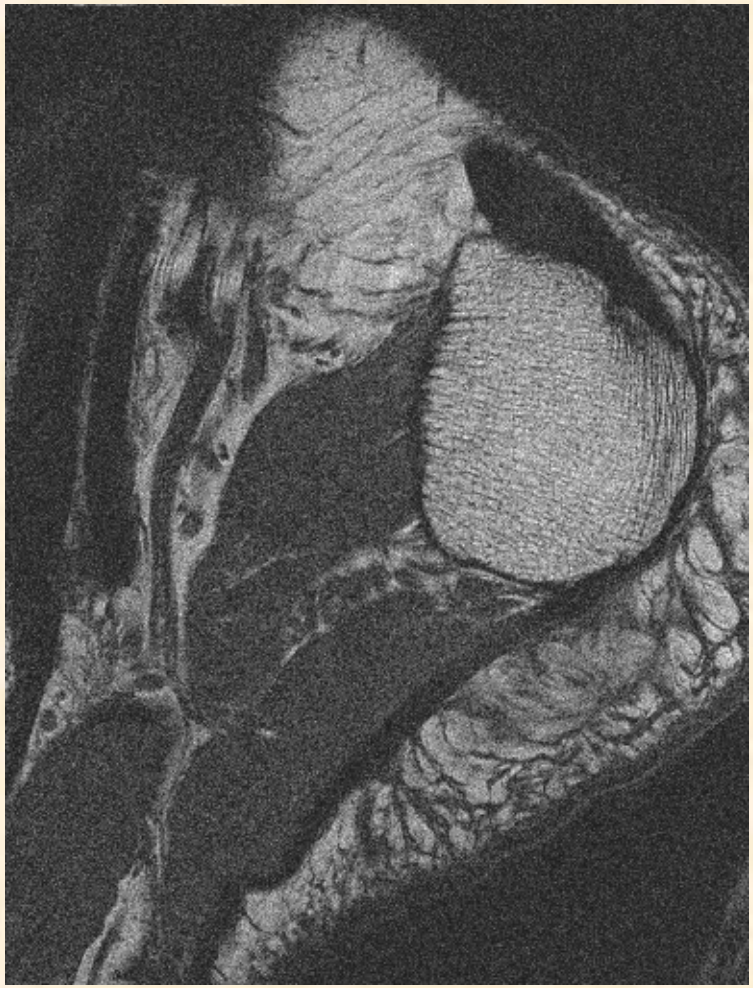
Selected methods of texture analysis

[Brodatz 1966]

Texture definition

There is no formal, mathematical definition of term “Texture”

Texture definition

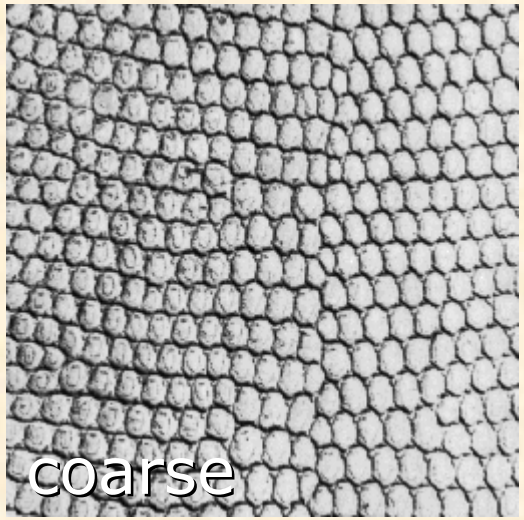


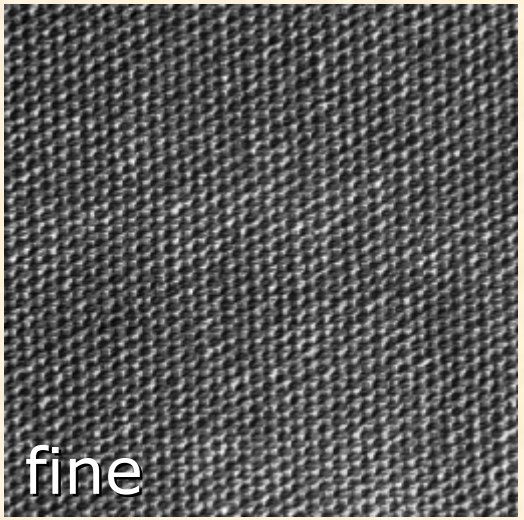
Texture – complex visual patterns, composed of spatially organized entities that have characteristic brightness, color, shape, size.
This local sub-patterns are characterized by given coarseness, fineness, regularity, smoothness etc.
Texture is homogeneous for human visual system.
[Hajek et al. 2006]

