Automatic segmentation of knee muscles in 3D MRI data using deep learning

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Introduction

An international survey among 18 countries (755 million people) showed that 1,324,000 patients undergo knee arthroplasty annually [1]. Higher accuracy of prosthesis placement in surgical outcome can be achieved through image guided surgery, which require image segmentation of anatomical structures around the knee, in particular the muscles. During recent years, convolutional neural networks (CNN) has excelled in image recognition and segmentation tasks, also within medical segmentations in MRI [2, 3]. Our aim was to create and evaluate an automatic segmentation algorithm based on deep learning for muscles around the knee in 3D MRI data.

Subjects and Methods

The data was composed of 18 knee 3D fast spin echo, proton density weighted images with volume dimension 512x512x256, voxel spacing 0.3125x0.3125x0.6 mm (GE Medical Systems 3T Discovery MR750 scanner) [4,5]. The 3D CNN was created in Python 3.6.0 using the libraries Lasagne v.0.2.dev1 and Theano v.0.9.0 with cuDNN 5110.

In the algorithm the volumetric MRI data were sampled voxelwise, and a 3D patch of size 28x28x28 voxels was created around each sampled center voxel. The patches were used as input to the network trained by backpropagation guided by expert annotations. Output from the network was a probability of the voxel either belonging to foreground (muscle) or background (non-muscle). In order to reconstruct the volumetric image, each single voxel was sampled and forward passed into the network resulting in a likelihood map. **Fig. 1** shows the CNN architecture used for this segmentation. A global thresholding on the likelihood map followed by morphological opening resulted in the final segmentation. The constructed CNN classifier was trained using 14 patients, two validation and two testing, and evaluated with Dice similarity coefficient.

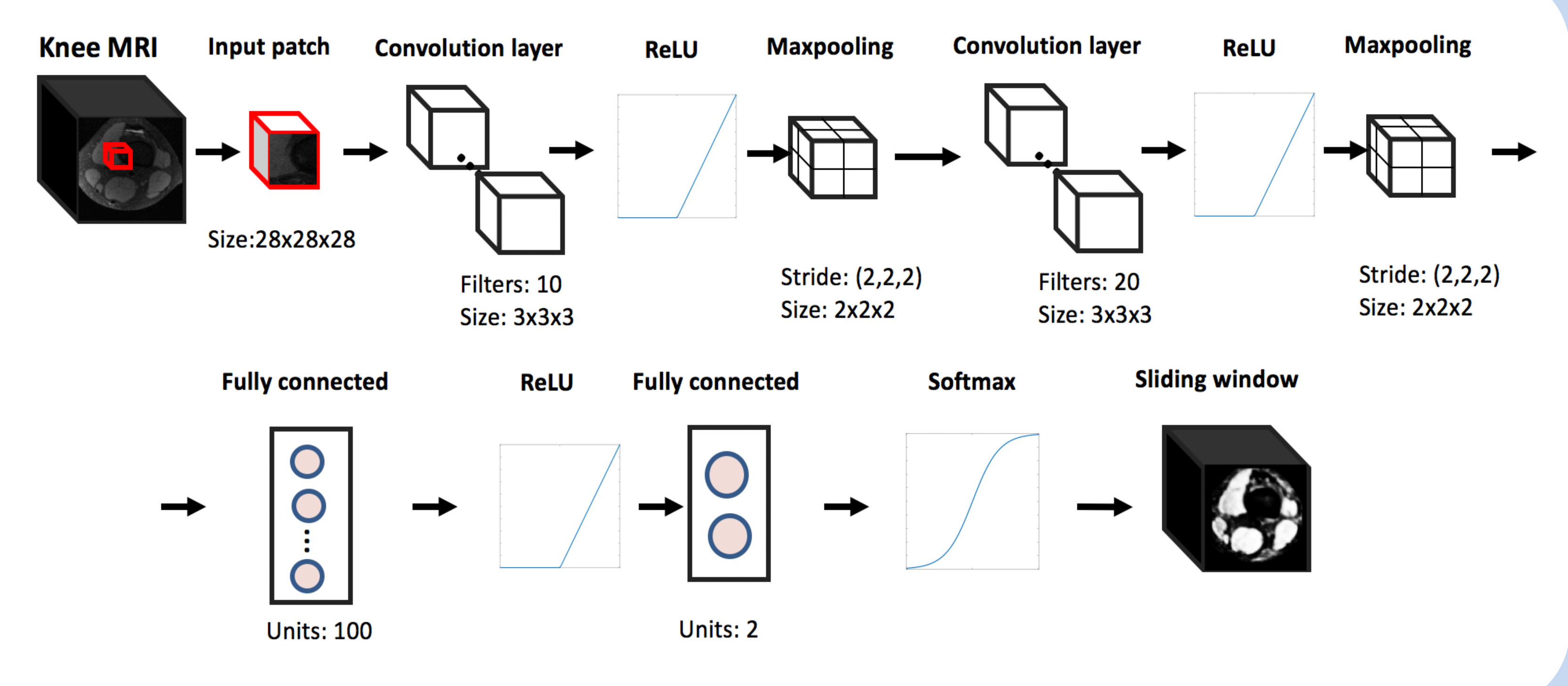

Fig. 1. The 3D CNN that was used for segmenting the muscles in knee MRI data.

