Cloud-Based Image Analysis and Processing Toolbox

http://cloudimaging.blogspot.com.au

Tomasz Bednarz, Yulia Arzhaeva, Piotr Szul, Alex Khassapov, Neil Burdett, Dadong Wang, Shiping Chen, Darren Thompson, Timur Gureyev, John Taylor

CMIS / ICT/ CMSE / IM&T / CSS TCP
www.csiro.au

Introduction

The Cloud Based Image Analysis and Processing Toolbox project, which is executed by CSIRO runs on the National eResearch Collaboration Tools and Resources (NeCTAR) [1,2] cloud infrastructure. It is designed to give access to biomedical image processing and analysis services to Australian researchers via remotely accessible user interfaces. The toolbox is based on software packages and libraries developed over the last 10-15 years by CSIRO scientists and software engineers:

HCA-Vision [3]: developed for automating the process of quantifying cell features in microscopy images - it can reproducibly analyse complex cell morphologies:

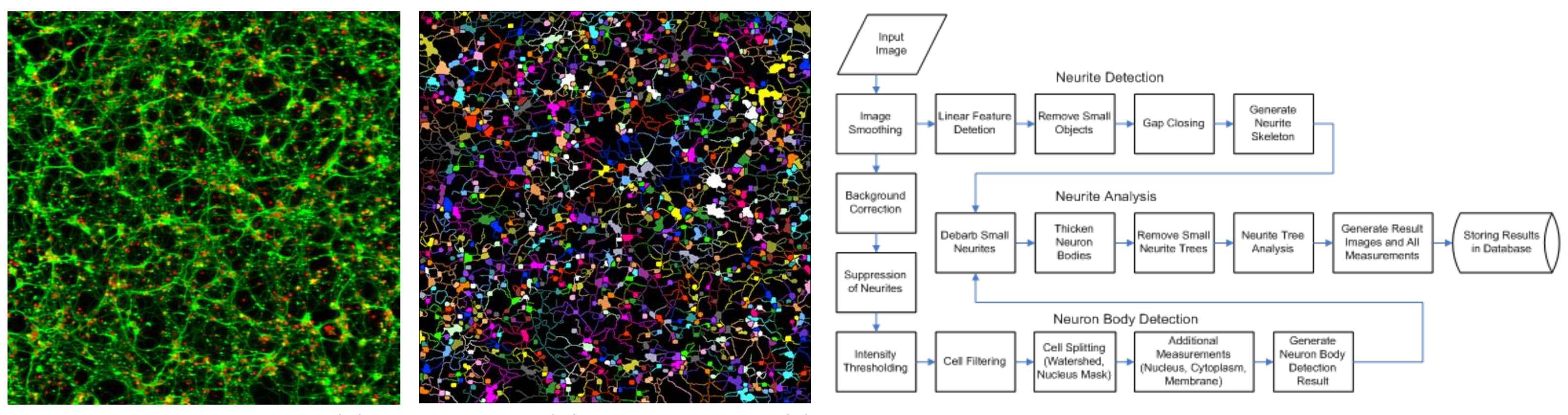

Figure 1: Neurite Analysis (a) input impage; (b) resulted image; (c) diagram of the algorithm.

MILXView [4]: a 3D medical imaging analysis and visualisation platform allowing researchers and medical specialists to analyse and visualise a variety of multi-modality images including MRI, PET and CT:

