Automatic Atlas Based Electron Density and Structure Contouring for MRI-based Prostate Radiation Therapy on the Cloud

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Automatic Atlas Based Electron Density and Structure Contouring for MRI-based Prostate Radiation Therapy on the Cloud

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Abstract. Our group have been developing methods for MRI-alone prostate cancer radiation therapy treatment planning. To assist with clinical validation of the workflow we are investigating a cloud platform solution for research purposes. Benefits of cloud computing can include increased scalability, performance and extensibility while reducing total cost of ownership. In this paper we demonstrate the generation of DICOM-RT directories containing an automatic average atlas based electron density image and fast pelvic organ contouring from whole pelvis MR scans.

1. Introduction

There are a number of benefits of the use of MRI for soft tissue visualisation in prostate cancer radiation therapy. However treatment planning requires the use of computed tomography (CT) scans for simulation. This is necessary as there are currently limited methods to convert MRI intensities to electron density (which is a requirement for dose calculations to be performed directly on MRI scans). Advantages of planning directly on MRI scans would include a reduction in costs and the uncertainties introduced by the registration process. A further motivation is the recent developments in MRI simulation and MRI accelerators (1–3) which bring the potential for MRI based adaptive treatment.

Our research group has been investigating the feasibility of MRI-alone treatment planning for prostate cancer radiation therapy. We have previously published methods for electron density generation from MRI with <2% difference between pseudo-CT and planning CT in point dose at isocentre (4), fast automatic organ contouring (5,6) and proposed a revised MRI-alone workflow (7). To assist with clinical validation of the MR-alone workflow this paper concentrates on a remote cloud platform solution.

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2. Method

2.1.1. Image data

As described in Dowling, et al. (4), a whole pelvis MRI atlas was generated based on 39 manually delineated 1.5T T2w MRI scans from patients prior to external beam radiation therapy for localised prostate cancer. In addition a conjugate electron-density atlas was generated from the co-registered CT-MRI scans (Figure 1). These atlases contain contours for the pelvic bones, bladder, rectum and prostate.

