Enhancing the automatic segmentation and analysis of 3D liver vasculature models

Yassine Machta, Omar Ali, Kevin Hakkakian, Ana Vlascenau, Amaury Facque, Nicolas Golse, Irene Vignon-Clementel

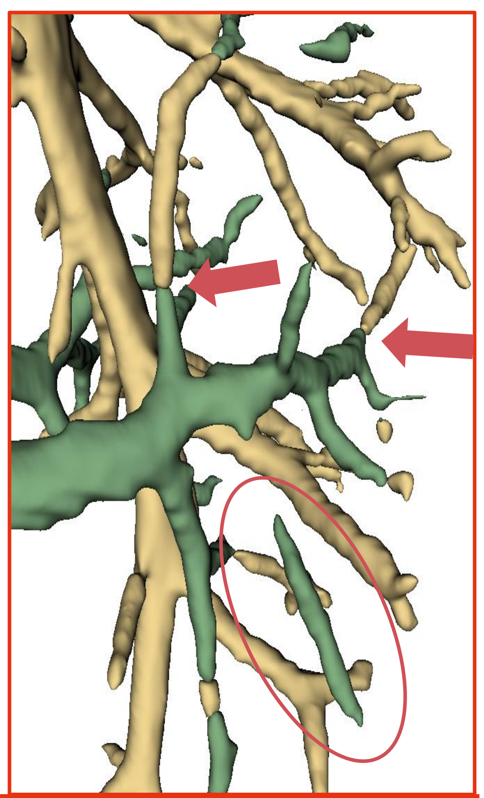
Introduction

Having accurate 3D models of liver vessels (portal and hepatic trees) is an important part of surgical liver resection. Such models also allow to study the morphometry of different vascular trees. In this research we aimed to :

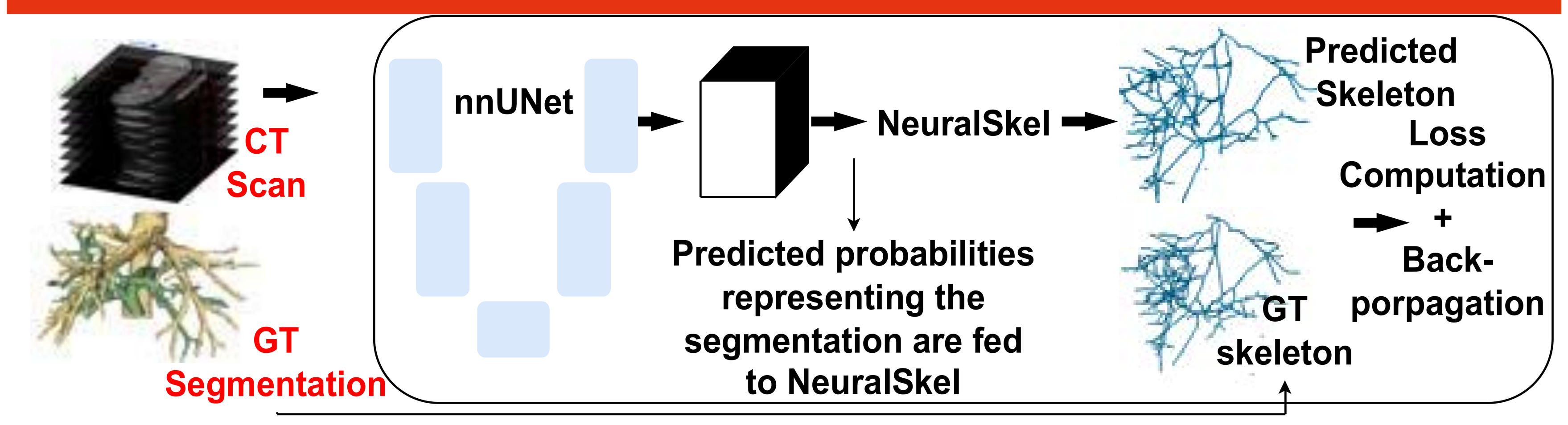
Enforce connectivity and obtain more accurate segmentations. Using topological loss functions (ClDice)[1], We innovate by trying a **new method of skeletonization**.

