Improving Automatic Tibial Medial Cartilage Segmentation by Incorporating Femoral Cartilage Compartment

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Introduction

Osteoarthritis (OA) is one of the major health concerns among the elderly today, and it is characterized by the degradation of the articular cartilage typically in weight-bearing joints such as hips or knees. Currently, the treatment of OA is restricted to symptom control, because disease-modifying drugs are yet to be discovered [1].

The knee cartilage compartment where OA occurs most frequently is the tibial medial [2], and we aim for quantitative evaluation of this compartment. The intended use of the evaluation is for clinical studies of new treatments. A well established OA disease marker is the cartilage volume, which is obtainable once the cartilage is segmented, however manual delineation of the cartilage is time consuming and prone to inter- and intra-observer variability. We segment the cartilage using a voxel classification method which is fully automatic and performed directly in 3D, and we show that the segmentation of the tibial medial cartilage is significantly improved by incorporating a probability map of the femoral medial cartilage compartment into the classification scheme.

Methods

An Esaote C-Span low-field 0.18 T scanner is used for the acquisition of Turbo 3D T1 knee scans (40° flip angle, T_R 50 ms, T_E 16 ms) with fairly isotropic voxels: approximately 0.8×0.7×0.7mm^3. The data set consists of 139 knee scans from subjects that are both males (41%) and females (59%) between 22-79 years old, and the data set includes both healthy and osteoarthritic knees (diagnosed as being between 0 and 3 on the Kellgren and Lawrence index [3]). The scans are manually segmented by a radiologist for validation purposes. Of the scans, 25 are used for training the classifier and 114 for testing.

A two-class classifier is trained to separate the tibial medial cartilage voxels from the rest of the scan [4]. When the segmentation of tibial medial cartilage is stated as such a two-class classification problem, many false positives from the femoral cartilage will contribute to the classification result because of its resemblance to tibial cartilage, especially where the cartilage from the two different compartments are adjacent. In order to remove false positives from the femoral cartilage, a two-class classifier is trained to find femoral medial cartilage. The femoral medial cartilage probability map is then incorporated into the segmentation scheme in order to resolve ambiguities in cartilage compartment belonging.

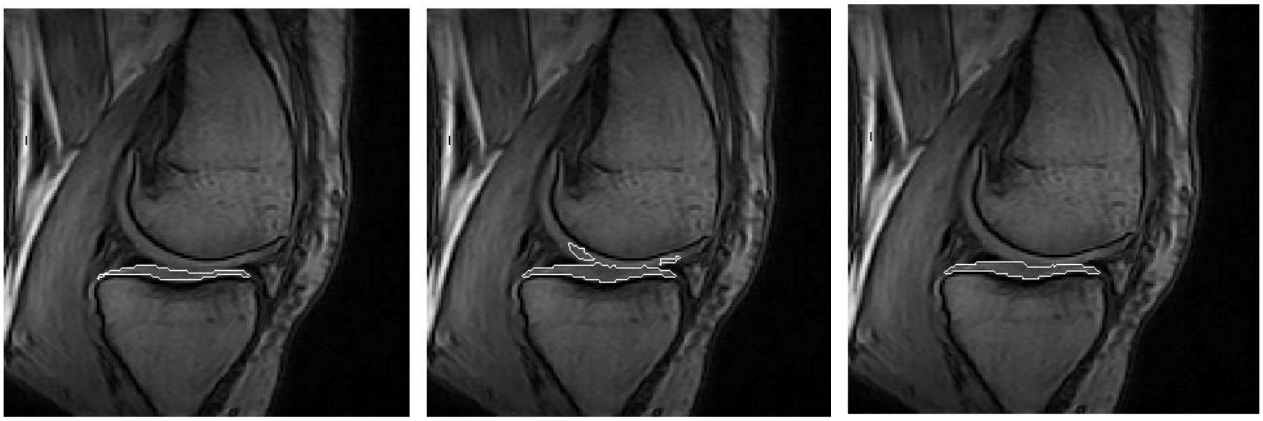

Figure 1. Left: manual segmentation by radiologist. Middle: standard two-class segmentation. Right: segmentation result improved by incorporating femoral cartilage probability map. A sagittal slice from a scan illustrating automatic tibial medial cartilage segmentation.

Results

The Dice volume overlap is a measure of how similar two segmentations are, it ranges from 0 to 1 where 0 means no correspondence and 1 is a perfect correspondence [5]. The Dice volume overlap between the two-class classifier and manual segmentations are 0.78 for the 114 scans. After the femoral cartilage probability map is incorporated the corresponding Dice volume overlap is 0.79, which is a statistical significant increase with a p-value of $6*10^{-8}$. The effect is illustrated in Figure 1.

The average volume of the manually segmented cartilage is 1750 mm^3, whereas the corresponding values for the two-class classifier and the classifier with probability map are 1970 (±300 st.d) mm^3 and 1900 (±290 st.d) mm^3 respectively.

Conclusions

By incorporating a femoral cartilage probability map the tibial medial cartilage classification scheme the volume overlap between manual automatic segmentations are significantly improved, and the volume estimates become more accurate. Because our segmentation method is fully automatic and because we use a low-field scanner which is much less expensive than a high-field scanner, our cartilage evaluation scheme can possibly become a useful tool in clinical studies involving OA.

References

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