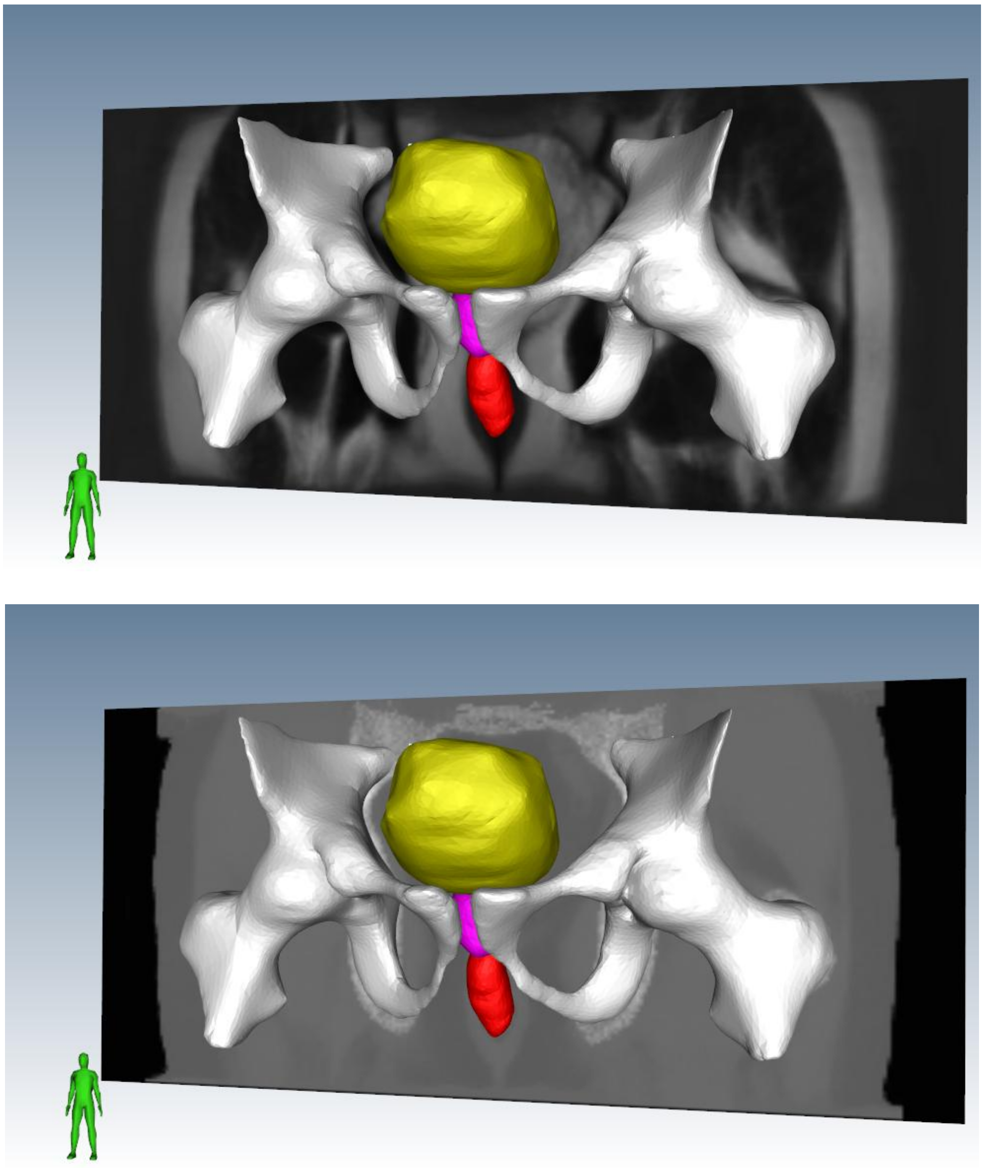

Figure 1. MRI (top) and matching pseudo CT (bottom) pelvic atlas with surface models of the main pelvic organs (bones, bladder, rectum and prostate).

2.1.2. Processing software

The current cloud pipeline for pseudo CT generation and automatic contouring is shown in Figure 2. The interface requires a DICOM series containing a whole pelvis (male) large field of view T2w MRI. Once received the DICOM series is converted into a single 3D volume (NifTI file format, http://nifti.nimh.nih.gov/nifti-1) and is pre-processed prior to average atlas based electron density estimation and initial organ contouring. Atlas based segmentation usually involves an atlas image (generally an average of a set of images) with a matching set of organ labels (eg. Figure 1). To segment a new image, the MRI atlas is registered to a patient's whole pelvis T2w MR image to obtain a good correspondence between structurally equivalent regions in the two images, and then the labels defined on the atlas are propagated to the image.