Reduce **the burden of annotating data** multiple labels by **automating label propagation** and obtaining a segmentation for distinct vessel trees [2]

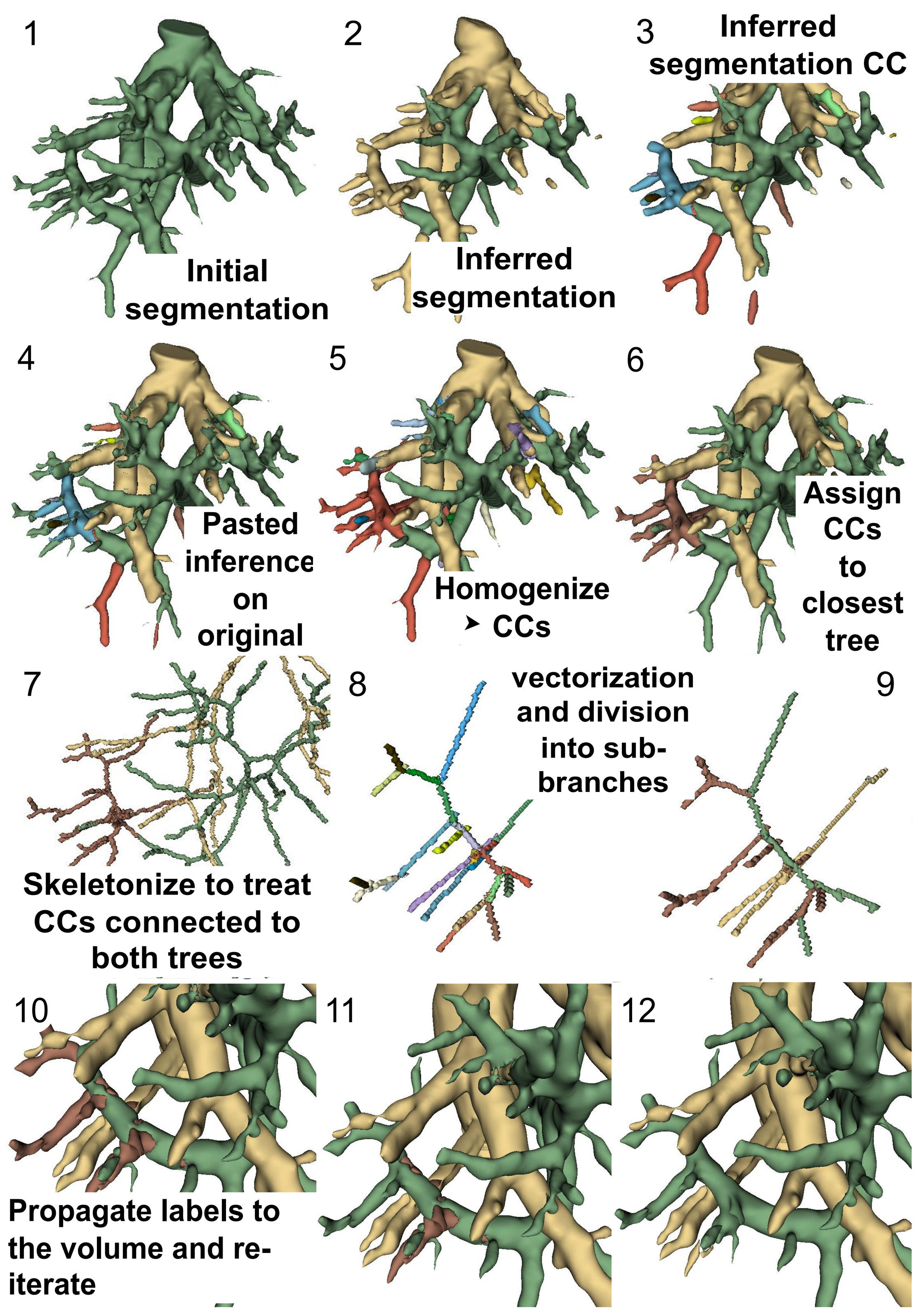
To improve **our understanding of the liver vessel structure**, we use the previously obtained segmentation to **extract morphological properties** of the liver's vessel trees



