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Segmentation of blood vessels in 3D Ultrasound-Datasets by a Model-Based Region Growing Algorithm

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Introduction:

Image based navigation is an important tool for the orientation during minimally invasive surgery. The registration of the preoperative image data for orthopaedic surgery is nowadays mostly based on anatomical landmarks and bone surface points. Only the bony structures can be registered reliably with these systems. Since the location of the patient has changed after acquiring the preoperative dataset, soft tissue such as vessels, sinews or muscles might be disarranged. For performing the surgery exactly, the current position of soft tissue can be very important. Our aim is to segment blood vessels in intraoperative 3D ultrasound datasets in order to support the surgeon's orientation during surgery. After registration of intraoperative 3D ultrasound data with preoperative data [1], we can superimpose the segmented blood vessels at their current position with the registered bone structures.

Most of the current segmentation methods like thresholding or region growing fail in segmenting blood vessels in ultrasound images because of two main reasons: The contour of a vessel is non-continuous due to shadowing effects and speckle, and the gray value is not constant all over the vessel. By modifying the convential region growing algorithm with an assumed vessel model, the proposed method compensates most of the artifacts in the ultrasound image data

Methods:

We present an algorithm for the segmentation of blood vessels in 3D ultrasound datasets, which is based on the region growing segmentation method. The algorithm is combined with knowledge of a vessel model: we assumed that a vessel is a bendable cylinder. The radius and curvature are constant or vary slowly and continuously. First, a seed point and a threshold for the maximum deviation of the gray value were calculated, and the radius of the vessel was estimated by acquiring a tracked Doppler-mode ultrasound image. Second, the algorithm verified for the six next direct neighbours whether the gray value derivation was smaller than the threshold. All neighbours which had fulfilled the condition were used to continue, until the number of segmented voxel covered more than a predefined volume. By using the principal component analysis, the direction and radius at the barycenter of the scatter plot were estimated. For the next added voxels, their distance to the normal vector of the direction was compared to the estimated radius of the last scatter plot. If the distance was larger than the radius, the allowed deviation maximally for the next added voxels was reduced by a factor depending on the distance. Finally, the model based region growing algorithm delivered the parameters, characterizing the vessel as a bendable cylinder, by the radius and the normal vector of the direction at the barycenter of the volume parts.

The 3D ultrasound dataset was acquired with a Toshiba ultrasound machine using a linear 7.5 MHz transducer and a NDI Polaris Tracking System.

Results:

The implemented algorithm was evaluated segmenting the vena saphena magna on a 3D freehand ultrasound dataset of the knee. Figure 1.a) shows the 3D ultrasound data set of the segmented vessel is depicted in red.

To verify the algorithm, the vena was segmented manually. The two resulting segmented volumes were compared by the calculated center and the estimated parameters of the resulting ellipse by cutting a cylinder in discrete section planes. The standard deviation of the estimated center und radius is smaller than 5%. In figure 1.b) the manually and automatic segmented vessels are shown. The computation time for segmenting the vessel was negligible for real time applications.

Discussion:

The presented algorithm was fast and able to run on 3D datasets. It worked independent of the radius or gray values of a vessel in the ultrasound image. The chance that the recursive algorithm finds a leakage in the contour of the vessel was minimized by using our model in comparison to conventional segmentation algorithms such as region growing.

We think that the combination of registered bone structures from preoperative image data and segmented soft tissue from intraoperatively acquired ultrasound data can improve the orientation of the surgeon.

In future work, the algorithm will be tested in preclinical studies and expanded on alternative models to segment other types of soft tissues.

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Keywords:

Image segmentation, ultrasound, region growing, vessel

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