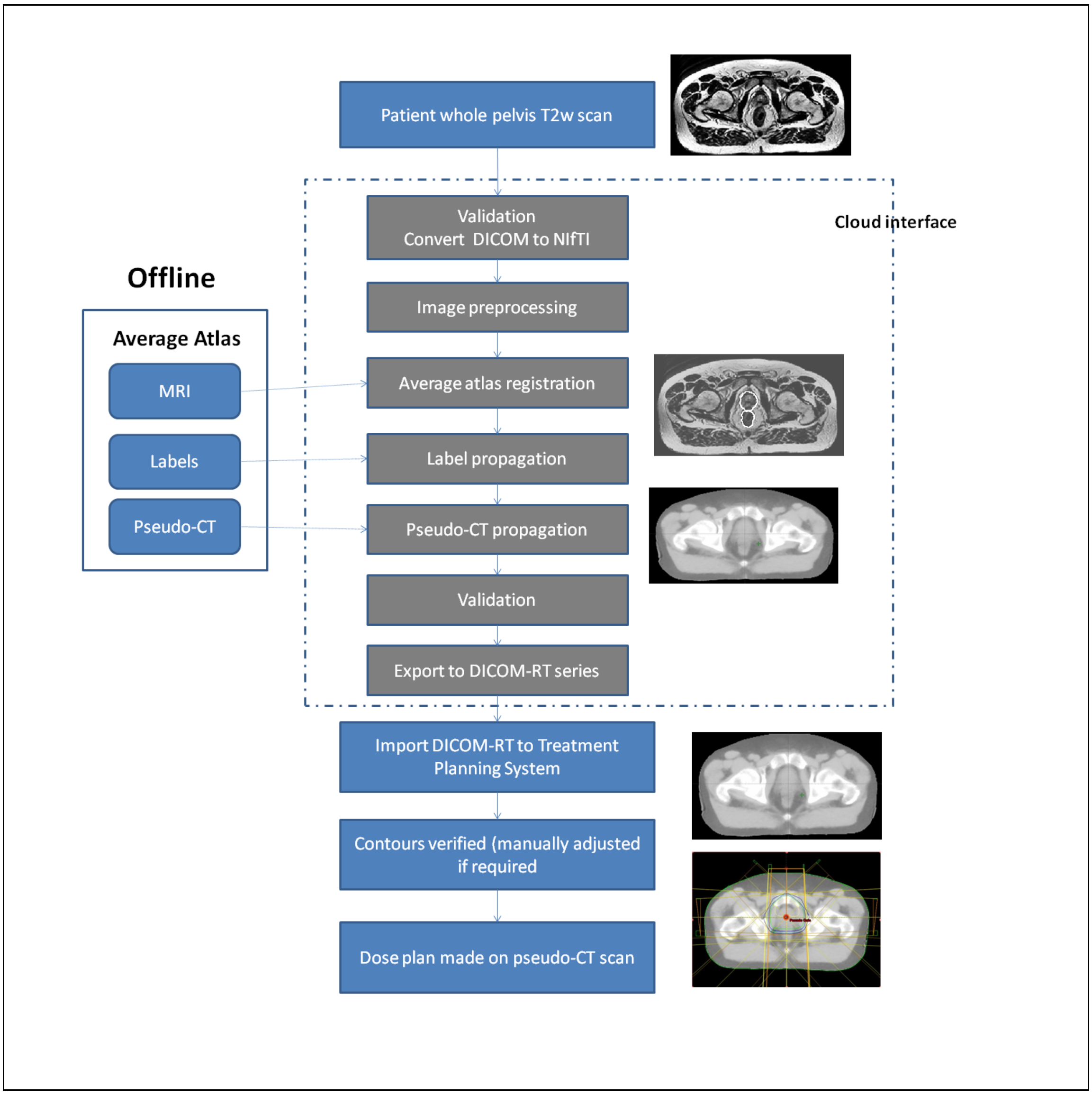

Figure 2. Overview of the main steps involved in average atlas based pseudo-CT and structure generation on the cloud

The technical details of the atlas generation has been reported previously (7). To generate a pseudo-CT from a patient's MRI the same transformation and deformations are then applied to the CT atlas (Figure 1, right) to create a pseudo-CT corresponding to the patient MRI scan anatomy. This pseudo-CT is then used for dose planning and digitally reconstructed radiograph (DRR) generation (Figure 2). In the final step, the resulting volume and structures are converted to a DICOM-RT series for the clinical site to download, QA and modify if necessary.

2.1.3. Cloud interface and environment

A medical imaging analysis and visualization platform has been developed at the CSIRO Australian e-Health Research Centre called MILXView, incorporating a number of advanced algorithms that provide improved automated image analysis and interpretation of medical imaging data. MILXView is designed to process data on a desktop install however the aim is to enable access and execute these algorithms in a cloud environment. The cloud offers several distinct advantages over desktop processing; including achieving economies of scale, reduced spending of technology infrastructure and support, improved accessibility, minimising licensing new software and the ability to deploy software upgrades instantly.

Galaxy (8) has been adapted to execute MILXView binaries in the cloud. Galaxy is a collection of XML and Python scripts that allow users to upload data to a cloud environment and then execute binaries using the uploaded data as arguments. Tools can be quickly added to the user interface by updating a single configuration XML file which states the location of a tool XML file. This tool XML file specifies the binaries or scripts to be executed and their arguments and output parameters.

All data uploaded and produced via Galaxy is stored in a database. Galaxy uses SQLite by default, but can use MySQL or PostgreSQL to overcome concurrency limitations. Galaxy contains a standalone web server. However, some tasks such as serving static content can be offloaded to a dedicated server for efficiency.

