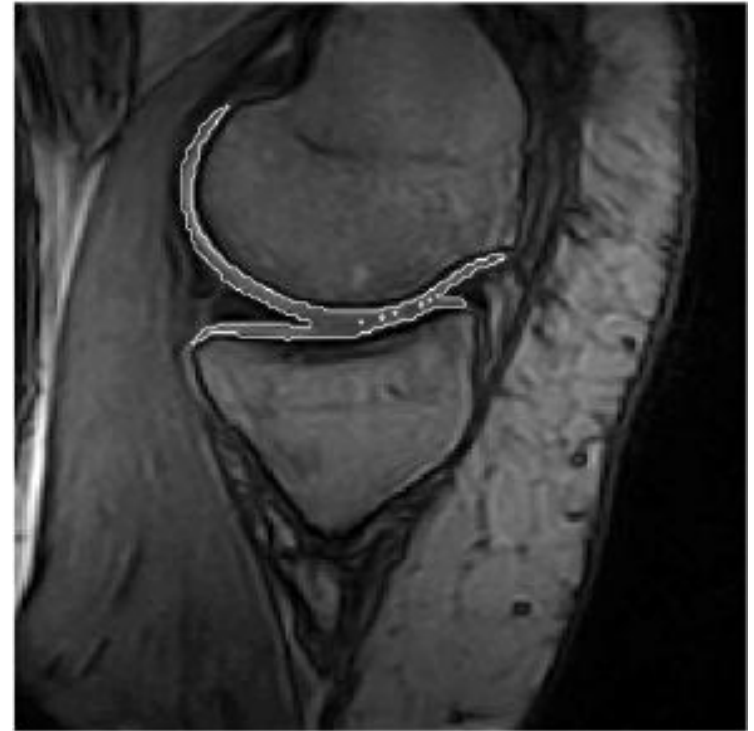


Knee Cartilage Segmentation

ENGN 2500 – Medical Imaging Analysis
Onur Ulusel

Introduction

- Osteoarthritis – one of the main health issues among elderly population.
- One of its main effects is the degradation of articular cartilage.
- MRI is the leading imaging modality to quantify knee cartilage and detect deterioration.
- Segmentation of the cartilage tissue is an important step in this process.



Clustering Method

- **Voxel Classification**

- Folkesson, J., Dam, E. B., Olsen, O. F., Pettersen, P. C., and Christiansen, C., “Automatic segmentation of the articular cartilage in knee mri using a hierarchical multi-class classification scheme,” in 8th Int. Conf. Med. Image Comput. Comput.-Assist. Intervention (MICCAI’05), Palm Springs, CA, 2005, pp. 327–334.

- **Approximate k-Nearest Neighbor classifier is used for classification.**

- Similar to kNN algorithms but trades off some precision for computation speed.
- kNN algorithm finds the nearest k neighbors to a query point over a given feature space.
- Euclidian distance is used to compute the distance of each feature parameter.