Results

The resulting volumetric Dice coefficient on the test data was 0.88 for muscle voxels (foreground) and 0.97 for background voxels, in the whole volume. Mean slice per slice Dice coefficient can be seen in Fig. 3. It demonstates that the 3D CNN has easier to classify non-central and non-end muscles. An example slice segmented is shown in Fig. 2, the brighter voxel, the higher probability of it being classified as muscle.

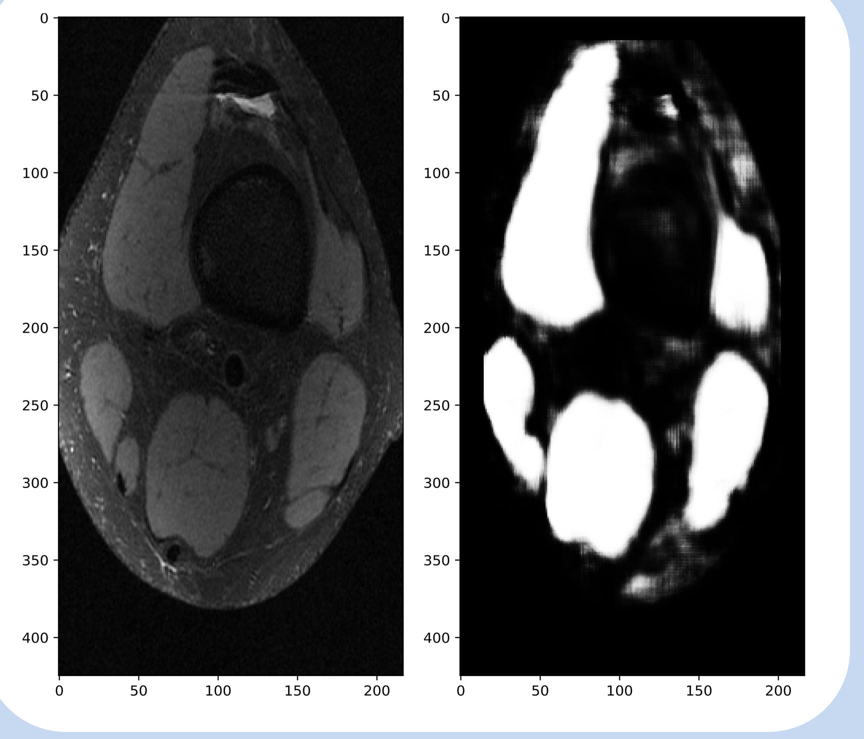

Fig 2. Example of an axial slice (**left**) and its corresponding network segmentation (**right**).

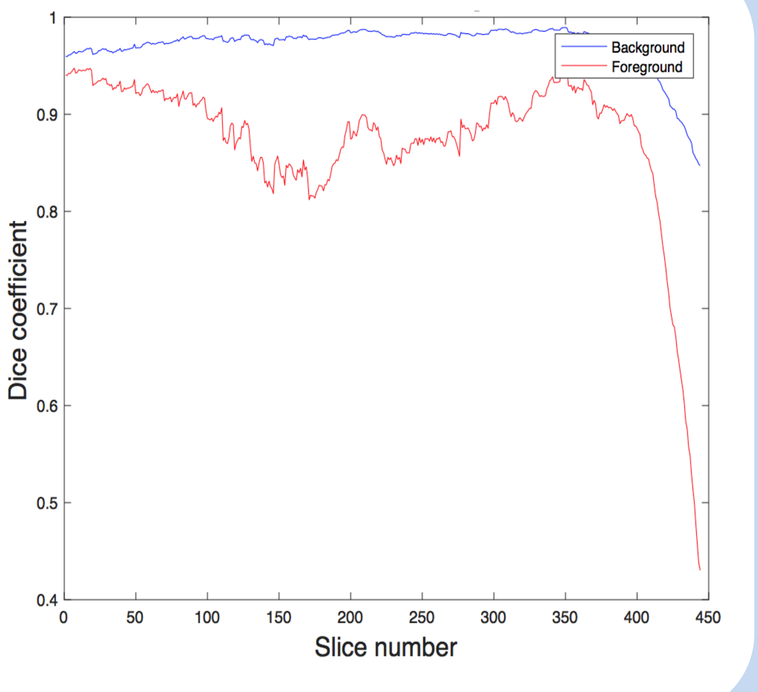

Fig 3. Mean Dice coefficient for each slice in the test volumes. We observe some variability on segmentation results, where the algorithm performs a bit worse in middle of the volume and bad in the end.

Discussion/Conclusion

The obtained level of segmentation accuracy suggests that 3D CNN based segmentation may be used in surgical planning and treatment. However, to avoid too optimistic results and overfitting, the classifier should be evaluated on a larger dataset and by k-folded cross-validation. Also the only postprocessing in the segmentation were through thresholding and morphological opening, which leaves room for improvement.

References

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