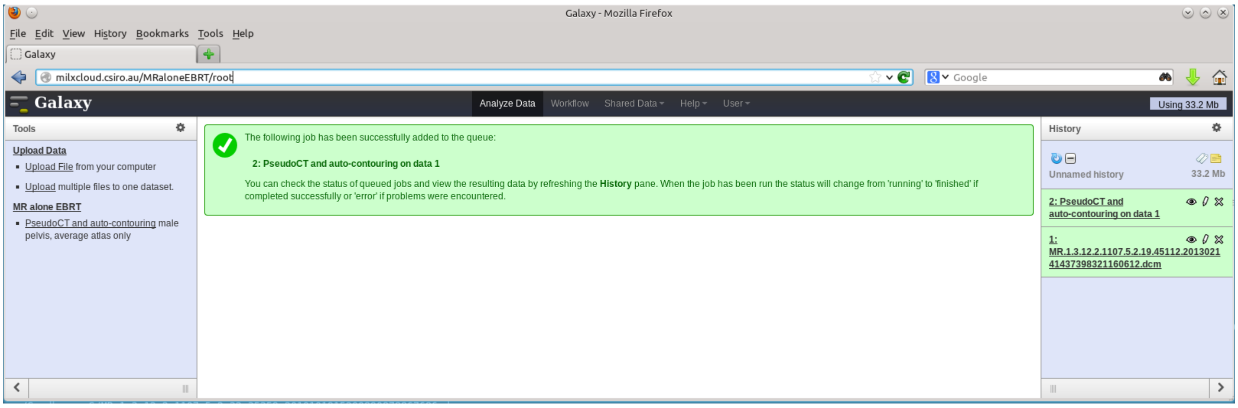

Figure 3. Screen snapshot from the proposed cloud interface. Uploaded DICOM series and automatically generated DICOM-RT directories are maintained in the history panel on the right hand side.

The installation of Galaxy is simple and nearly identical for UNIX/Linux and Mac OS X environments. It is not supported under Windows so users would have to build their own Python Eggs (a method of distributing Python packages). Galaxy can be run on a single desktop, or on a compute cluster. Galaxy currently supports TORQUE, PBS, PBS Pro, Platform LSF, HT Condor, Open grid Engine and Sun Grid Engine clusters and does not require a dedicated or special cluster configuration. Finally, Galaxy can be instantiated on cloud computing infrastructures (primarily Amazon Elastic Compute Cloud (EC2)), or in a user created cloud environment using CloudMan.

3. Results

3.1.1. Pseudo-CT generation

The cloud implementation enables the generation of pseudoCT and automatic bone, bladder, prostate, and rectum contours within approximately 3.5 minutes (using the average atlas shown in Figure 1). Figure 4 shows qualitative results from the automatic conversion of a 3T T2w whole pelvis MRI.

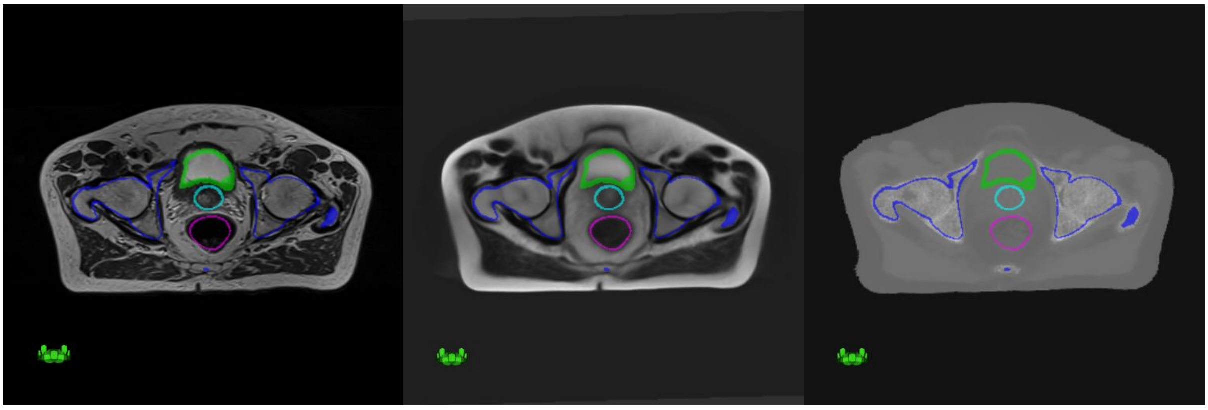

Figure 4. Left: Axial sample slice from a whole pelvis T2w MR scan (not part of the atlas set). The central image shows the result from deformable registration of the whole pelvis MRI atlas (from Figure 1) to the new scan; and the matching pseudo-CT is shown on the right. Automatic organ segmentations for the prostate, bladder, rectum and bones have been overlaid.

4. Discussion

The cloud research in this paper has been motivated by a need to allow increased scalability, performance and extensibility while reducing total cost of ownership and providing access to powerful CPU and GPU clusters for efficient parallel methods in medical image analysis. The cloud architecture has been applied in this work to demonstrate a previously published method working through a cloud interface and producing DICOM-RT files which are ready for import into a commercial treatment planning system for research purposes. The architecture allows us to easily include new methods for pseudo-CT and automatic contouring (for example fast, parallel multi-atlas registration and selection methods), and to interface with both internal and commercial clusters.

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