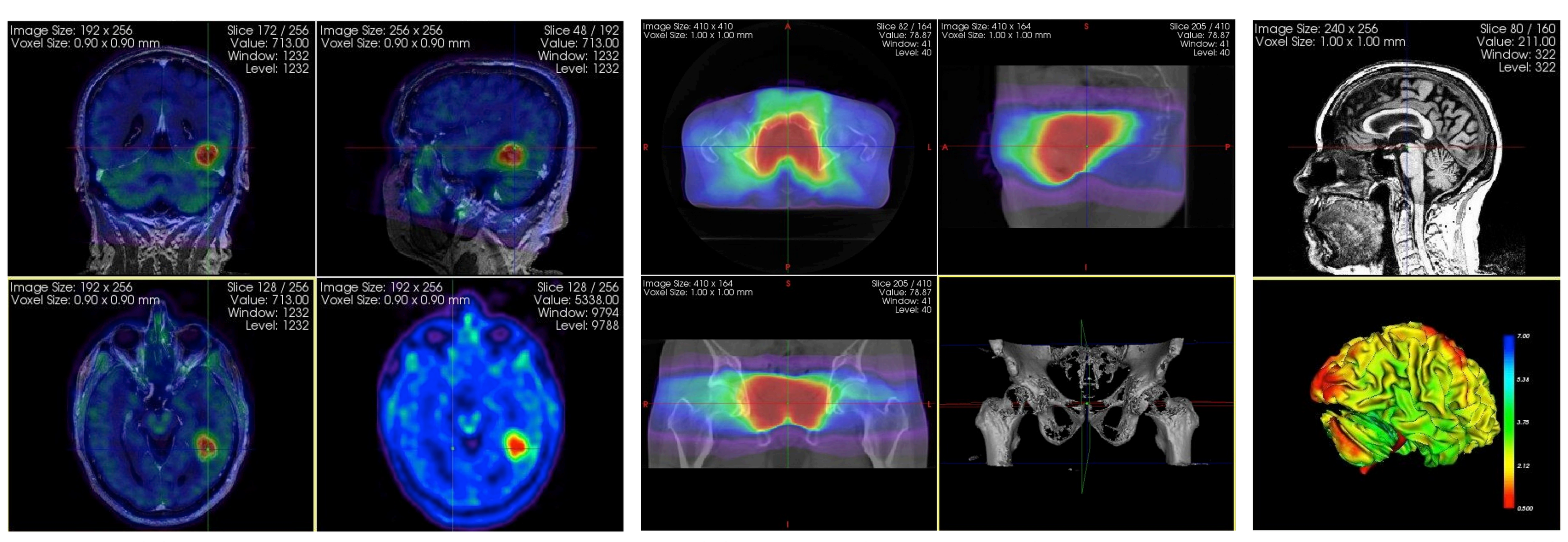

Figure 2: (a) Brain tumor - PET scan and MRI overlaid; (b) CT scan of a prostate of a patient overlaid with radiation dose; (c) Generated 3D view of a brain allowing study of atrophy pattern characteristics of diseases such as Alzheimer's disease.

X-TRACT [5]: developed for advanced X-ray image analysis and Computed Tomography – implements a large number of conventional and advanced algorithms for 2D and 3D X-ray image reconstruction:

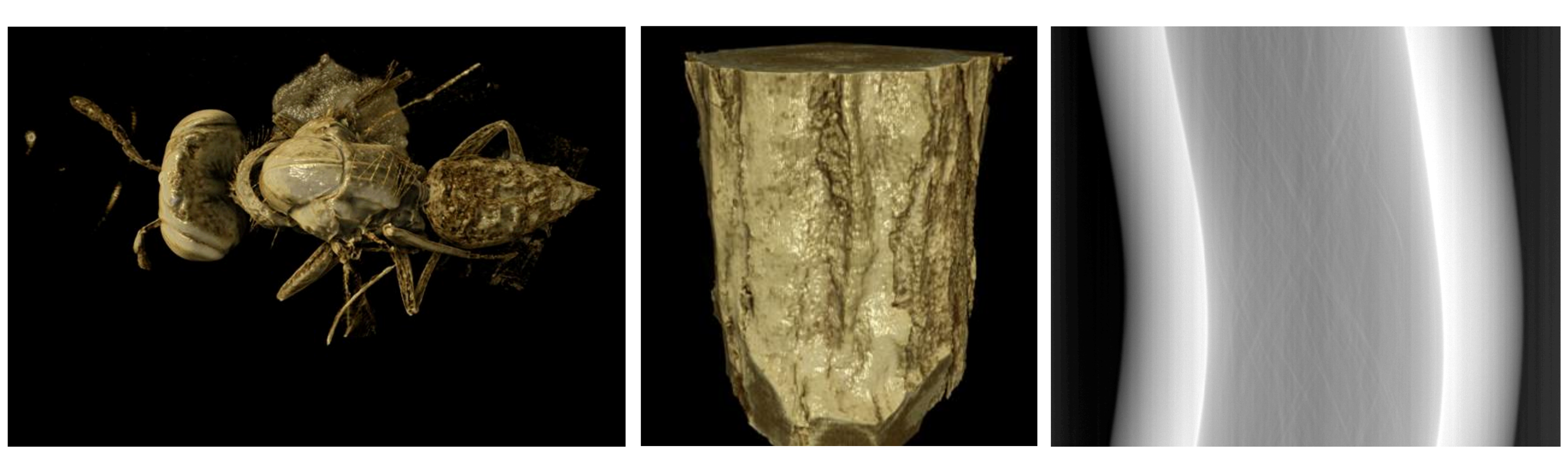

Figure 3: (a) Insect, reconstruction and rendering by Sherry Mayo (CSIRO); (b) Acacia plant, sample (~1 mm across) provided by Mel Linton (CSIRO), collected, reconstructed and rendered by Sherry Mayo; (c) Sample input Sinogram.