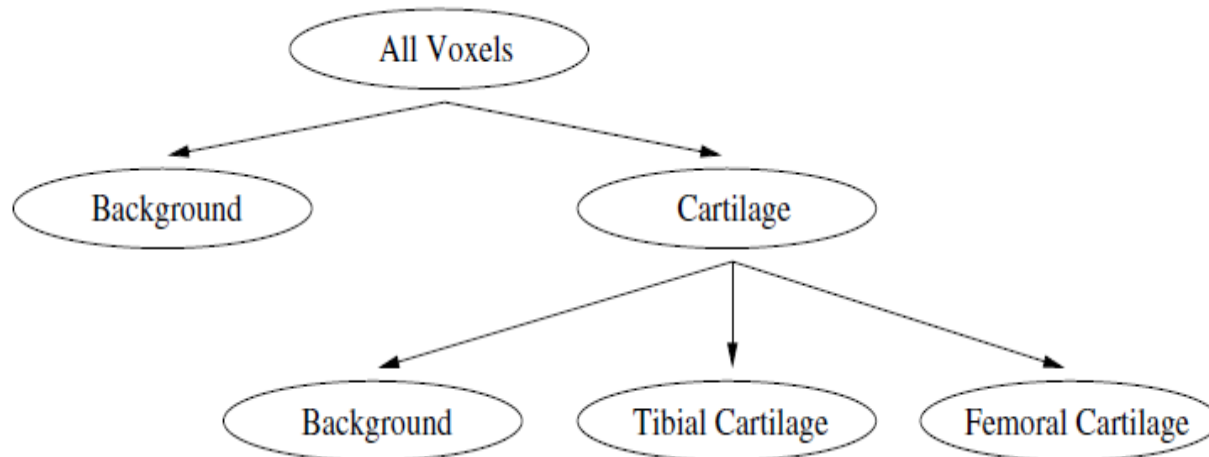
Specifications

- In the paper
 - 0.18 T MR scanner used
 - Image sizes: 256x256x104
 - Image size processed: 170x170x104
 - Sample size: 71 scans, 25 used for training
- Project work
 - 1.5 T MR scans used
 - Image sizes: 512x512x52
 - Image size processed: 340x340x51
 - Sample size: 4 scans, 3 used for training

Feature Selection

- The features used are selected to take advantage of pixel intensity and geometry of the cartilage.
- Selected features for each voxel as given in the paper:
 - position in the image (x, y, z coordinates)
 - raw and Gaussian smoothed (on scales 0.65, 1.1 and 2.5) intensities of the voxels
 - 1st, 2nd and 3rd order Gaussian derivatives of the Gaussian smoothed values
 - eigenvalues of the Hessian matrix, which describes the local curvature the voxel.
 - eigenvalues and eigenvectors of the structure tensor matrix which is used to detect thin structures

Hierarchical Classification



Hierarchical Classification

Hessian matrix and Structure Tensor

$$H = \begin{pmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{pmatrix}$$

The eigenvectors of the Hessian points in the directions of the principal curvatures and its eigenvalues corresponds to the curvature in those directions.

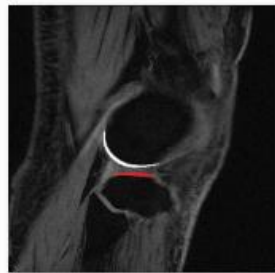
The ST examines the local gradient distribution at each location (x, y, z). The directions of the eigenvectors depend on the variation in the neighborhood.

$$ST = G_{\sigma_2} * \begin{pmatrix} I_x I_x & I_x I_y & I_x I_z \\ I_y I_x & I_y I_y & I_y I_z \\ I_z I_x & I_z I_y & I_z I_z \end{pmatrix}$$

Segmentation Evaluation Metrics

- Sensitivity
 - Measure of identifying positive results
 - True Positives / (True Positives + False Negatives)
- Specificity
 - Measure of identifying negative results
 - True Negatives / (True Negatives + False Positives)
- Dice Similarity Constant (DSC)
 - Measure of spatial overlap
 - $(2 \times (A \cap B)) / (|A| + |B|)$

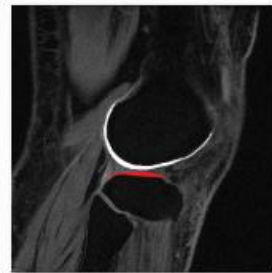
Learning Set



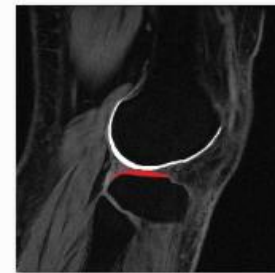
SP973_15T_noscrew_edits2_010.png



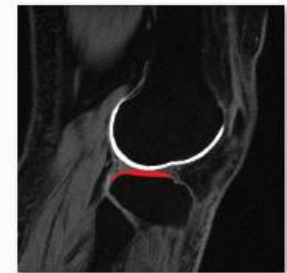
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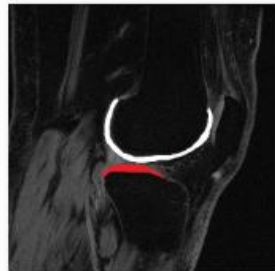
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SP973_15T_noscrew_edits2_013.png



