Automated Segmentation of Knee Bone and Cartilage from MRI

Combining Benefits of Convolutional Neural Networks and Statistical Shape Models

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Abstract

We propose a segmentation method for femoral and tibial bone as well as for its respective articular cartilage from MRI. It combines the shape knowledge of Statistical Shape Models (SSM) with the strong classification capability of Convolutional Neural Networks (CNN), namely a variant of the well known U-Net ([RFB15]). In contrast to [SKL+10] the proposed method does not rely on heuristic cost functions to adjust SSMs, since it is only fitted to a binary mask.

Methods

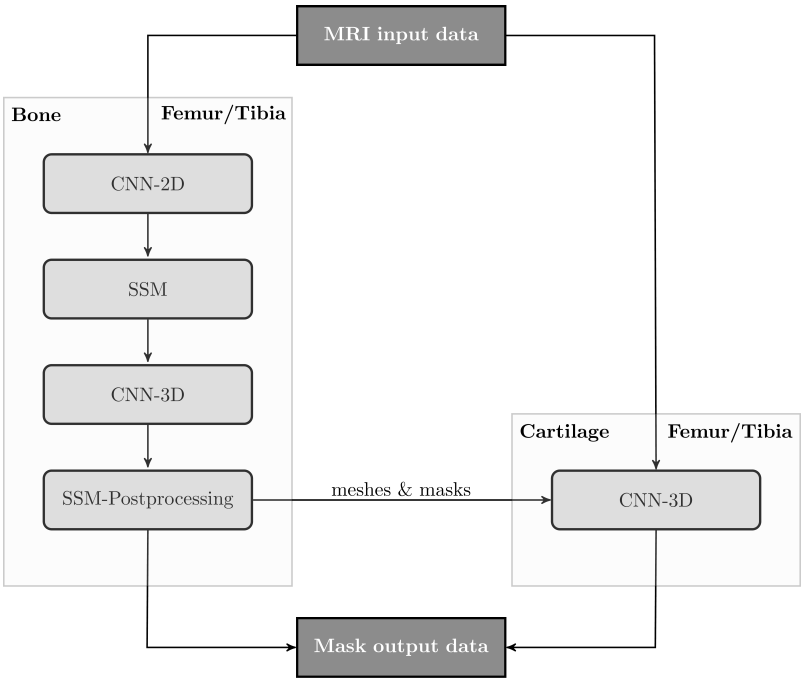

Figure I: Scheme of the proposed segmentation method.

Our segmentation pipeline handles each bony and each cartilaginous structure separately. At first femur and tibia are segmented by a slicewise acting network, afterwards an SSM is fitted to the outcome in order to achieve an

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anatomical plausible shape without caves and bulges. In the next step a CNN trained on cuboidal volumes along the bony surface (full 3D convolution) segments anatomical details like osteophytes. The fourth and last step again relies on SSMs. Since the 3D network acts only locally there might occur some segmentation errors in anatomically simple but w.r.t low contrast hard to segment regions, e.g. the bone shaft. This step detects those errors and corrects them with the help of the anatomical knowledge incorporated in an SSM.

The outcome of the bony strucures is used to deliniate the region of interest for the cartilage segementation, that is done again with 3D CNNs on cuboidal volumes of the cartilage. This is similar to the third step of the bone segmentation before. Fig. I gives an overview of the hole pipeline.

Data

The SKI10 data consists of MRI scans of different modalities and is divided into three parts:

- 60 MRI dataset for training,
- 40 MRI dataset for validation,
- and 50 MRI dataset for testing.

All used SSMs were build up from surface reconstrutions of the training sets only, as well as all CNNs where trained only on the training sets.

References

[RFB15] Olaf Ronneberger, Philipp Fischer, and Thomas Brox. U-net: Convolutional networks for biomedical image segmentation. In *MICCAI*, pages 234–241. Springer, 2015.

[SKL+10] Heiko Seim, Dagmar Kainmueller, Hans Lamecker, Matthias Bindernagel, Jana Malinowski, and Stefan Zachow. Model-based auto-segmentation of knee bones and cartilage in MRI data. In B. v. Ginneken, editor, *MICCAI Workshop Med Image Anal for the Clinic*, pages 215 – 223, 2010.