By providing user-friendly access to cloud computing resources and new workflow-based interfaces, our solution will enable the researchers to carry out more challenging image analysis and reconstruction tasks.

Software Architecture

The architecture comprises of a collection of physical and virtualised resources connected through networks, including the NeCTAR cloud resources, cloud enabled image analysis and processing platform, and CSIRO developed image analysis services, which can be accessed by users through a web portal. Figure 4(a) presents a high-level architectural view of the proposed system.

The image analysis and processing platform represents the development and runtime environment where the image analysis and processing tools are executed. The platform also provides the basic management features of the single node and leverages all the other operations on the services that it is hosting. The services include task submission, job and resource scheduling, error handling, reporting (traffic, client demands and usage), execution of the tools, operation status and progress monitoring, results returning etc. The platform encapsulates a layer of software and provides it as a service that can be used to build high level image analysis and reconstruction services.

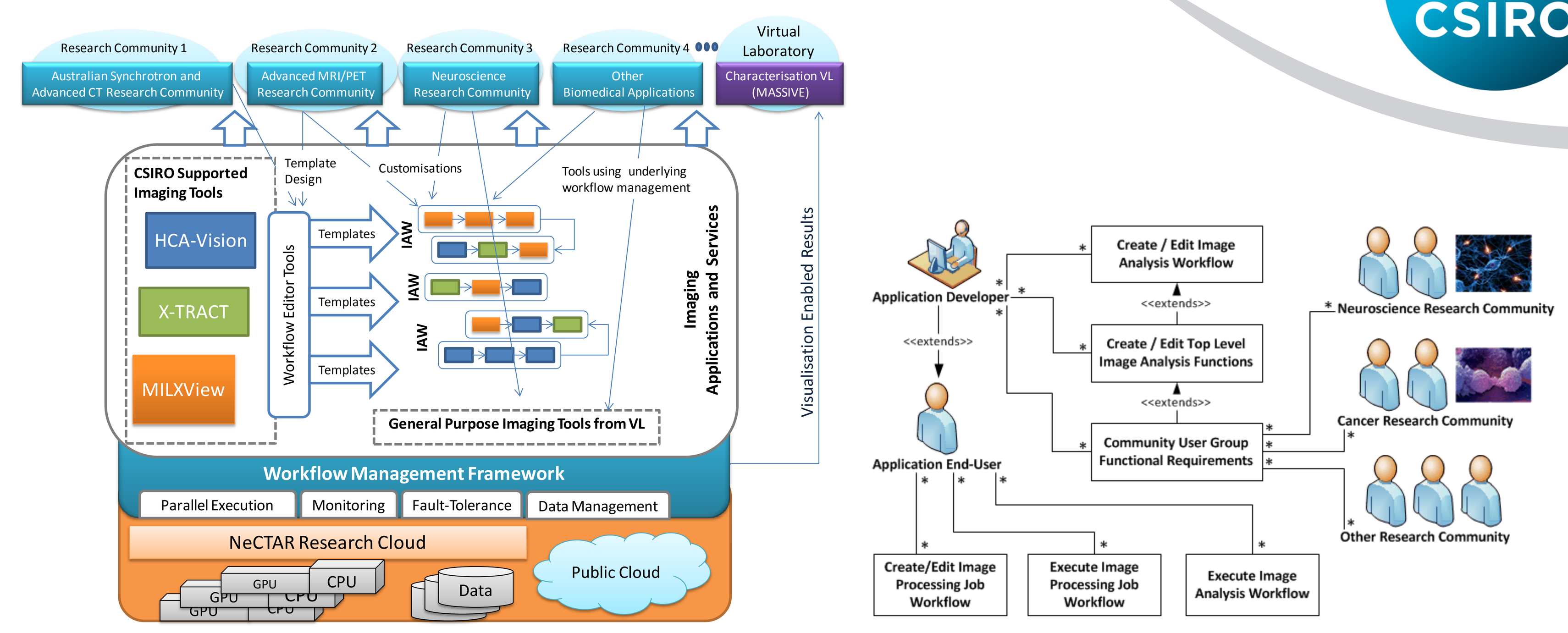

Figure 4: (a) Software architecture of the system; (b) The use case of the workflow environment.