Methods



- Skeletonization **Unet** (NeuralSkel) in the ClDice loss module



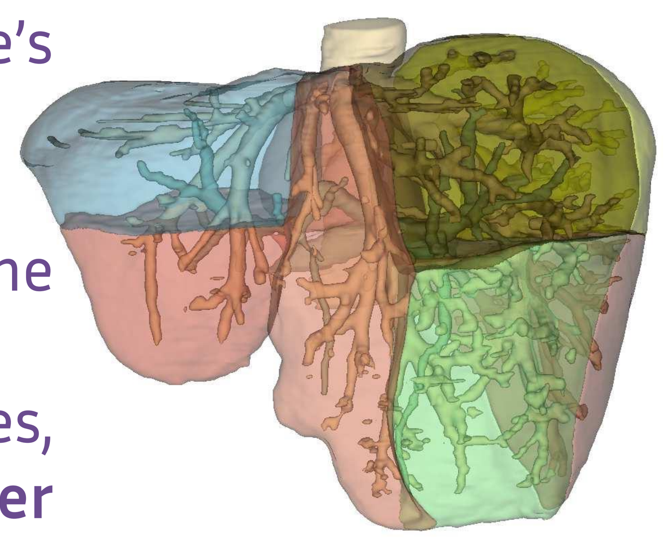
Obtain an **initial segmentation** out of a Unet trained with 2-label IRCAD[3] cases (2)

Find **connected components** (CCs) and **assign** them to the **closest** main tree

When unsure which tree, **study the angles of the branches** to evaluate likeliness

Propagate the labels from the skeleton to the segmentation

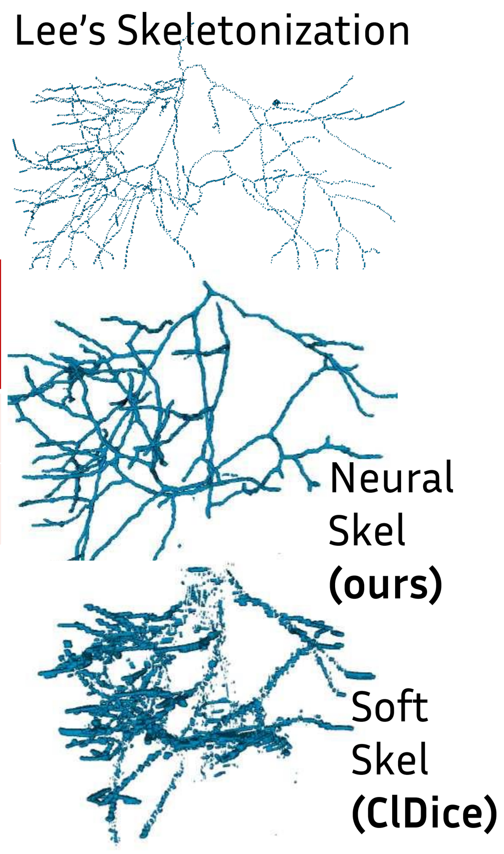
- Extract the **centerline** from each tree's segmentation
- Transform the **centerline into a graph**.
- Find the **origins by finding the leaf** of the graph that is **outside the liver volume.**
- Graph search to single out branches, compute their **radius, lengths and other properties**



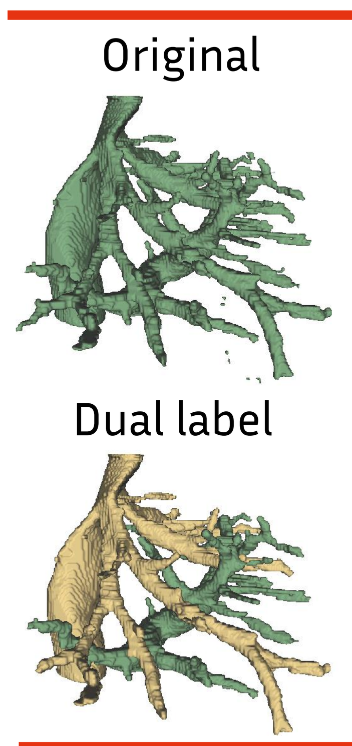
Results

The neural Skeletonization method **achieves better results** than the morphological ones when **comparing to lee's skeletonization**