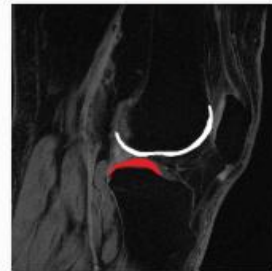
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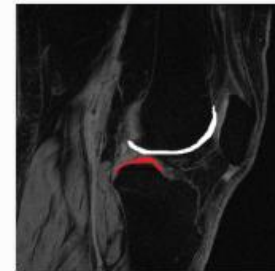
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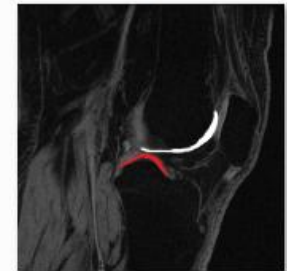
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SP973_15T_noscrew_edits2_021.png



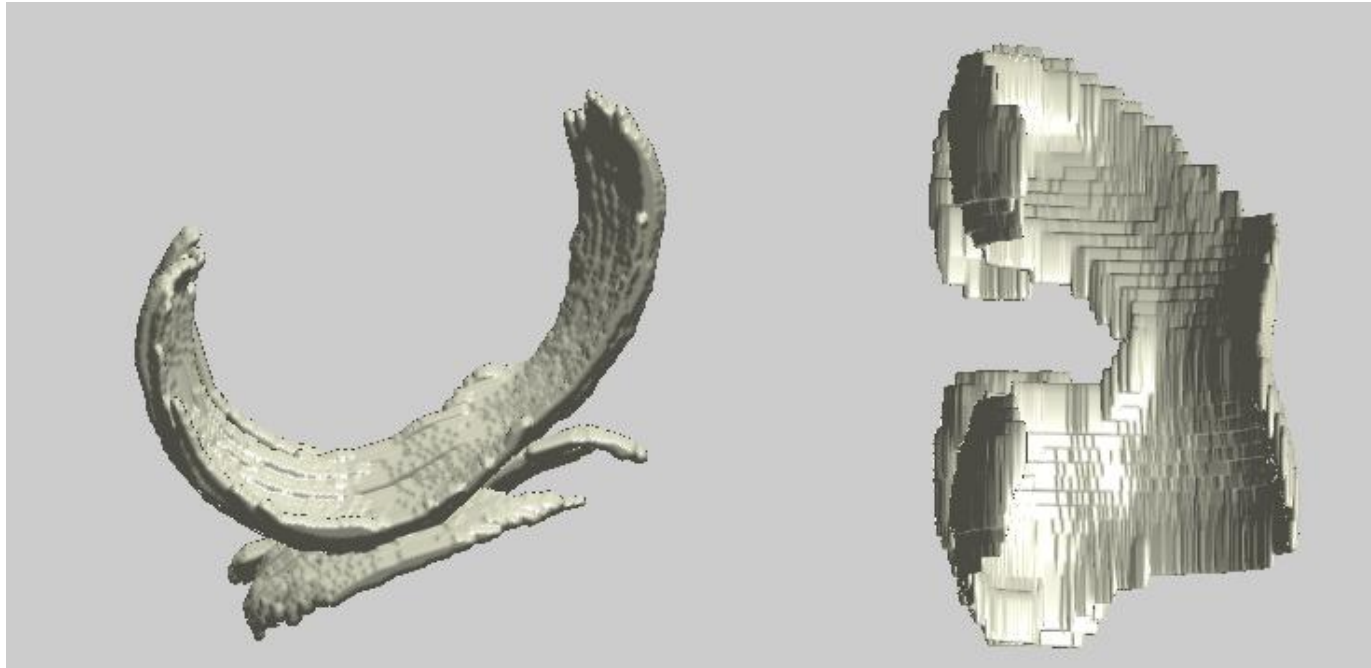
SP973_15T_noscrew_edits2_022.png



SP973_15T_noscrew_edits2_023.png

Consecutive Sagittal Slides from the same MRI data set, 51 slides in total used as a single test set