Processing Example – Cellular Imaging

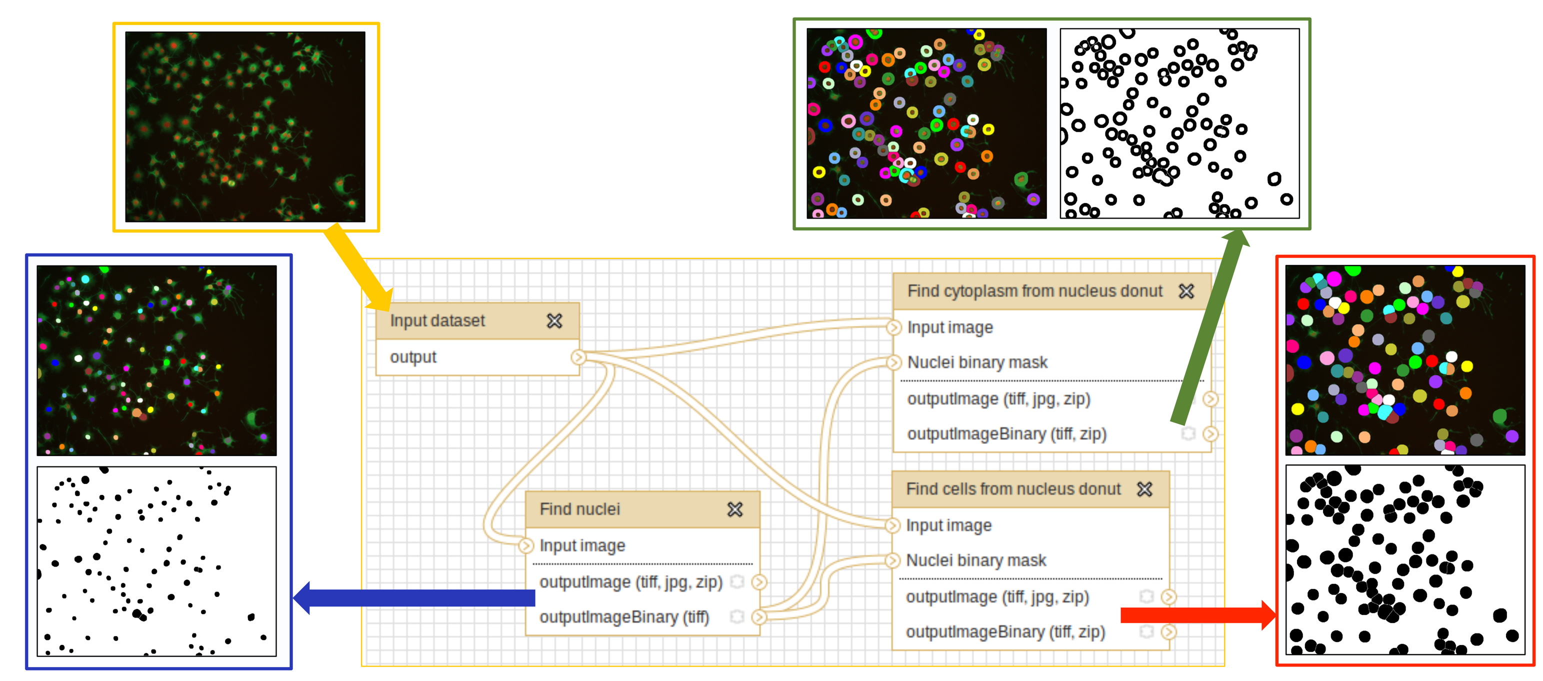

Figure 5: Sample processing imaging workflow prepared in Galaxy [6].

