Segmenting Labeled Intervertebral Discs in Multi Modality MR Images

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1 Method

The task it so segment seven well-defined intervertebral discs (IVDs) in multi modality MR images. For this we propose a method specifically designed to be trained on a very small training set. The key idea is to reorient sections around the individual IVDs to a standard orientation in order to be efficiently segmented by an IVD-agnostic V-Net [2]. This leads to the following four step approach, as illustrated in Fig. 1.

1.1 Localizing and labeling IVDs

First, we use our approach proposed in [1] to localize and label the IVD's center of mass positions. It is a general method to localize and label arbitrary key points by applying landmark-specific localizers (e.g., random forests or FCNs, here random forests) followed by a conditional random field (CRF) to model the global shape. It has been applied to different dimensionalities (2D, 3D) and modalities (X-ray, CT) already, but has neither been applied so far to MR images nor to a multi modality setup. Here, we extend our method to work with multi modality (i.e., multi-channel) MR images by correspondingly increasing the depth of the image volume (4 in this case instead of a single channel volume). An additional modification compared to our previous work applies to the CRF: Instead of using the proposed binary potentials, we use ternary potentials to increase the rotation and scaling invariance in combination with unary potentials related to

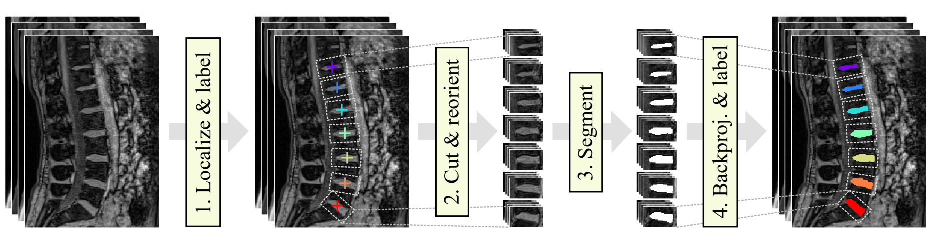

Fig. 1: Illustration of our four step approach to predict labeled IVD segmentations.

the localizers. I.e., we use a Gaussian distribution to model the ratio between two distances and a von Mises distribution to model the relative angle between two vectors projected to one plane. Applying this method we obtain a labeled localization hypothesis for each IVD.

1.2 Sampling reoriented IVD sections

Given the IVD locations predicted by the previous step, we sample small reoriented fixed-size sections around each prediction. The size (6 x 5 x 3 cm) is chosen such that the classes are balanced and the sections are reoriented such that the IVDs are level inside the sections (see second step in Fig. 1). PCA was applied to the training segmentations to find the standard orientation of each IVD.

1.3 Segmenting IVDs

As third step, we perform the actual segmentation of the disc tissue using the fully convolutional network V-Net [2]. We use the standard architecture and train it using the setup proposed by the authors. A mini-batch size of 7 is used and the optimization is carried out for 5000 epochs. To tackle the problem of few training cases, we train one label agnostic model to segment all seven IVD sections, effectively using the network to discriminate disc tissue from non-disc tissue (2-class problem instead of 8-class problem). To further accelerate the performance, we increase the training set size even more by a factor of 10 using data augmentation in the form of translation and rotation. Note that histogram matching is performed prior segmentation as data normalization.

Finally, the resulting segmentations are back-projected into the original label space and relabeled according to the label predicted by the CRF in first step.

1.4 Evaluation

We used an 8-fold cross validation setup (14 training images, 2 test images) to estimate essential parameters and to evaluate the training performance. On average, our method achieves a Dice coefficient of 0.894 and a mean surface distance of 0.45 mm, while processing one image in (on average) less than 10 s. For testing, we use an ensemble of our 8 models to improve robustness.

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