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[9] http://www.bic.mni.mcgill.ca/software/N3/

[10] A complete discussion of 'N4' is provided at hdl.handle.net/10380/3053.

***Nick Tustison*** *borders his moments of software-writing serenity at the Penn Image Computing and Science Lab (PICSL) with attempts at integrating Heidegger's notion of "Dasein" with the open source software paradigm---oh, and battling ninjas, too.*

# EXPORTING CONTOURS TO DICOM-RTSTRUCT

The "radiotherapy structure set" (RTSTRUCT) object of the DICOM standard is used for the transfer of patient structures and related data, between the devices found within and outside the radiotherapy department. It contains mainly the information for regions of interest (ROIs) and points of interest (e.g., dose reference points). In many cases, rather than manually drawing these ROIs on the CT images, one can indeed benefit from the wealth of automated segmentation algorithms available in ITK. But at present, it is not possible to export the ROIs obtained from ITK to RTSTRUCT format. In order to bridge this gap, we have developed a framework for exporting contour data to RTSTRUCT [1].

## RTSTRUCT

The mandatory modules contained by the RTSTRUCT are presented in Table 1. These modules are grouped based on the type of information entity that they represent. Here is a brief description of each of these modules:

1. "Patient Module" specifies the attributes that describe and identify the patient who is the subject of a diagnostic study. This module contains attributes of the patient that are needed for diagnostic interpretation of the image and are common for all studies performed on the patient.
2. "General Study Module" specifies the attributes that describe and identify the study performed upon the patient.
3. "RT Series Module" has been created to satisfy the requirements of the standard DICOM query/retrieve model.
4. "General Equipment Module" specifies the attributes that identify and describe the piece of equipment that produced a series of composite instances.
5. "Structure Set Module" defines a set of areas of significance. Each area can be associated with a frame of reference and zero or more images. Information which can be transferred with each ROI includes geometrical and display parameters, and generation technique.
6. "ROI Contour Module" is used to define the ROI as a set of contours. Each ROI contains a sequence of one or more contours, where a contour is either a single point (for a point ROI) or more than one point (representing an open or closed polygon).
7. "RT ROI Observations Module" specifies the identification and interpretation of an ROI specified in the Structure Set and ROI Contour modules, and
8. "SOP (Service-Object Pair) Common Module" defines the attributes which are required for proper functioning and identification of the associated SOP Instances. They do not specify semantics about the real-world object represented by the IOD.

[2] contains a comprehensive documentation of the DICOM standard covering all the modules. Refer to [1] for a brief summary of the RTSTRUCT.

| Information Entity | Mandatory Modules |
|---|---|
| Patient | (i) Patient |
| Study | (ii) General Study |
| Series | (iii) RT Series |
| Equipment | (iv) General Equipment |
| Structure Set | (v) Structure Set<br>(vi) ROI Contour<br>(vii) RT ROI Observations<br>(viii) SOP Common |

*Table 1: Mandatory Modules of RTSTRUCT.*

## IMPLEMENTATION

Figure 1 illustrates the pipeline that we use for exporting the automated segmentation results to RTSTRUCT format. It mainly contains three steps: Automated Segmentation, Mask to Contour Conversion and RTSTRUCT-Exporter.

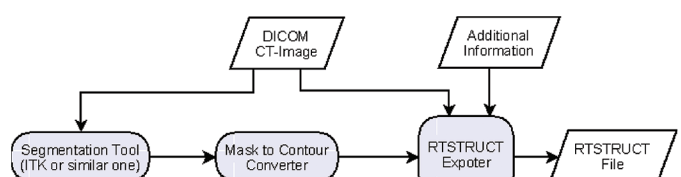


*Figure 1: Block diagram illustrating the pipeline for exporting the automated segmentation results to RTSTRUCT.*

- **Automated Segmentation:** The input DICOM CT images are converted into a convenient image format (if required) and an automated segmentation is performed using ITK or similar tools. The output ROIs from this tool should be a mask. There can be multiple masks corresponding to different structures of interest and the current program indeed allows for the export of multiple masks. It is also possible to export the ROIs obtained on images that are cropped along z-axis; in such cases, the information of starting-slice-number and the number of slices used should be later passed to the RTSTRUCT-exporter module. The output of this module is passed to the "mask to contour converter".