Supported Functions MILXView & X-TRACT

ID	FUNCTION	SHORT DESCRIPTION
MC.01	Atlas registration	Align an atlas image to a target image
MC.02	Segmentation	Segment the MRI into grey matter (GM), white matter (WM) and cerebrospinal fluid (CSF)
MC.03	Bias Field Correction	Estimate and remove the noise on the image
MC.04	Partial Volume estimation	Quantify the amount of partial voluming inside each voxel
MC.05	Topology Correction	Create the topology of the brain to ensure that it is genus zero
MC.06	Thickness Estimation	Compute the thickness of the cortex for each Grey matter voxel
MS.01	Cortical surface extraction	Extract a 3D mesh from the brain segmentation
MS.02	Topological correction	Remove holes and handles from the mesh
MS.03	Biomarker mapping on cortical surface	Mapping of various values on the mesh i.e. thickness, PET values, MR intensity etc ...
MS.04	Surface registration	Align the meshes of any given subject to a template to obtain a correspondence across subjects
MS.05	Transfer of biomarkers on template surface	Map all the values from all subjects to a common space where they can be compared
MP.01	PVC Registration	Registration of the PET image to its corresponding MRI
MP.02	Segmentation	Segmentation of the MRI into GM, WM, and CSF
MP.03	Partial Volume correction (PVC)	Correction for spill in and spill over of the PET image using the MRI segmentation
MR.01	SUVR Registration	Registration of the PET image to its corresponding MRI
MR.02	Segmentation	Segmentation of the MRI into GM, WM and CSF
MR.03	Atlas Registration	Registration of an atlas to the MRI to define a reference region on the MRI
MR.04	Image Normalisation	Normalising the PET intensity with the intensity of the reference region

IDs MC.xx – Application area: neuro-imaging analysis, cortical thickness estimation (CTE)
IDs MS.xx – Application area: neuro-imaging analysis, CTE surface
IDs MP.xx – Application area: neuro PET analysis, PET PVC
IDs MR.xx – Application area: neuro PET analysis, PET SUVR

ID	FUNCTION	SHORT DESCRIPTION
XPR.01	Sinogram creation	X-ray projection data must first be converted into sinograms before CT reconstruction can be carried out. Each sinogram contains data from a single row of detector pixels for each illuminating angles. This data is sufficient for the reconstruction of a single axial slice (at least, in parallel-beam geometry).
XPR.02	Ring artefact removal	Ring artefacts are caused by imperfect detector pixel elements as well as by defects or impurities in the scintillator crystals. Ring artefacts can be reduced by applying various image processing techniques on sinograms or reconstructed images.
XPR.03	Dark current subtraction	Dark current subtraction compensates for the readout noise, ADC offset, and dark current in the detector. The dark current images are collected before and/or after CT measurements with no radiation applied and with the same integration time as the one used during the measurements. The dark current image is subtracted from each CT projection.
XPR.04	Flat field correction	Flat-field images are obtained under the same conditions as the actual CT projections, but without the sample in the beam. They allow one to correct the CT projections for the unevenness of the X-ray illumination.
XPR.05	Positional drift correction replaced with Hot Pixel Replacement	The function is used for correction of transverse drift between related experimental images. Image drift is assessed by cross-correlating pairs of images.
XPR.06	Data normalisation	Data normalisation Including normalisation to a user-defined region
XPR.07	TIE-based phase extraction	The TIE algorithm allows the recovery of the optical phase of an electromagnetic wave (e.g. an X-ray beam) from a single near-field in-line image by solving the Transport of Intensity equation under the assumption that the phase shift and absorption distributions are proportional to each other. This method is usually applied in propagation-based in-line CT imaging (PCI-CT).
XCT.01	FBP CT reconstruction	Filtered back-projection (FBP) parallel-beam CT reconstruction
XCT.02	FDK CT reconstruction replaced with **Gridrec** Reconstruction	Feldkamp-Davis-Kress (FDK) cone-beam CT reconstruction **Gridrec reconstruction is fast enough without GPU!**
XCT.03	Centre of rotation	Automated calculation of the centre of sample rotation in a CT scan from experimental X-ray projections, sinograms or reconstructed axial slices.
XCT.04	CT Reconstruction Filters	The choice of available CT reconstruction filters will include at least the Liner-Ramp, Shepp-Logan, Cosine, Hamming and Hann filters.
XCT.05	ROI reconstruction	This option enables the user to select a subset of axial slices to be reconstructed and/or limit the reconstruction area to a user-defined rectangular subarea of the axial slice. The option reduces the reconstruction time and the size of the output data.

