Automatic 3-D Skeleton-Based Segmentation of Liver Vessels from MRI and CT for Couinaud Representation

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Objectives

- Visualize automatically liver components on both modalities (CT and MRI).
- Extract the hepatic vascular tree through 3D skeletonization process for Couinaud representation.

Data used:

- 20 CT from SLIVER, 20 CT from IRCAD
- 40 MRI from local hospitals

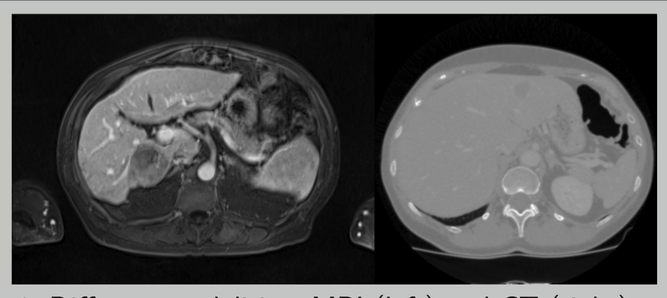
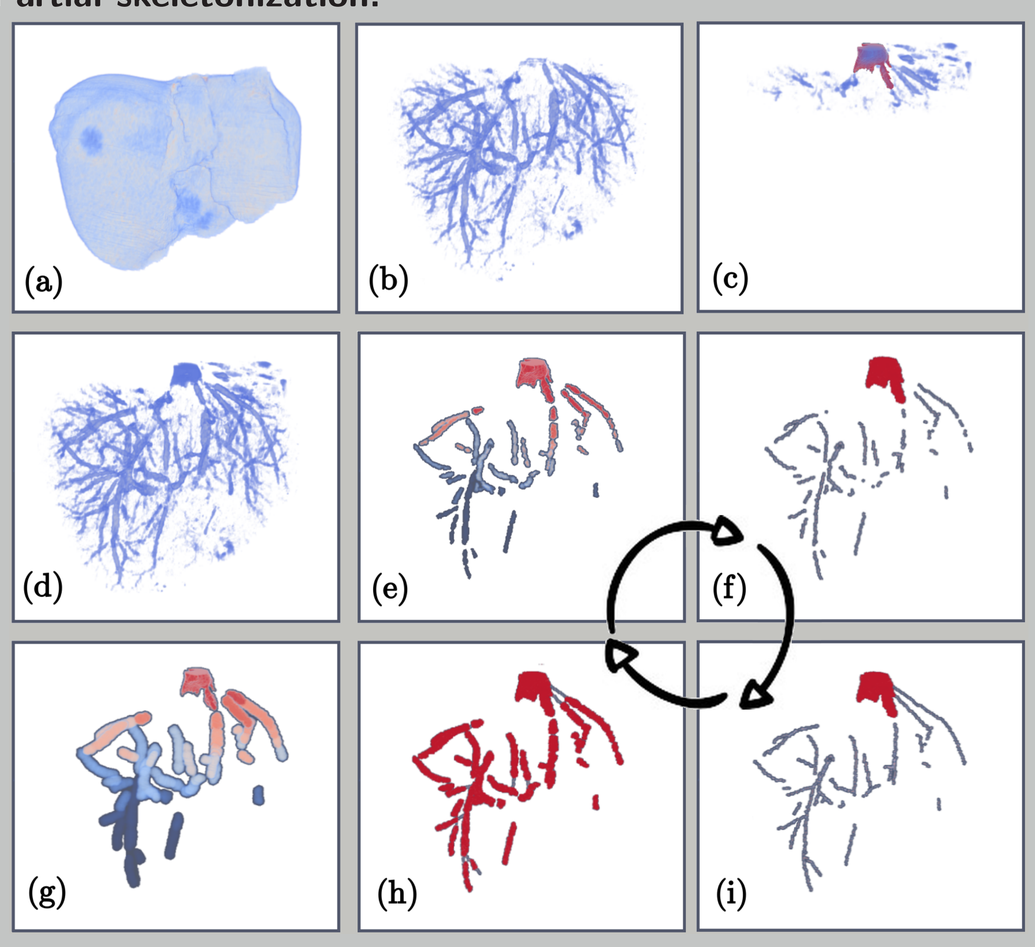


Figure 1: Different modalities: MRI (left) and CT (right)

Methodology

I. Partial skeletonization:



- (a) Automatic liver segmentation: I [1]
- (b) Brightest vessels detected by Sato's filter: I_s
- (c-d) Largest component detection for the common trunk
- (e) Main components extraction
- (f) Centerlines extraction
- (g-h) Centerlines extension - Connection - Validation
- (i) Skeleton : $\mathrm{S}_{partial}$

