Cloud Computing for High Performance Image Analysis on a National Infrastructure

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Cloud computing services offer highly scalable and efficient solutions with a large pool of virtualized resources. They are becoming an increasingly prevalent service delivery model. We have developed a cloud-based image analysis toolbox to provide a wide user base with easy access to the software tools we have developed over the last decade. The toolbox is provided as a service on an Australian national cloud infrastructure [NeCTAR].

Architecture of Cloud-Based Image Analysis

Our cloud-base image analysis and processing toolbox comprises a collection of physical and virtualized resources connected through networks, including the NeCTAR research cloud Infrastructure as a Service (IaaS), cloud enabled image analysis and processing Platform as a Service (PaaS), and CSIRO developed image analysis Software as a Service (SaaS). Figure 1 shows a high-level architectural view of the cloud-based services.

Workflow Management Framework

Using scientific workflow for developing and executing data processing and analysis pipelines has gained wide attentions over the past decades. A workflow is one or more pipelines consisting of a series of functional steps needed to solve a specific problem. Biomedical image analysis is typically conducted using multiple functions and proceeds in a staged fashion with the output of one function used as an input of another. The workflow system provides a flexible approach to both developing and executing image analysis applications and makes use of scalable and cost-effective resources in cloud.

We adopt Galaxy, an open-source, web based platform for data intensive biomedical research, as a workflow engine in our system. Its web portal serves as a Graphical User Interface (GUI) to allow users to add a list of image analysis and processing tools. Each of the tools provides a special user interface to upload image datasets, specify image analysis parameters, and execute the tool. As the user submits a sequence of tasks with the output of one task feeding the input of another, Galaxy automatically records a history log, which is then presented to the user as a graphical workflow. The workflow can be edited and submitted for further executions if needed. A typical high-level use case for the workflow environment is shown in Figure 2.

Biomedical Image Analysis Applications

Our cloud-based services provide a suite of common and advanced image analysis, processing and visualization tools, including (1) Get Data – for a user to upload images, (2) Image Processing, (3) Image Registration, (4) Image Segmentation, (5) Cellular Image Analysis, (6) CT Reconstruction, and (7) Medical Image Analysis. Figure 3 demonstrates the graphical user interface of the toolbox after login to the cloud system. Figures 4 – 9 show the example applications of the cloud-based toolbox in the biomedical image analysis.

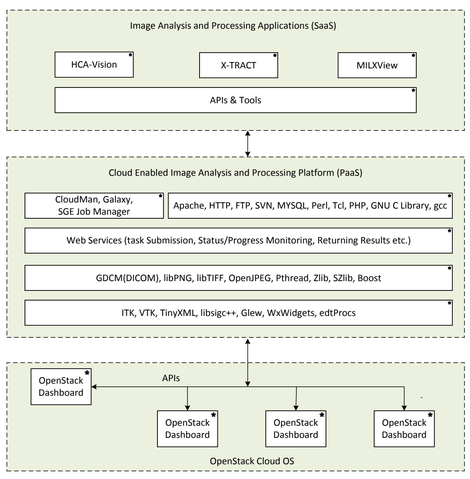

Figure 1: The architecture of the cloud enabled image analysis and processing tools

