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The 3D Slicer RVXLiverSegmentation plug-in for interactive liver anatomy reconstruction from medical images

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Software

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Summary

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

Statement of need

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

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Overview of RVXLiverSegmentation

For research purpose needing annotation of liver anatomy from medical images, the `RVXLiverSegmentation` provides 7 main tabs:

- loading and managing medical imaging data;
- liver segmentation;
- annotation of portal veins and segmentation;
- editing portal veins segmentation;
- annotation of inferior vena cava and segmentation;
- editing inferior vena cava segmentation;
- tumor segmentation.

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

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

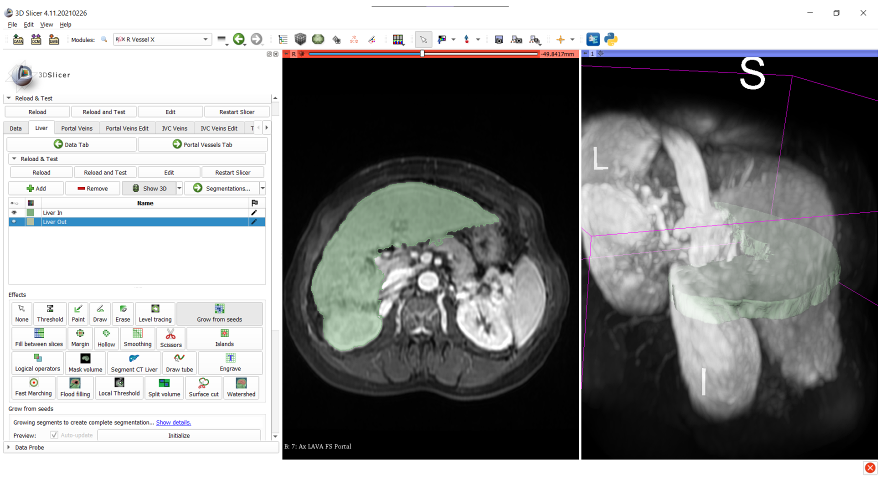

Figure 1: Liver segmentation tab.

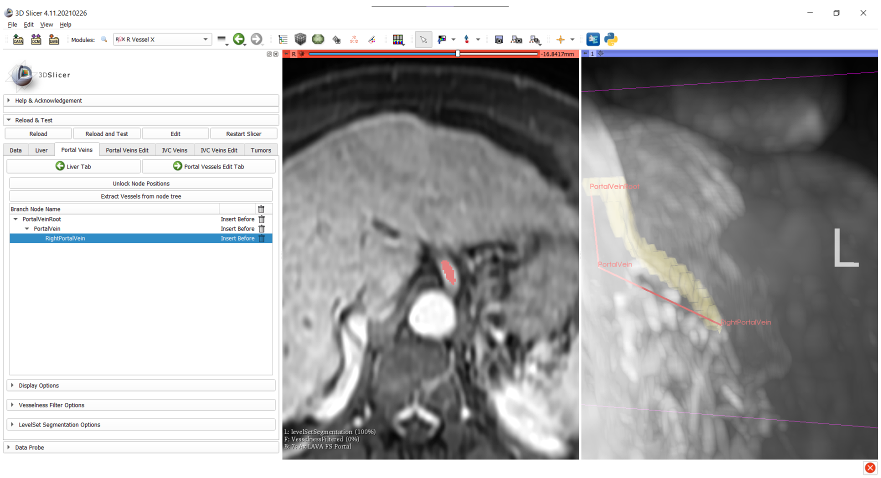

Figure 2: Tab for portal vein annotation and segmentation.

Preliminary results obtained with the plug-in

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

Future works

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

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