Comparison of Deep Learning and Shape Modelling for Automatic CT-based Liver Segmentation

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Introduction

Liver segmentation is required for planning of numerous medical procedures. Automatic liver segmentation, which is challenging due to liver's varying appearance, would allow for a speed-up and reproducibility of the planning process. We compared two automatic liver segmentation methods employing fully convolutional neural networks (FCNN) and statistical shape models (SSM).

Material and Methods

Data

- 219 CT scans

Reference liver segmentations were created semi-automatically by qualified medical staff using live-wire-based algorithm [1].

Statistical Shape Model

- Point correspondences established with the MDL algorithm [2]
- Landmark distribution refinement [3]
- Multi-scale segmentation pipeline
- Activate Shape Model and Deformable Model search modes [4]

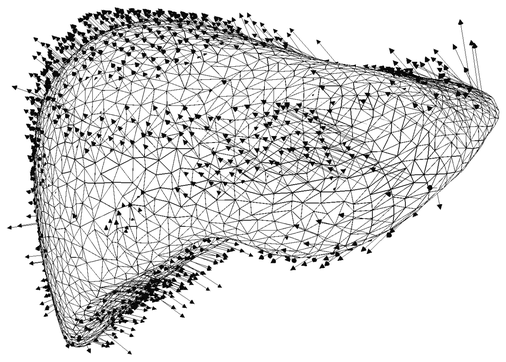

Figure 1: Visualization of the statistical shape model and forces attracting the model to the liver boundary.

Convolutional Neural Network

- 2D CNN trained with axial slices resampled to 2 mm
- U-net architecture with 4 resolution levels [5]
- Receptive field of 99 voxels
- 7 781 826 trainable parameters

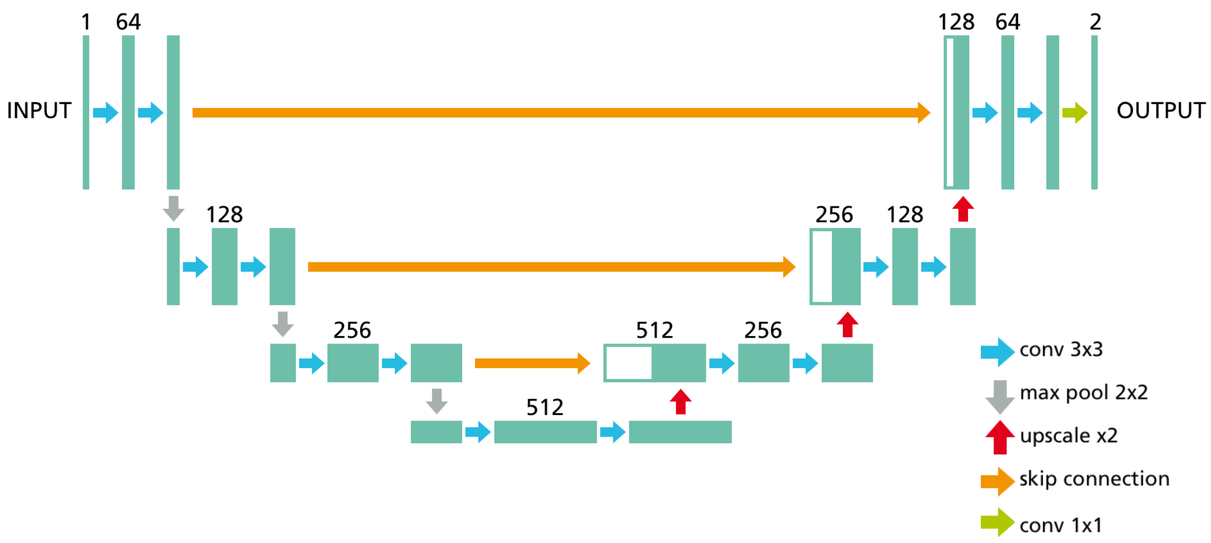

Figure 2: U-net architecture with four resolution levels. The numbers on the top of layers are corresponding to the channel count.

