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1 The 3D Slicer RVXLiverSegmentation plug-in for  
2 interactive liver anatomy reconstruction from medical  
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## Summary

12 RVXLiverSegmentation is a 3D Slicer ([Kikinis et al., 2014, 2022](#)) plug-in aiming at speeding-  
13 up the annotation of liver anatomy from medical images (CT -Computerized Tomography-  
14 scans or MRI -Magnetic Resonance Imaging- for instance). This organ has particular anatomy  
15 and physiology; within its parenchymal volume, the liver receives blood from the portal vein and  
16 hepatic artery (the former one being the most visible in medical images), and delivers filtered  
17 blood through the hepatic veins, toward inferior vena cava. The blood vessels subdivide into the  
18 liver as fine vascular tree structures, which makes the segmentation difficult, especially in the  
19 case of MRI. To facilitate this task, our plug-in is decomposed into modules dedicated to the  
20 segmentation of the liver volume, inner vessels and possible tumors. RVXLiverSegmentation  
21 can be downloaded from ([Pelletier et al., 2022](#)) or installed from the 3D Slicer software as  
22 an official module.

## Statement of need

24 Annotation plays a key role in clinical practice and in the creation of reference datasets that  
25 are useful to evaluate medical image processing algorithms and to train machine learning  
26 based architectures ([Park et al., 2020](#)). Since softwares embedded into acquisition machines  
27 are not always accurate for this task, researchers and engineers have developed more and  
28 more interactive annotation and segmentation tools ([Wang et al., 2021](#)). But, despite these  
29 developments, annotated datasets are still missing for many clinical applications. The creation  
30 of the RVXLiverSegmentation plug-in has been motivated by the dramatic absence of a public  
31 dataset providing hepatic MRI data together with their ground-truth segmentations of liver  
32 anatomy. By creating our own dataset, we have developed a plug-in specifically dedicated to  
33 this task, that can be used publicly by any user for the construction of new datasets related to  
34 liver pathologies. Moreover, our plug-in has numerous clinical applications, such as the hepatic  
35 volumetry, which is becoming increasingly important in view of the growing number of chronic  
36 hepatopathies requiring transplants or hepatectomies ([Lim et al., 2014](#)).

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## 37 Overview of RVXLiverSegmentation

38 For research purpose needing annotation of liver anatomy from medical images, the RVXLiver  
39 Segmentation provides 7 main tabs:

- 40 ■ loading and managing medical imaging data;
- 41 ■ liver segmentation;
- 42 ■ annotation of portal veins and segmentation;
- 43 ■ editing portal veins segmentation;
- 44 ■ annotation of inferior vena cava and segmentation;
- 45 ■ editing inferior vena cava segmentation;
- 46 ■ tumor segmentation.

47 Once the medical image data is loaded into the 3D Slicer interface, the liver can be segmented  
48 with the associated tab, either by using interactive tools (such as region growing approaches)  
49 or by an automatic deep learning based algorithm (for CT scans only), as exposed in Figure 1.  
50 Then, the reconstructions of hepatic vessels (portal vein and inferior vena cava) are based on  
51 tree structures interactively built by the user, who places the nodes of important branches and  
52 bifurcations (with specific anatomical nomenclature) into the scene of the medical image to  
53 be processed. After this step, a VMTK (Vascular Modeling Tool Kit) (Antiga et al., 2008)  
54 module segments the vessels by using those graphs as initialization patterns (see Figure 2);  
55 also, the user can verify and edit this segmentation. The last tab allows the user to segment  
56 interactively possible tumoral tissues with dedicated tools.

57 This tab also permits to export the complete scene, comprising:

- 58 ■ segmentation label maps (liver, inferior vena cava, portal vein, tumors);
- 59 ■ portal vein and inferior vena cava intersection positions (fiducial CSV and adjacency  
60 matrix);
- 61 ■ the complete scene as a MRB file.

