Automatic Bone Segmentation using Voxel Classification

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INTRODUCTION

This experiment applies a Voxel Classification approach [1] to **automatic segment the Tibia** as a first step to develop quantitative methods for analysis of bone morphometry and structure. The dataset is composed of 14 MRI scans selected of a population of 139 test subjects knees. The original population has approximately equal distribution between healthy and diseased, laterality, sex and age.

1 FEATURE SELECTION

The method uses a voxel classifier to select a subset of features by sequential floating selection. At each time, it iteratively adds one feature and might excludes the least significant feature according to the volume overlap with the manual segmentation.

The **candidate features** are the intensity, the position, the three-jet, eigenvalues, and eigenvectors of both the Hessian and the structure tensor. All features except the position are calculated in different scales (0.5, 1.1, and 2.4 mm).

The **resulting features** are the first-order derivative on the three scales, the position, the structure tensor with outer scale of 0.5mm and derivative scale of 2.4mm, the Hessian on all three scales, the gradient on 0.5mm and 2.4mm and the third-order derivative on scale 1.1mm. The final feature vector has 27 dimensions.

2 VOXEL CLASSIFICATION

The voxel classifier follows the approximate nearest neighbor approach, not classifying all voxels, but focusing on the anatomical structure being analyzed.

The algorithm starts from a set of randomly sampled voxels, it classifies them as either the object (tibia) or background. If a voxel is classified as tibia, it continues with classification of the neighboring voxels and this expansion process continues until no more tibia voxels are found.

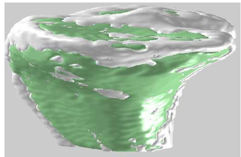
To determine the accuracy of the segmentation, the training and evaluation steps use the Leave-one-out cross validation algorithm.

In a standard configuration machine, the classification takes approximately six minutes of processing for each scan.

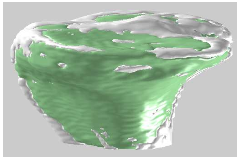
3 POSITION ADJUSTMENT

Regarding the variations in the knee placement, in some cases it is necessary an adjustment on the scan coordinates. The method consists of two steps:

1. Shift the coordinates so that the object center of mass, found from the segmentation, is positioned at the location of the center of mass of the object points in the training set;
2. Re-classify the voxels. The outcome is combined and the largest connected component is selected as the object segmentation.



Before adjustment:
DSC 82%, Sensitivity 69.6%



After adjustment:
DSC 93.5%, Sensitivity 87.9%

RESULTS AND DISCUSSION

Before applying the position adjustment scheme, the automatic segmentation method yields an average **sensitivity of 88.6%** and **DSC of 93.8%** in comparison with manual segmentations. After applying the automatic position normalization, the average **sensitivity Increases to 90%** and **DSC to 94.5%**.

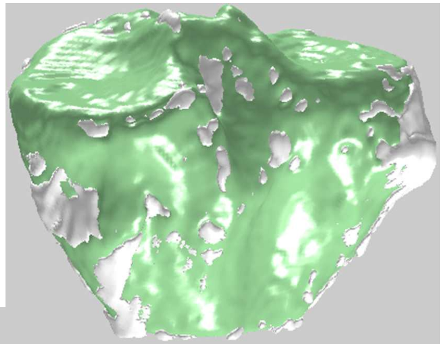
The results show that the method has a good accuracy in the dataset evaluated. But in order to do a better analysis, we plan to apply the method in the whole dataset with 139 test subjects knees.

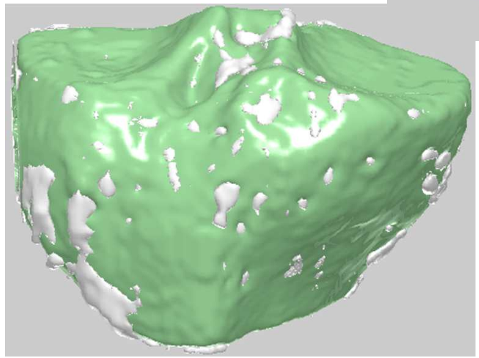
Also as a future work, considering the improvement of the position adjustment, a shape model of the bone could be applied to better adjust the segmented object to the scan coordinates.

In addition, it is possible to evaluate the features with different scales regarding the size of the anatomical structure being analyzed.

MRI with manual segmentation

Tibia Bone (anterior) – DSC 96.8%, Sensitivity 93.8%





Tibia Bone (posterior)

Measures to **evaluate** the segmentation:

- **Dice Similarity Coefficient** (**DSC**): volume of the correctly segmented voxels divided by the mean of the volume of the segmentation and the volume of the golden standard segmentation;
- **Sensitivity**: measure of the true-positive rate.

REFERENCES
[1] Jenny Folkesson, Erik B. Dam, Ole Fogh Olsen, Paola Pettersen, and Claus Christiansen. "Segmenting articular cartilage automatically using a voxel classification approach". IEEE Transactions on Medical Imaging, 26(1):106-115, 2007.

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