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Registrierung von verschiedenen Phasen kontrastmittelgestützter MR Daten für die Leberchirurgie

Registration of different phases of contrast-enhanced MR data for liver surgery

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Purpose

The exact location of intrahepatic vessels in relation to a tumor is an important issue in oncological liver surgery. A sufficient blood supply via the portal veins and blood drainage via the hepatic veins has to be ensured after tumor resection. Computer-aided preoperative surgery planning based on CT or MR data can help to achieve this aim. Intraoperatively the surgeon can be supported by an 3D ultrasound-based navigation system to transfer the plan accurately on the patient in the OR. In this case the preoperative vessel models have to be registered to the intraoperative 3D B-mode or Powerdoppler ultrasound data of the vessels. The problem is, that portal and hepatic veins are imaged in two consecutive acquisitions: In the portal venoues (PV) phase and in the late venous (LV) phase of the contrast enhancement. Accurate registration of PV and LV phase has to be performed in order to compensate for different respiration states of the patient during image acquisition.
The aim of this contribution is to investigate the amount of misregistration and how well it can be improved by automatic intensity-based registration methods.

Materials and Methods

A rigid and a non-rigid registration approach has been implemented using Normalized Mutual Information as the similarity measure. The rigid implementation is the standard multiresolution method of Studholme et al. To improve the accuracy only voxels inside the liver were considered in the similarity measure. This was easily possible because a segmentation of the liver in one phase was made for the planning anyway.

The intensity-based non-rigid registration algorithm is an implementation of the technique introduced by Rueckert et al. and Rohlfing et al. The algorithm determines the set of parameters of a deformation T that maximizes the image similarity measure. The transformation model is a free-form deformation defined on a discrete uniform control point grid (CPG) with cubic B-spline interpolation between adjacent control points.
The optimization of the similarity measure is done in a combined multiresolution (data pyramid) and multigrid (parameter pyramid) fashion in order to avoid local minima. It turned out that it was necessary to preprocess the images in order to reduce the MRI intensity inhomogeneity using a method of Likar et al.

Results

We applied the rigid and non-rigid registration method to 5 contrast-enhanced MRI pairs of the liver using a VIBE sequence with 2.5 mm slice thickness. The resulting registrations were evaluated by visual inspection of all slices with the intersecting vessel surface of the other phase and interactive measurement of deviations. We used the transformed vessel centre lines of the portal veins to quantify deviations between rigid (masked and unmasked) and non-rigid registration. Rigid registration with masking leads to significantly more accurate results than without masking. The RMS deviation between masked and unmasked registered centre lines was 3.5, 5.7, 5.2, 5.6 and 5.8 mm. The RMS deviation between masked rigid registration and the start position of the centre lines was 4.6, 7.1, 10.0, 11.0, 11.1 mm. In all cases masked rigid registration provides quiet accurate results. The remaining inaccuracies were in the range of 2-3 mm at some vessel segments. The RMS deviations between rigidly and non-rigidly registered centre lines was 1.5, 2.4, 1.9, 3.0 and 2.3 mm. In all 5 cases non-rigid registration further improves accuracy, accept for minor deviations for some vessel segments in case 4.

Conclusion

The masking of the liver significantly improves rigid registration and leads in many cases to accurate results. Using inhomogeniety correction non-rigid registration further improves accuracy and provides very sufficient results.

Figures

1. Original position of vessels.
2. Rigidly (masked) registered liver phases.
3. Non-Rigidly registered liver phases.