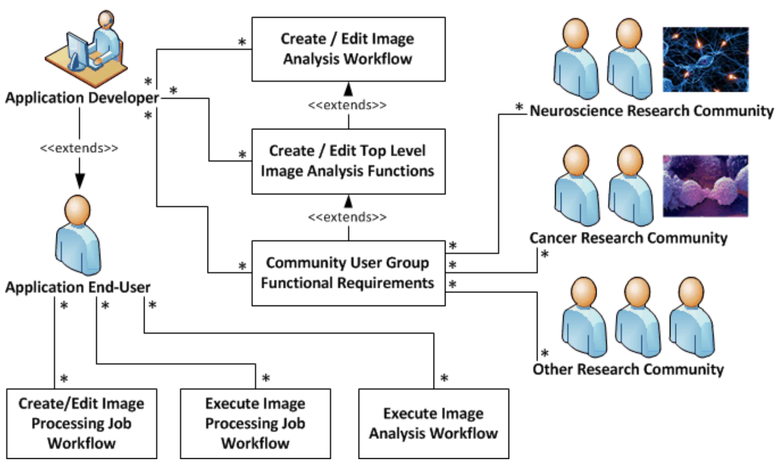

Figure 2: A typical high-level use case for the workflow environment

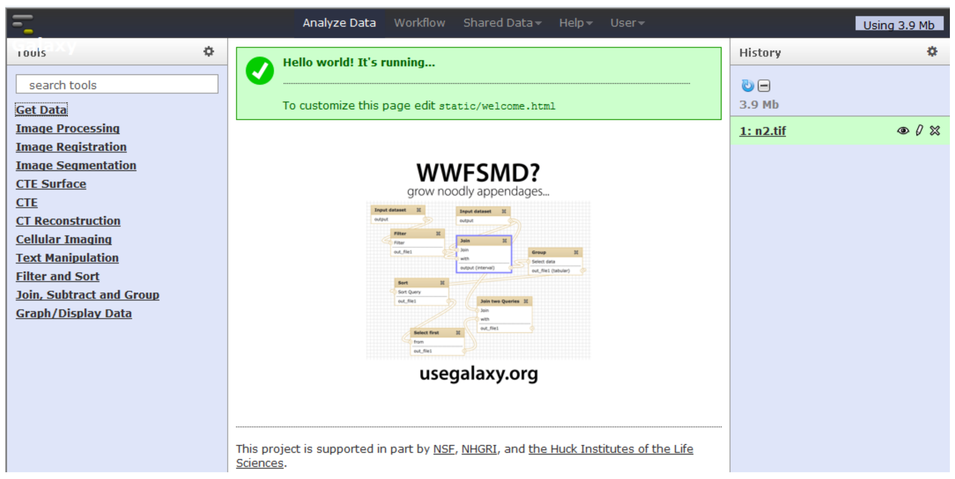

Figure 3: The graphical user interface of the cloud-based image processing and analysis services