IDs XPR.xx – Application area: data processing functions
IDs XCT.xx – Application area: CT reconstruction functions

Examples

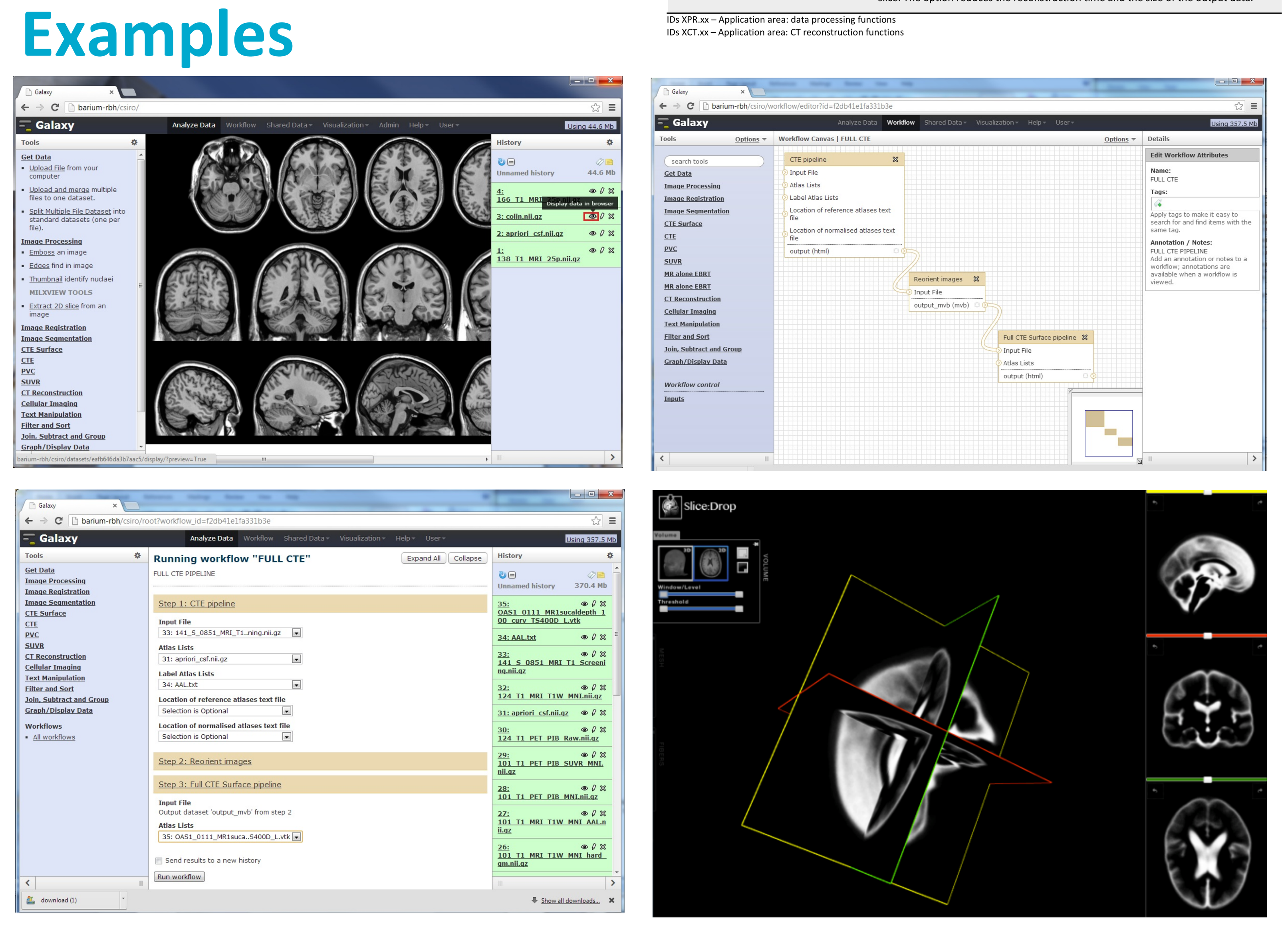

Figure 6: Visualisation, workflows and Galaxy UIs.

FOR FURTHER INFORMATION

Dr Tomasz Bednarz
e tomasz.bednarz@csiro.au
w www.csiro.au/cmis

REFERENCES

[1] NeCTAR www.nectar.org.au
[2] OpenStack www.openstack.org
[3] HCA-Vision www.hca-vision.com
[4] MILXView 3D http://research.ict.csiro.au/software/milxview
[5] X-TRACT http://www.ts-imaging.net
[6] Galaxy http://galaxy.psu.edu

ACKNOWLEDGEMENTS

This work is supported by the National eResearch Collaboration Tools and Resources (NeCTAR) [1] and CSIRO.

CALL FOR PILOT USERS

If you are interested in trying out this service for your research, please send e-mail to tomasz.bednarz@csiro.au to get access.