COMPUTER AIDED CHARACTERIZATION
OF DEGENERATIVE DISC DISEASE
EMPLOYING DIGITAL IMAGE TEXTURE
ANALYSIS AND PATTERN RECOGNITION
ALGORITHMS

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In this study...

- The use of texture for the characterization of cervical intervertebral disc degeneration in magnetic resonance images was investigated.

- A computer-based classification system using textural features was proposed for the diagnosis of Degenerative Disc Disease and more specifically for the detection of disc space narrowing.
Degenerative Disc Disease (1/3)

- Cervical DDD refers to the degeneration of cervical intervertebral discs
- In DDD the intervertebral disc loses its hydration and elasticity leading to disc space narrowing and/or disc herniation
Degenerative Disc Disease (2/3)

- DDD is a major cause of neck pain and stiffness
- In severe cases cervical DDD can cause sciatica and back pain, as well as muscle weakness
Degenerative Disc Disease (3/3)

Several imaging modalities are used in DDD diagnosis such as:

- X-rays
- Magnetic Resonance Imaging (MRI)

MRI is considered the modality of reference since it is non-invasive, involves no ionizing radiation and provides excellent soft tissue contrast.
DDD Evaluation Using MR Images

- DDD diagnosis is based on manual measurements of the intervertebral disc space and comparison to the adjacent levels disc space.

- For the needs of the present study, T2-weighted MR sagittal images of the cervical spine were reviewed by an experienced orthopaedist and the discs were characterized as normal or degenerated (narrowed).
In this study a computer based system was proposed for the automatic characterization of intervertebral disc degeneration.

The system was based on texture analysis of the disc images.

The selection of texture as a descriptor for DDD was motivated by the physics behind MRI. More specifically, MR signal depicts the biochemical composition of the imaged structures and especially the hydrogen nuclei. Because of that, the alterations caused by the degeneration of intervertebral discs are expected to change the texture of MR images.
The Image Analysis System

For the design of the image analysis system 4 steps were followed

1. Selection of Regions of interest (ROIs)
2. Generation of Textural Features
3. Investigation of Texture Differentiation
4. Feature Combination and Classification Algorithm Selection

In addition the system was evaluated by means of classification accuracy, sensitivity and specificity
ROIs Selection
ROIs examples

Degenerated Disc

Normal Disc
Textural Features Generation

Utilizing custom developed algorithms, textural features were extracted from each segmented disc ROI. More particularly features were calculated using:

- First order statistics
- Co-occurrence matrix
- Grey level run-length matrix
- Laws Texture Energy Measures
Laws Texture Energy Measures

- 25 Laws 2-D convolution kernels are calculated by combining the five 1-D kernels named L5(Level), E5(Edge), S5(Spot), W5(Wave), and R5(Ripple).

- 14 Texture Energy Measures (TEMs) Images are computed by applying the 2-D convolution kernels to a digital image, and then performing a nonlinear windowing operation.

- From each TEM image 4 textural features are calculated utilizing first order statistics.
Investigation of Texture Differentiation

- Student's paired t-test was used to investigate the existence of statistically significant differences (p<0.05) between the textural features values that were generated from normal and degenerated discs.

- This statistical analysis revealed the existence of statistically significant differences and verified the differentiation in texture between normal and degenerated discs.
Feature and Classifier Selection (1/2)

- Feature Selection was performed in two steps.

- In the first step, Student’s paired t-test was used to detect the features that had the highest discriminating power (p<0.01).

- Through this process a subset of 10 features was selected from the entire set of 76 features (8 from Laws TEMs and 2 from first and second order statistics).
Feature and Classifier Selection (1/2)

- In the second step, from the subset of the 10 features, the optimum combination of features along with the most accurate classification algorithm were selected.

- For this purpose the Exhaustive Search method was used to test all possible combinations of 2–5 features.

- In addition the Leave-One-Out method was used to evaluate 8 different classification algorithms for all the abovementioned combinations in order to find the most accurate.

- The selected algorithm was the Least Squares Minimum Distance Classifier designed with the best combination of features which comprised four textural features, three from Laws TEMs and one from 1st order statistics.
Classification Results

<table>
<thead>
<tr>
<th>Disc characterization</th>
<th>Normal</th>
<th>Degenerated</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>15</td>
<td>1</td>
<td>93.8%</td>
</tr>
<tr>
<td>Degenerated</td>
<td>1</td>
<td>15</td>
<td>93.8%</td>
</tr>
<tr>
<td>Overall accuracy</td>
<td></td>
<td></td>
<td>93.8%</td>
</tr>
</tbody>
</table>

The confusion matrix shows that 30 out of 32 discs were correctly classified. One disc from each class was misclassified. Consequently, the overall accuracy, sensitivity, and specificity of the system were 93.8%.
Conclusion

- Textural features statistical analysis revealed texture differentiation between normal and degenerated disc images.

- In this study a computer-based image analysis system was designed for the characterization of DDD.

- The proposed system discriminated successfully normal from degenerated cervical intervertebral discs and achieved high accuracy, sensitivity and specificity.

- Further investigation and the use of a larger sample is needed to make the suggested approach a trustworthy 2nd opinion tool for the physicians.
Future Work

- To verify the system’s accuracy using a larger sample
- To use different textural and morphological features in order to improve the system’s accuracy
- To design a similar system for the characterization of intervertebral disc herniation
- To apply similar techniques for the characterization of lumbar intervertebral discs
- To use 3D methods in order to characterize the degenerative alterations of intervertebral discs
References

Thank you for your attention!!! ☺