Texture properties

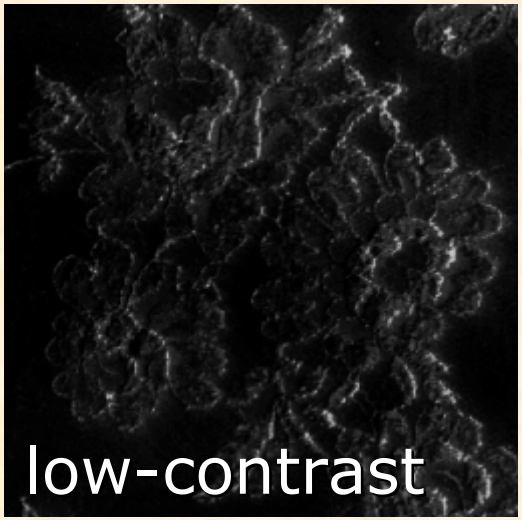
- One of the first quantitative/physiological texture description: [Tamura et al. 1978]
- Definition of texture features that correspond to human visual perception:

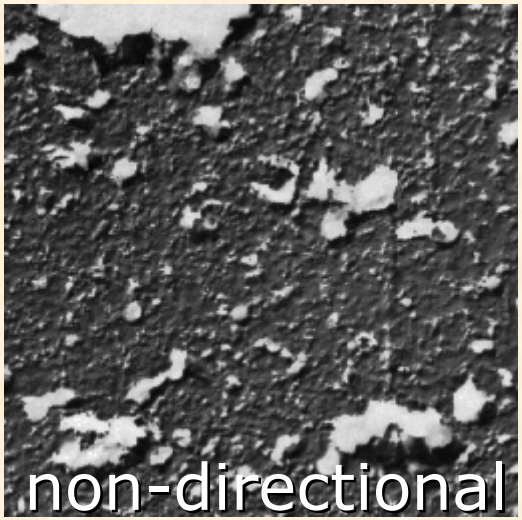
coarseness, contrast, directionality, line-likeness, regularity, roughness