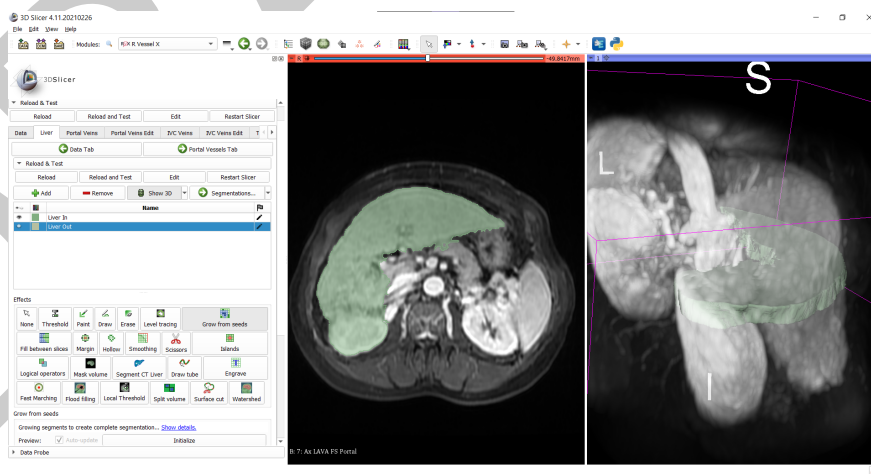


Figure 1: Liver segmentation tab.

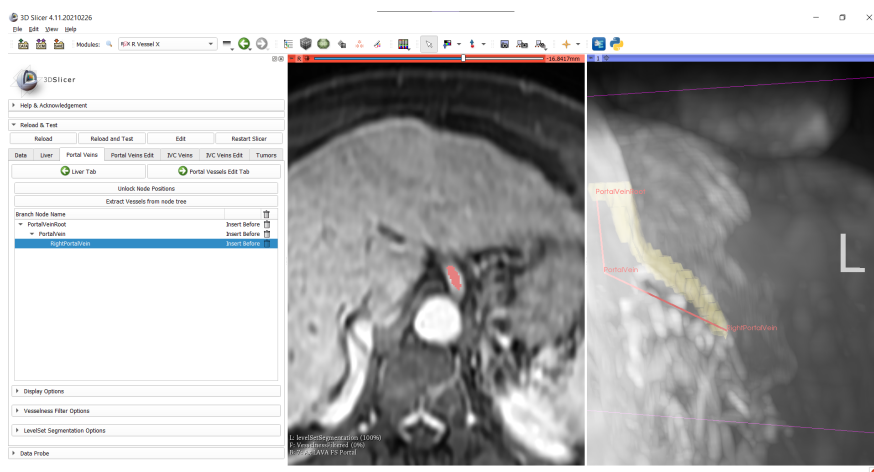


Figure 2: Tab for portal vein annotation and segmentation.

## 62 Preliminary results obtained with the plug-in

63 A first version of the RVXLiverSegmentation has been employed for segmenting livers from  
 64 dynamic-contrast enhanced MRI data in order to test and evaluate a combined registration-  
 65 segmentation algorithm, described in (Debroux et al., 2020). We have also compared the time  
 66 of segmentations obtained by RVXLiverSegmentation and by the embedded image processing  
 67 tool General Electric AW solution (Server 3.2). Our first results (Lamy et al., 2020) have  
 68 shown a significant speed-up in the segmentation of liver volume and inner vessels. The  
 69 following averaged times were measured with a first cohort of 6 “healthy” patients (*i.e.* not  
 70 suffering from any hepatic disease) and 4 patients with liver cancer and cirrhosis.

Healthy patients	RVXLiverSegmentation	General Electric AW
Liver	3 ± 2 mins	10 ± 5 mins
Vessels	5 ± 3 mins	30 ± 10 mins

Cirrhotic patients	RVXLiverSegmentation	General Electric AW
Liver	4 ± 2 mins	15 ± 10 mins
Vessels	7 ± 4 mins	35 ± 15 mins

## 71 Future works

72 We first would like to integrate advanced deep learning models for liver and hepatic vessels  
 73 segmentation (Affane et al., 2021) into our RVXLiverSegmentation plug-in, in order to provide  
 74 automatic reconstructions that can be then edited by the user with the other tools proposed in  
 75 the plug-in and in 3D Slicer. Another important work concerns the VMTK module, which  
 76 needs more adaptations for MRI processing. As an example, the Frangi filter is employed as  
 77 a pre-processing step (as a vascular enhancement algorithm), while other approaches could  
 78 be opted instead (Lamy et al., 2021). Finally, a more complete evaluation protocol will be  
 79 conducted with our plug-in, compared to commercial solutions, by taking into account larger  
 80 patient cohorts.

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