II. 3-D Reconstruction

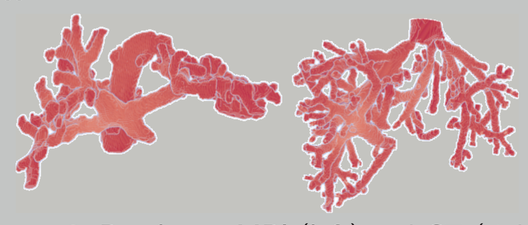


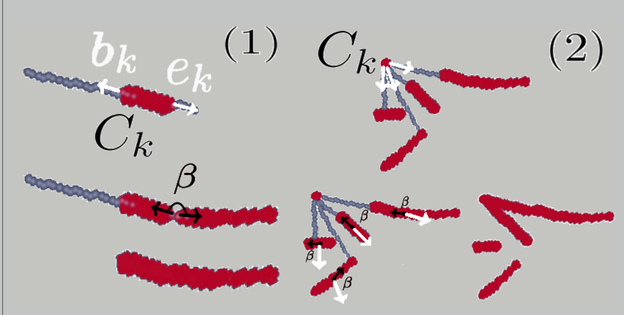
Figure 2: Results on MRI (left) and CT (right)

- RORPO algorithm applied on the liver segmentation I, it enables multi-scale vessel extraction: I_{RORPO} [3]
- Fast marching phase used at each voxel of $\mathrm{S}_{partial}$ in I_{RORPO} (Figure 2)

III. Hepatic and portal veins extraction

- Erosion of the vessel segmentation obtained in step **II.** to retrieve largest vessels
- Extraction of the two main components (hepatic and portal veins are not connected) (Figure 3)
- Extraction of their centerlines (Figure 4)

Centerlines extension - Connection - Validation



- (1) C_k with $|l_k| > 1$: directional vectors computation b_k and e_k and centerlines extension
- (2) C_k with $|l_k| = 1$: four closest components and directional vectors computation
- Validation according to conditions on β and r_j with $j \in \{1, 2\}$ defined by:

$$r_j = \frac{\sum_{i=1}^{|\mathrm{E}_{k,l}|} \mathrm{I}_s^j[i]}{max(\mathrm{I}_s^j) \times |\mathrm{E}_{k,l}|} \quad (1)$$

$\mathrm{E}_{k,l}$: voxels centerline between C_k and the encountered component C_l.
I_s^j: results from Sato's filter with the jth set of parameters.
$\mathrm{I}_s^j[i]$: intensity with $i \in \{1, |\mathrm{E}_{k,l}|\}$ of each voxel of $\mathrm{E}_{k,l}$ in I_s^j.

Results

Performance of vessels segmentation on 15 CT and one MRI:

Table 1: Results on CT and MRI.

CT	Accuracy	Specificity	Sensitivity
	0.97±0.01	0.98±0.01	0.69±0.10
	Precision	False Positive Rate	False Negative Rate
	0.61±0.07	0.01±0.01	0.32±0.09

MRI	Acc	Spec	Sens	Pre	FPR	FNR
hepatic	**0.98**	0.98	0.54	0.30	0.010	0.45
portal	**0.97**	0.98	0.70	0.51	0.002	0.32

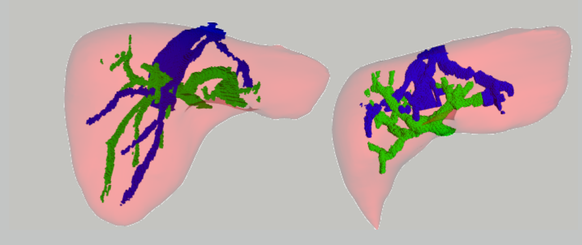


Figure 3: Results of hepatic vein (blue) and portal vein (green) extraction on MRI of patients with advanced cirrhosis

Performance of hepatic and portal veins skeletonization on one MRI:

$$\mathrm{M}_0 = \frac{|\mathrm{S}_{partial}|}{|\mathrm{I}_{Ref}|} \quad (2)$$

M_0: overlap of the detected skeleton $\mathrm{S}_{partial}$ within the reference vascular segmentation image I_{Ref} [2]

Table 2: Overlap rate $\mathrm{M}_0(\%)$ and mean distance $\mathrm{M}_d(mm)$ with the reference skeleton

Hepatic vein	$\mathrm{M}_0(\%)$	$\mathrm{M}_d(mm)$	Portal vein	$\mathrm{M}_0(\%)$	$\mathrm{M}_d(mm)$
	95.46	8		100	7

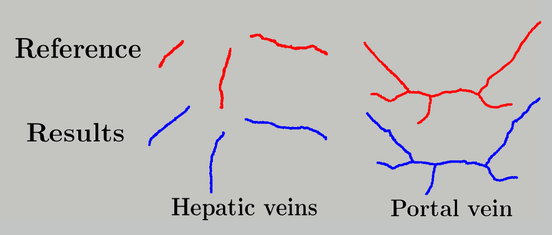


Figure 4: Results on one MRI

This step is essential to construct the Couinaud scheme whose method will be presented in a future work

Discussion & future works

- Automatic 3D liver vessels segmentation based on partial skeletonization process
- Efficient on MRI and CT even in case of advanced disease
- Segmentation of enough vessels to obtain a Couinaud representation
- Add comparisons with skeletonization process
- Evaluate more results on MRI
- Create gold MRI standard annotations for benchmarking
- Evaluate the Couinaud representation on CT and MRI

References

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