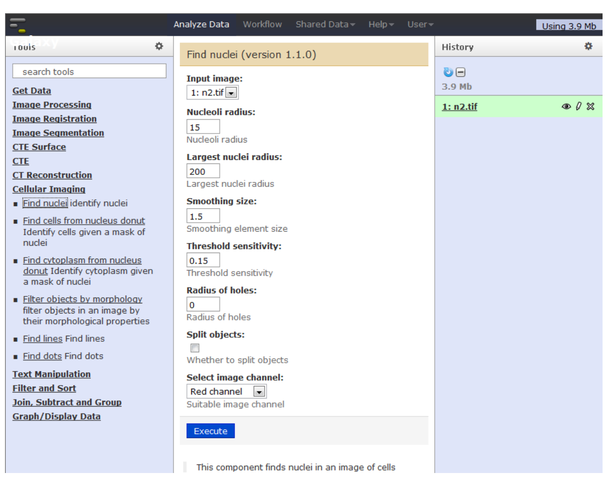

Figure 4: Parameter panel for nucleus detection tool

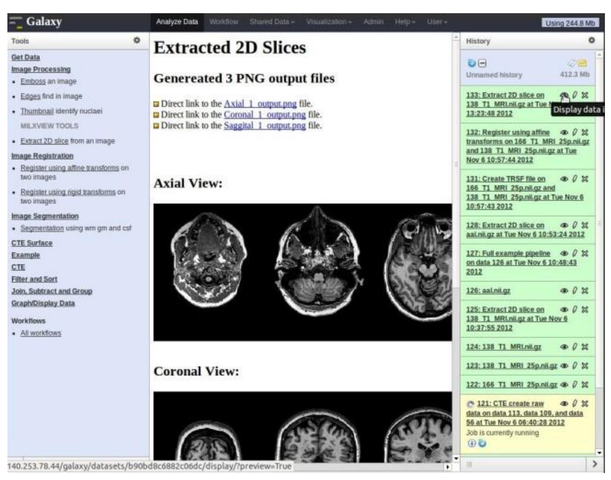

Figure 5: HTML page showing the 2D slices extracted from a 3D MRI image

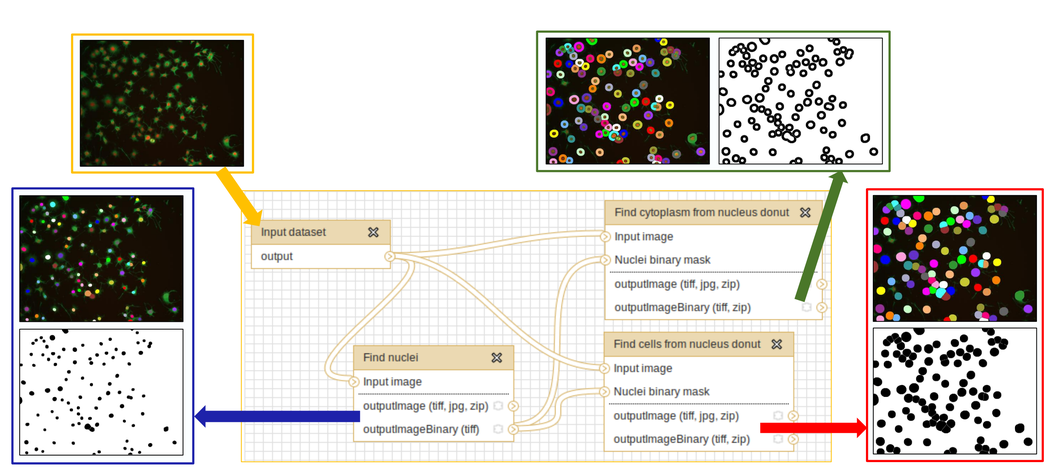

Figure 6: Image analysis workflow for detecting nuclei, cytoplasm and cells

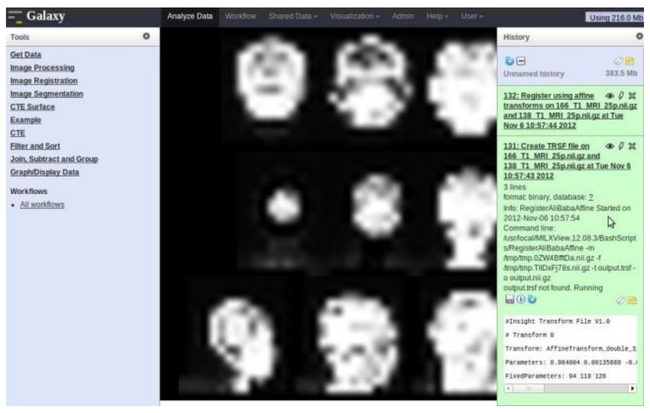

Figure 7: Registration results using affine transformation

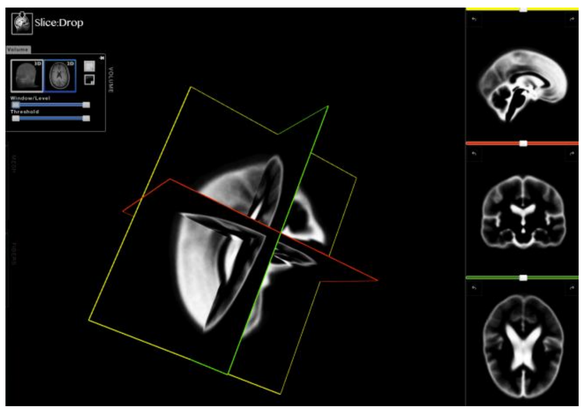

Figure 8: Slice:Drop image viewer used in the cloud-based image analysis toolbox

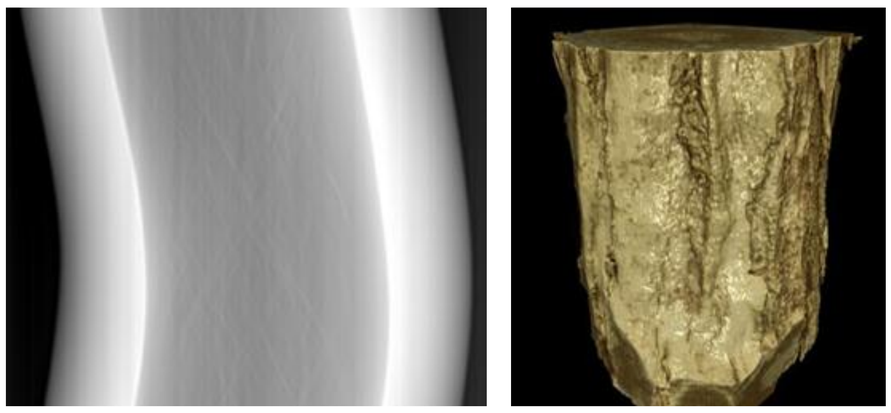

Figure 9: A sample sinogram (left) and the reconstructed 3D image (right) of an acacia plant. Image courtesy of Sherry Mayo and the acacia plant sample provided by Mel Linton (CSIRO)

Conclusions

We have presented the architecture, design and implementation of the cloud computing services for biomedical image analysis, which is running on a national cloud infrastructure. The toolbox provides an easy way for various user communities to access the well-established image processing and analysis algorithms and software as services without knowing and caring about the details of these algorithms and how and where they are executed. Our preliminary experimental results have shown that the toolbox offers a powerful new resource for scientists, due to its scalability, nimbleness and cost-effectiveness.

FOR FURTHER INFORMATION

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REFERENCES

NeCTAR: http://nectar.org.au
HCA-Vision : http://www.hca-vision.com
X-Tract: http://www.ts-imaging.net
MILXView: http://research.ict.csiro.au/soLware/milxview
Galaxy: http://galaxyproject.org/

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