Learning Set

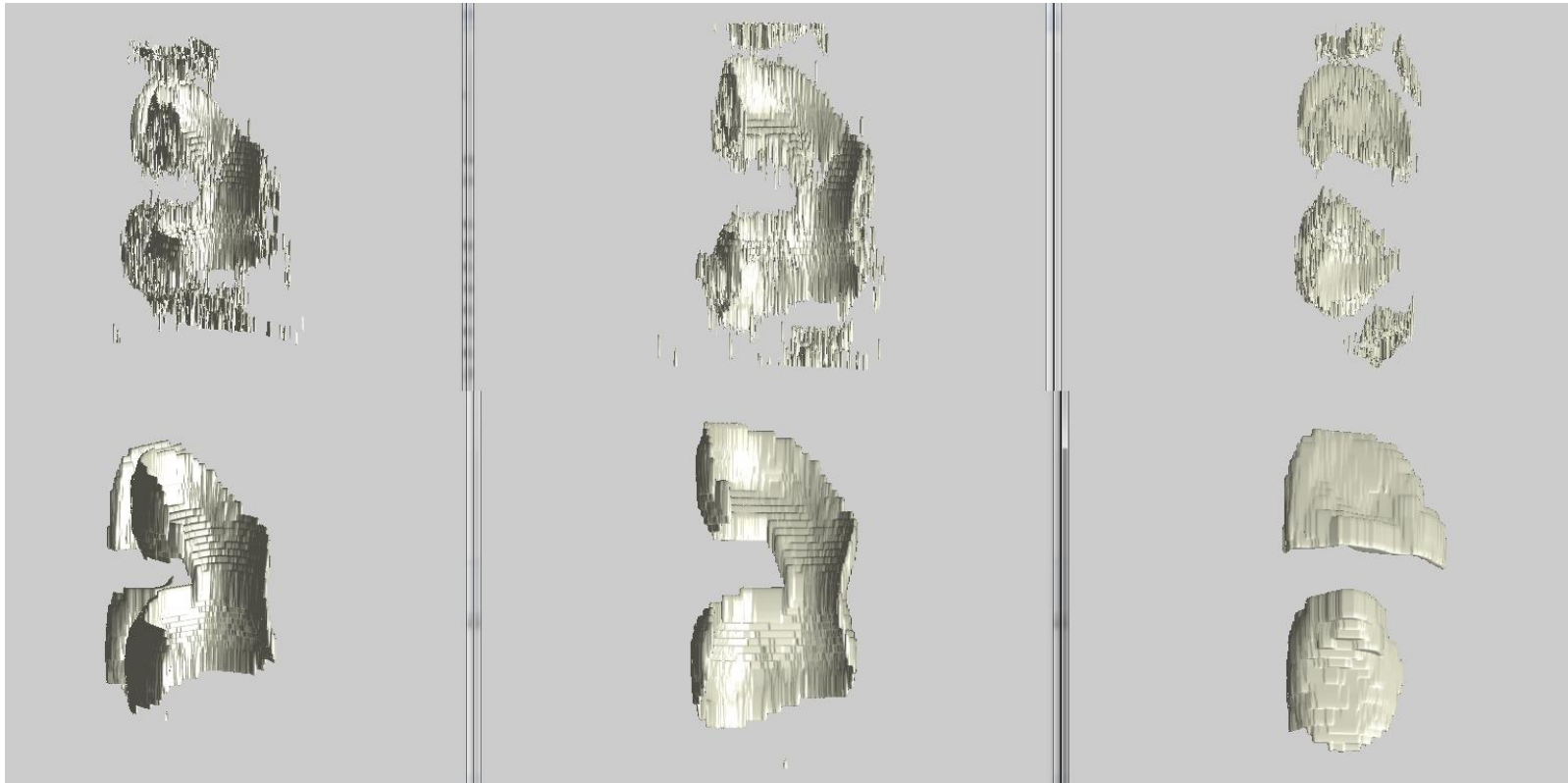


(a)

(b)

Segmented Cartilage from manual segmented slices. Views from (a) sagittal and (b) angled transversal planes

Test Image & Results



Top row obtained using first stage of the given algorithm with $k=8$ and $\text{eps}=2$ values. Bottom row is the ground truth via manual segmentation. Both columns are full cartilage, femoral cartilage and tibial cartilage from left to right.

Test Image & Results

- Obtained segmentation metrics

	Cartilage	Femoral Cartilage	Tibial Cartilage
Sensitivity	99.48%	99.78%	99.62%
Specificity	57.16%	41.99%	54.57%
Dice Similarity	0.9885	0.9917	0.9942

- Values given in paper
 - After first stage
 - Sensitivity: 99%
 - Final
 - Sensitivity: 94.82%, Specificity 99.79%, DSC 0.81

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