: near-realtime Computed Tomography (CT) reconstruction service for the Imaging and Medical Beamline (IMBL) at the Australian Synchrotron, using XLI / X-TRACT software[2] [3]. We will present XLI CT reconstruction performance results across the MASSIVE platform.

THE MULTI-MODAL AUSTRAIAN SCIENCES IMAGING AND VISUALISATION ENVIRONMENT

MASSIVE is a unique Australian facility with a focus on fast data processing "in-experiment", and large-scale visualisation. It offers Australian scientists access to two separate facilities with computer systems linked by a high-bandwidth communications link:

- MASSIVE1, located at the Australian Synchrotron at 800 Blackburn Road in Clayton; and
- MASSIVE2, located at the Monash University campus in Clayton.

These two interconnected computers operate at 5 teraflops each, using traditional CPU processing, and accelerated to 50 teraflops, using GPU co-processors. MASSIVE1 and the first stage of MASSIVE2 became openly available to Australian researchers in May 2011.

MASSIVE is unique because it is designed to support near real-time HPC access connected to a beamline experiment, for example reconstructing a 3D image as the image detector is relaying information to the reconstruction application. It also supports users who want to render and visualise large images, such as those that would exceed the capabilities of a single computer or graphics card.

NEAR REAL-TIME CT RECONSTRUCTION USING XLI

The Imaging and Medical beamline (IMBL) at the Synchrotron will provide a wide range of advanced X-ray imaging techniques for the biomedical and materials science research communities.

[1] MASSIVE is funded by its partners, the Australian Synchrotron, CSIRO, Monash University, and VPAC, and the Victorian Government, and the National Computational Infrastructure (NCI)
[2] http://www.ts-imaging.net/Services/.
[3] This service has been developed as a result of a project funded by National e-Research Architecture Taskforce (NeAT), CSIRO, VeRSI, ANU and VPAC.

About 50% of the available time on the beamline is scheduled to be devoted to 3D CT imaging. CT is computationally demanding, particularly when reconstructing high resolutions images, such as those that will be generated by next-generation sensors at the IMBL. High-resolution 3D CT reconstruction, analysis and visualization typically also require too much memory and compute power to be performed on a desktop PC. Furthermore, it is important that scientists creating CT volumes at the IMBL can reconstruct and visualize their data during their allocated beamtime. This will provide an opportunity to check results, ensure that the experiment was captured correctly, and adjust or repeat the experiment for a better outcome.

A software system, XLI, has been developed for high-performance CT reconstruction, simulation and other X-ray image processing tasks and has been deployed on the MASSIVE cluster. The system supports X-ray CT in plane-wave and cone-beam forms, and includes multiple functions for X-ray phase retrieval and simulation of phase-contrast imaging (propagation-based, analyser crystal based and Talbot interferometry). Other facilities include several methods for image deconvolution, simulation of various phase-contrast microscopy modes (Zernike, Schlieren, Nomarski, dark-field, interferometry, etc.) and a large number of conventional image processing operations (such as FFT, algebraic and geometrical transformations, pixel value manipulations, simulated image noise, various filters, etc.). All operations can be applied to batches of images in a variety of standard image formats. Some scripting capabilities are also included. The architectural design of the system includes a two-level parallelization of the most computationally-intensive modules utilising both the multiple CPU cores and multiple GPUs available in a local PC or a remote computer cluster.

This remote CT service allows researchers to simulate and test the planned experiments "in silicon" in preparation for the real CT experiments. Additional modules in this software facilitate the process by allowing the user to modify, visualize and analyze the data at any stage of the CT simulation and reconstruction process. Quick pre-processing, reconstruction and visualization of experimental CT data allows researchers to make the necessary adjustments during the experimental shift and modify the experimental conditions accordingly. This will significantly increase the productivity of synchrotron-based CT compared with the conventional mode of operation, where the CT reconstruction is typically performed "off-line" after the experiments, when the researchers have returned back to their home base. In the post-experiment stage, the access to efficient CT reconstruction and visualization codes running on MASSIVE will allow for optimal post-processing and analysis of the experimental CT data.

XLI has been deployed on the MASSIVE system and early results allow scientists to perform CT reconstruction on $4K^3$ data within 10 minutes. Comprehensive results and a discussion of the effect of these systems on synchrotron imaging will be presented. Furthermore, the imaging and visualisation capabilities of the MASSIVE cluster will be illustrated.