Evaluation and Results

We evaluated both methods on 40 CT volumes. Three cases were excluded from the evaluation, where the SSM-based approach failed.

Performance measures

- *Relative volume error*

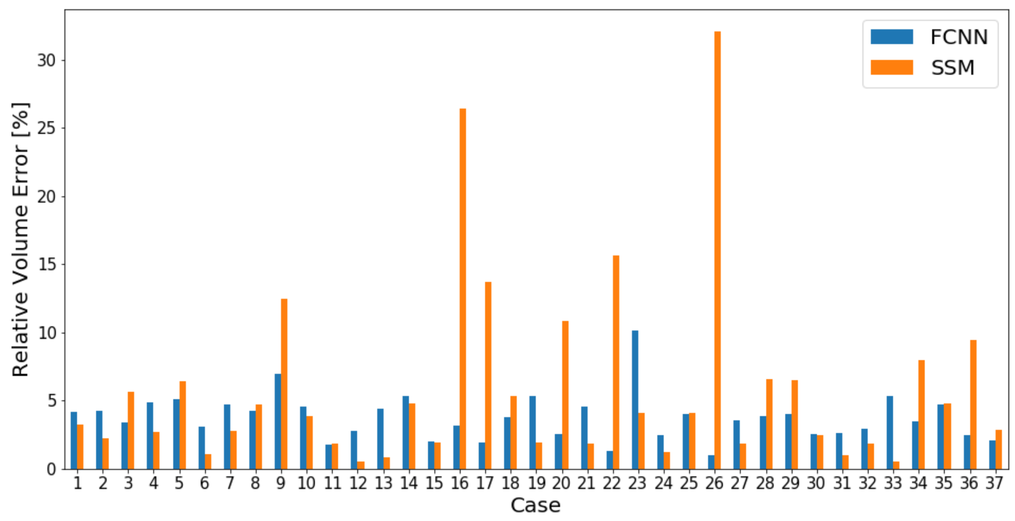

Figure 3: Relative volume error of the FCNN- and SSM-based methods.

- *Elapsed time*
  - FCNN 3±1s
  - SSM 39±8s

Figure 4: Example segmentations produced by FCNN (orange) and SSM (white) compared with reference (green).

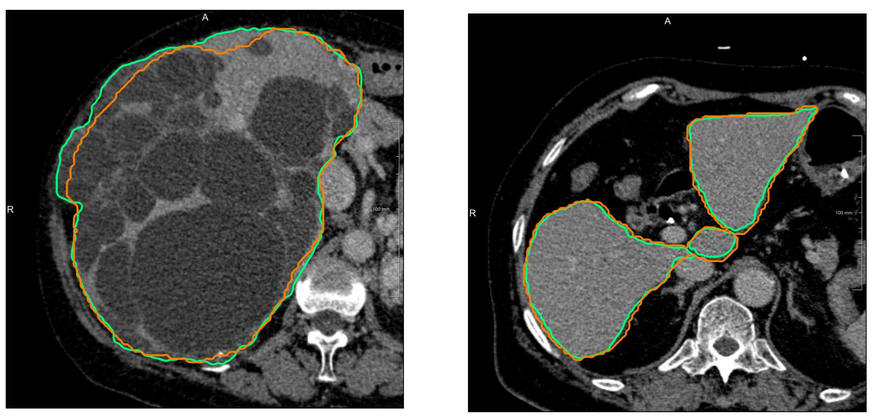

Figure 5: Cases where the SSM-based approach failed to segment the liver: polycystic (left) and resected (right) case.

Conclusions

- Both FCNN- and SSM-based methods compute liver volumes with an acceptable accuracy.
- The FCNN-based method is significantly faster and more robust than the SSM-based approach.

References

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