- **Mask to Contour Conversion:** We first extract axial slices of the mask using ExtractImageFilter of ITK. We then use the ContourExtractor2DImageFilter [3] from ITK, for obtaining contours on each of these slices. We finally create an output text file containing the information of total number of contours, coordinates of each contour-point along with the corresponding slice number, number of contour points for each contour and type of geometry of each contour (open or closed).
- **RTSTRUCT-Exporter:** Exporting the contours to RTSTRUCT format requires the implementation of RTSTRUCT-Writer. We implemented this in a class called "RTSTRUCTIO". For creating instances of RTSTRUCTIO objects using an object factory, "RTSTRUCTIOFactory" class is also implemented. Refer to [1] for a detailed description of class-design and key implementation issues.

The inputs to the RTSTRUCT-Exporter are:

- An axial slice of the DICOM CT image of the patient (for extracting the information that is common to both CT image and RTSTRUCT, as described in [1]).
- Output(s) of the "Mask to Contour Converter" (multiple contours can be exported, as described in [1]).
- Few additional inputs like starting slice number with respect to the original image, total number of slices to be considered, ROI interpreted types and the colors to be assigned to each ROI.

All of these parameters are passed to the RTSTRUCT-Exporter through a text file.

## EXAMPLE

The DICOM CT image used in this paper is acquired during routine clinical practice at Divisions of Radiotherapy, Fribourg Hospital (HFR) in Switzerland. The image is acquired on GE Medical System (Model: LightSpeedRT16). The size of each slice is 512 × 512 pixels with a spacing of 1.27 mm × 1.27 mm; the inter-slice distance is 2.5 mm. There are 116 slices in total.

Since we are interested only in the first 83 slices of the patient's image, the original DICOM image is cropped in the Z-direction to contain only these slices, and a new image file (with .mhd extension) is created. The image is then thresholded in selected regions for removing the bed and other immobilization devices. Figure 2 shows the thresholded image. We created separate masks for the external-contour and bones through simple windowing of the image, as shown in Figure 2. These masks are shown in Figures 3 and 4. The contours of these masks are obtained using the "Mask to Contour Convertor". The contour data, along with a slice of the DICOM CT image and other information, is passed to the RTSTRUCT-Exporter using a parameter-file. Figure 5 shows the resultant RTSTRUCT file superposed over the original DICOM CT image.

## CONCLUSIONS & FUTURE WORK

An ITK implementation of the RTSTRUCT-Exporter is presented. The details of the pipeline used and description of each module in the pipeline is presented. The implementation is validated on a 3D CT image, by exporting the ROIs of the external-contour and bones to RTSTRUCT format.

We would also like to mention the recent work of Dowling et al. [4] that presents a method to do the reverse, i.e., importing the contours from the RTSTRUCT. It would be interesting to integrate these two implementations. RTSTRUCT-Exporter is currently tested only on the DICOM CT images acquired from a GE Medical System (Model: LightSpeedRT16). A thorough testing on more images, acquired from various manufacturers and models, will make it more robust.

