Abstract

HIERARCHICAL CLUSTERING METHOD AND RADIOMICS ROBUSTNESS ANALYSIS TO IMPROVE AN ATLAS BASED SEGMENTATION ALGORITHM: A 25 CARDIAC SUB-STRUCTURES STUDY

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PURPOSE:

Image segmentation of targets and organs at risk (OARs) is a fundamental task in Radiation Therapy (RT) to obtain an adequate treatment plan. In a standard clinical workflow, segmentation is carried out manually in a time-consuming and error prone process. Auto-contouring, overcoming limits of manual approach, is making its way into clinical RT as a tool to accelerate the treatment planning workflow and to enable on-line Adaptive Radiation Therapy (ART) strategies. An important potential application of auto-contouring is the segmentation for large scale retrospective dosimetric treatment plan to create more detailed dose-volume-toxicity models.

Various approaches, among them Hierarchical Clustering, were applied in this study to improve performance of Atlas Based Segmentation (ABS) of cardiac sub-structures.

Moreover, a reliable set of radiomics features was explored to pave the way for prognostic and predictive future studies about cardiac features in large prospective cohort.

METHODS:

Training dataset of ABS, as implemented in a commercially available treatment planning system, consisted of 36 manually contoured CTs. Twenty-five cardiac sub-structures were contoured as regions of interest (ROIs). The list of cardiac sub-structures with related acronyms is reported in Table 1.

Cardiac sub-structure	ROI Acronym
Heart	Heart
Left Atrium	LA
Right Atrium	RA
Left Ventricle	LV
Right Ventricle	RV
Anterior Left Ventricle	AntLV
Apical Left Ventricle	ApLV
Lateral Left Ventricle	LatLV
Inferior Left Ventricle	InfLV
Septal Left Ventricle	SepLV
Ascending Aorta	Aorta
Pulmonary Artery	PA
Left Main Coronary Artery	LMCA
Proximal Right Coronary Artery	ProxRCA
Mid Right Coronary Artery	MidRCA
Distal Right Coronary Artery	DistRCA
Posterior Descending Right Coronary Artery	DescRCA
Proximal Left Anterior Descending Coronary Artery	ProxLADCA
Mid Left Anterior Descending Coronary Artery	MidLADCA
Distal Left Anterior Descending Coronary Artery	DistLADCA
Proximal Circumflex Coronary Artery	ProxCCA
Distal Circumflex Coronary Artery	DistCCA
Coronary Sinus	CS
Inferior Vena Cava	IVC
Superior Vena Cava	SVC

Table 1 - List of cardiac sub-structures with related acronyms

Four auto-segmentation methods were compared:

- Method-: simultaneous automatic contouring of all 25 ROIs,
- Method-2: automatic contouring of all 25 ROIs using lungs as anatomical barriers,
- Method-3: automatic contouring of a single ROI for each contouring cycle,
- Method-4: Hierarchical Cluster-based automatic contouring.

Results were evaluated on 10 patients. Dice similarity coefficient (DSC), average Hausdorff distance (AHD), volume comparison and physician score were used as validation metrics.

The robustness of radiomics features derived from automatically and manually segmentation was analyzed focusing on 25 cardiac sub-structures. The generic radiomics workflow is shown in Figure 1. The intra-class correlation coefficient (ICC) was calculated for each feature extracted. Moreover, the feature range and the correlation between the feature robustness and the accuracy of the segmentation was evaluated.

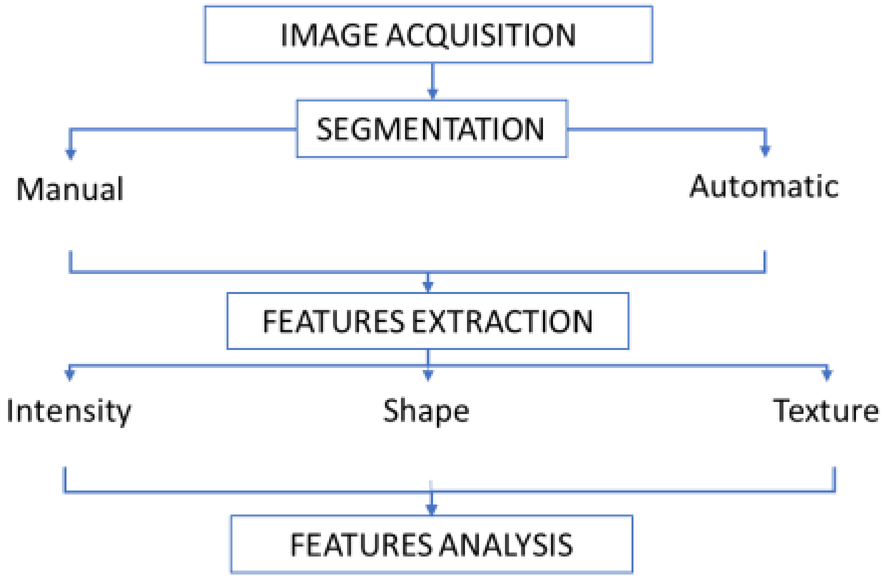

Figure 1 – Radiomics workflow.

RESULTS:

ABS performance improved with an increasing number of atlases. Passing from 24 to 36 atlases, greatest improvements of qualitative indexes (i.e. DSC and AHD) were observed for challenging ROIs with volume less than 1cc (i.e. coronary arteries). Among the four ABS methods, the Hierarchical Clustering workflow showed a significant improvement (proved by ANOVA and Bonferroni post-hoc tests) maintaining a clinically acceptable time for contouring. Using a GPU equipped hardware, the computational time needed was: 6 minutes for Method-1, 11 minutes for Method-2, 100 minutes for Method-3, 8 minutes for Method-4. The mean time needed to contour all 25 OARs within a full manual approach was around 70 minutes. Physician scoring was acceptable for 70% of the ROI automatically contoured.

Twenty among ninety-six radiomics features were found to be robust in cardiac sub-structures contouring. No feature class was found to be more reproducible than another (Kruskal-Wallis test). A significant correlation was discovered between robust features and quantitative indexes used to quantify the segmentation performance.

CONCLUSIONS:

Hierarchical Clustering resulted in best ABS results. A set of robust radiomics features was detected. Among the standard quantitative indexes generally used, also a selected-feature metric could be introduced to quantify the segmentation accuracy.