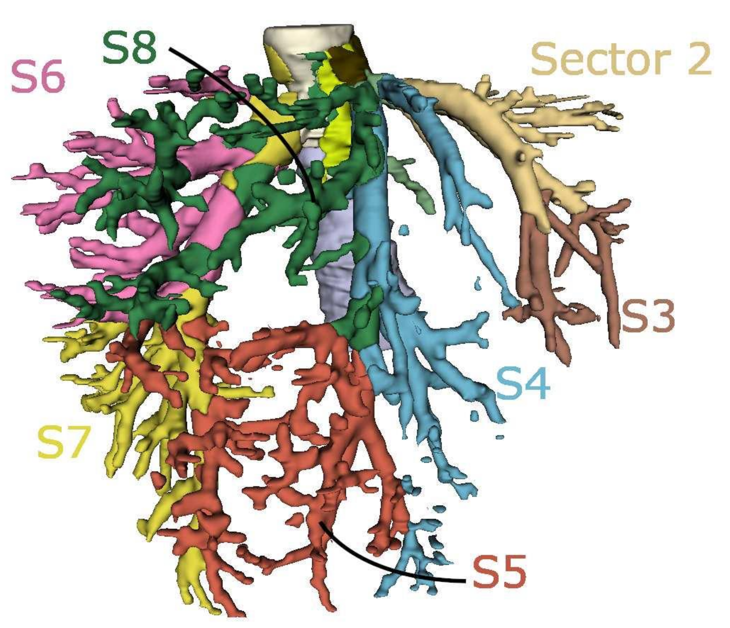
Model	Dice (%)	CLDice(%)	SurfaceDice (%)	Hausdorff (mm)
Soft-Skel	76.05(5.2)	77.95 (5.1)	83.62 (5.1)	61 (51.7)
Neural-Skel	75.5 (6.0)	76.75 (5.8)	82.4 (6.0)	70 (53.6)



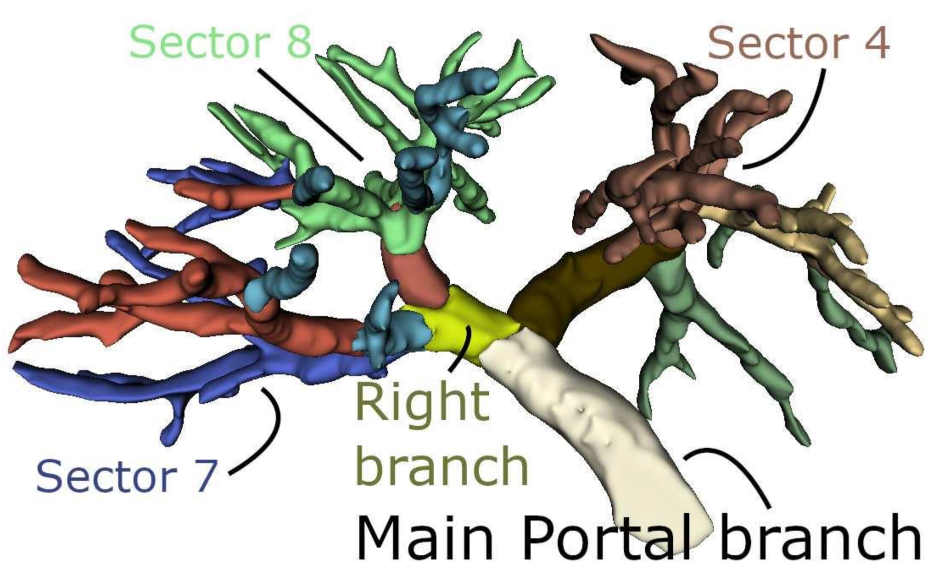
The segmentation results using both methods are not that different



- Evaluated by surgeons, achieves a score **of 35/62 satisfying separations.**
- **18 having minor issues** that can be fixed quickly thus reducing the annotation burden **(total 53/62)** .
- New data cases increase score in segmentation metrics by 4 points



First dataset to **label the trees' subbranches**. (portal and hepatic)



Using these subbranches, we extract data about the vessels' **morphological properties**

Conclusions and discussions

- Skeleton continuity **is not that important** for morpholgical loss.
  Neural-Skel is **a general purpose** skeletonization for tubular structures. **Can be faster** than Lee's method
- The label propagation tool has a **good enough accuracy** when it comes to **automating** part of the annotation process
- We collect a **dataset of morphological properties** and a new segmentation volumes **labelling the liver's vessel trees' subbranches**

[1] S. Shit, J. et al, ClDice-a Novel Topology-Preserving Loss Function for Tubular Structure Segmentation.
[2]P. Bilic et al., The Liver Tumor Segmentation Benchmark (LiTS)
[3] L. Soler et al, 3D image reconstruction for comparison of algorithm database: A patient specific anatomical and medical image database