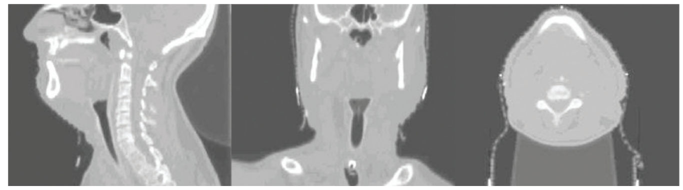

*Figure 2: Sagittal, Coronal and Axial views of the 3-D CT image of the Patient. This is a cropped image containing only the first 83 slices of the original image.*

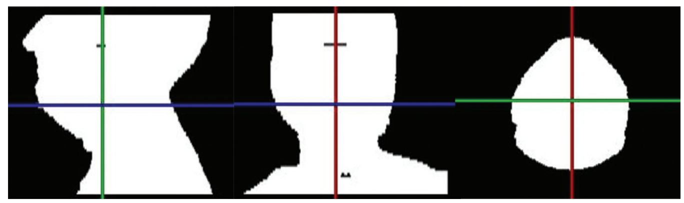

*Figure 3: Sagittal, Coronal and Axial views of the mask for external-contour of the 3-D CT image.*

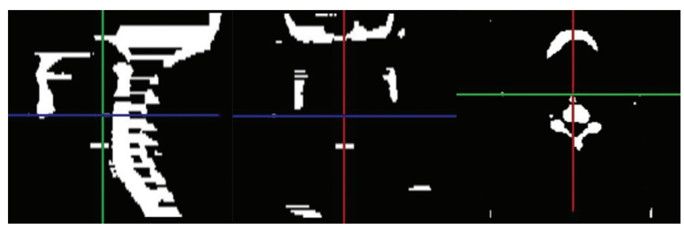

*Figure 4: Sagittal, Coronal and Axial views of the mask for bones of the 3-D CT image.*

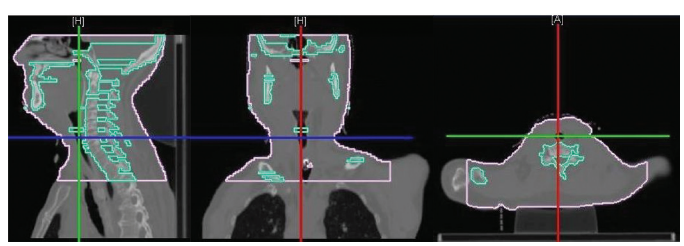

*Figure 5: A screen-shot showing the contours of the external-contour and bones in the RTSTRUCT file, superposed over the original DICOM CT image.*

## ACKNOWLEDGMENTS

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# KITWARE NEWS

## KITWARE WINS PHASE II FUNDING FOR ARMY CFD PROJECT

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## KITWARE SPONSORS THIS IS GIT TALK AT UNC

Kitware sponsored a "This is GIT" talk for UNC's graduate and undergraduate computer programming clubs. Kitware provided pizza and drinks to about 25 students, faculty, and staff at a talk by Jason Sewall, a UNC CS PHD candidate. The talk lasted nearly 2 hours. There was excellent interaction with the audience throughout the talk, with questions resulting in live demonstrations and extended discussions.

Kitware also handed out job advertisement flyers. At least one potential interviewee was discovered.

## ITK DASHBOARD FEST A HUGE SUCCESS

Dashboard Fest 1.0 was a huge success thanks to your contributions. Our goal was to hit 200 experimental builds, and by the end of the day on Friday November 6, 2009, 1,033 experimental builds had been submitted to the Dashboard from 106 different computers. The following users submitted the largest number of builds:

Gaëtan Lehmann (INRA)
Kevin Hobbs (Ohio University)
Oleksander Dzyubak (Mayo Clinic)
Arnaud Gelas (Harvard)
Alexandre Gouaillard (Harvard)
Kishore Mosaliganti (Harvard)
Hans Johnson (Iowa)
Kent Williams (Iowa)
Bradley Lowekamp (NLM/Lockheed Martin)
Sean McBride (Rogue Research)
Mathieu Coursolle (Rogue Research)
Christian Haselgrove (NITRC)
Steve Pieper (Brigham and Women's Hospital)
Iván Macía (Vicomtech)
Tom Vercauteren (Mauna Kea Technologies)

Kitware would like to thank everyone who contributed to this event.

## KITWARE WINS PHASE II FUNDING FOR ARMY CFD PROJECT

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