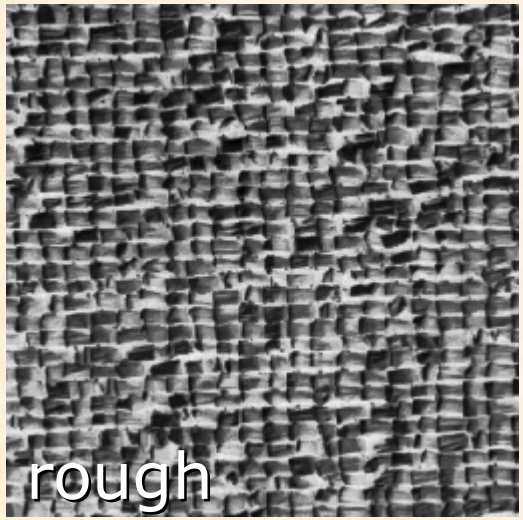


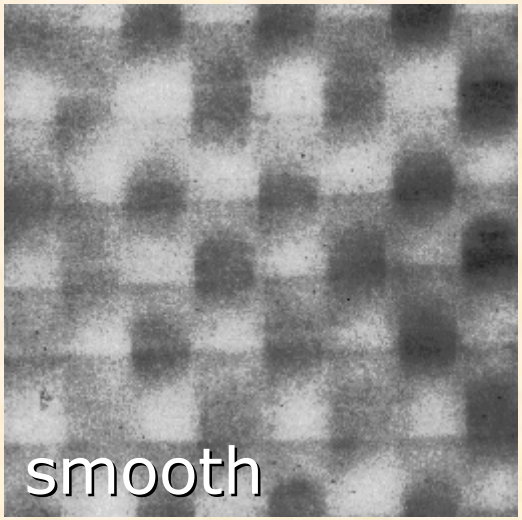
Texture properties

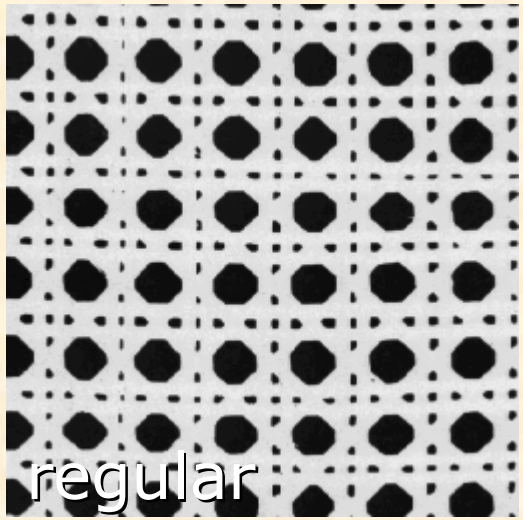




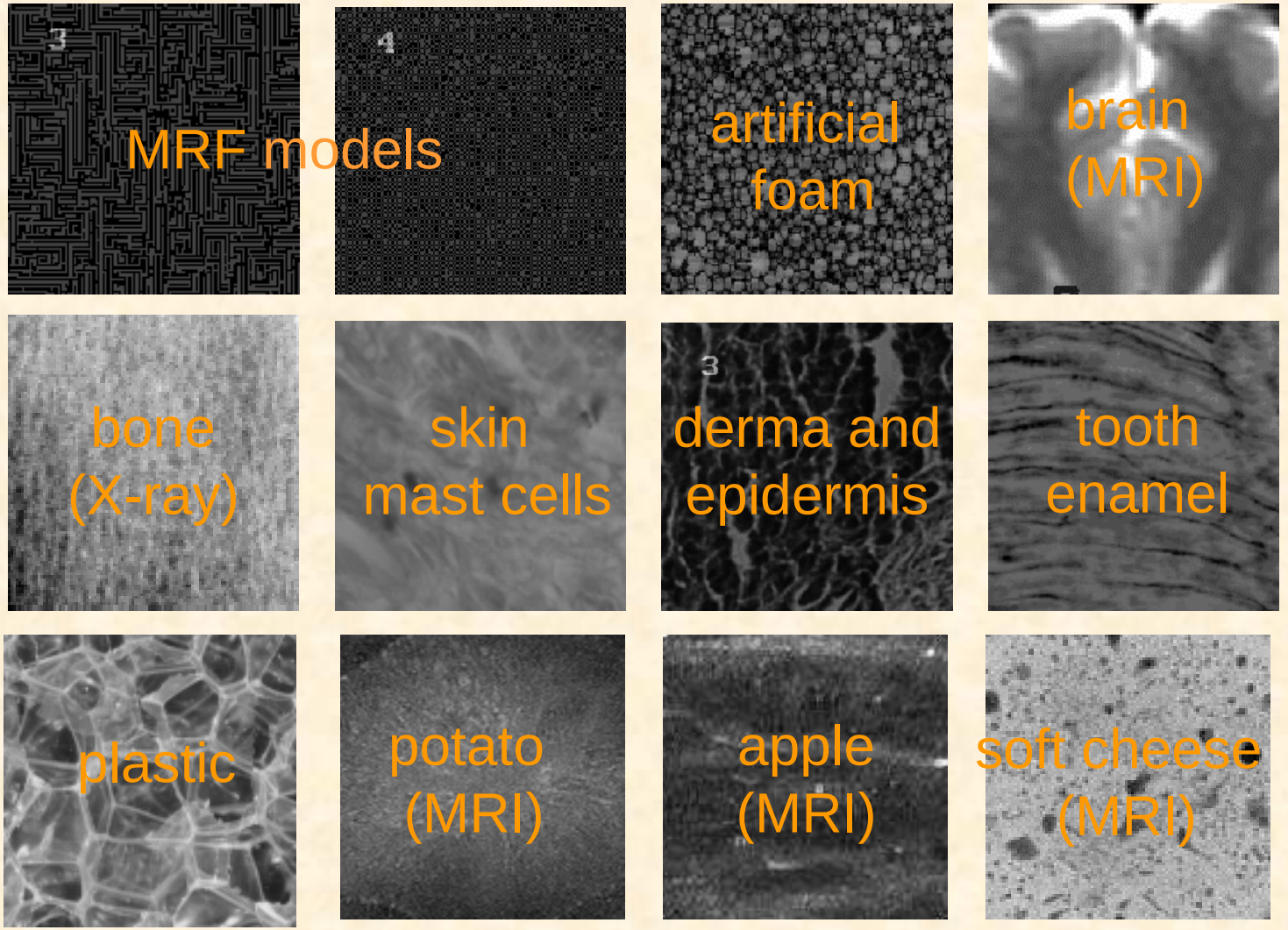
Texture properties







Texture examples



Texture analysis

Basic steps in quantitative texture analysis:

- **Feature extraction**

(computation of a vector of mathematical parameters which describe texture properties)

- **Texture classification**

(determination to which of predefined classes given texture belongs)

- **Texture segmentation**

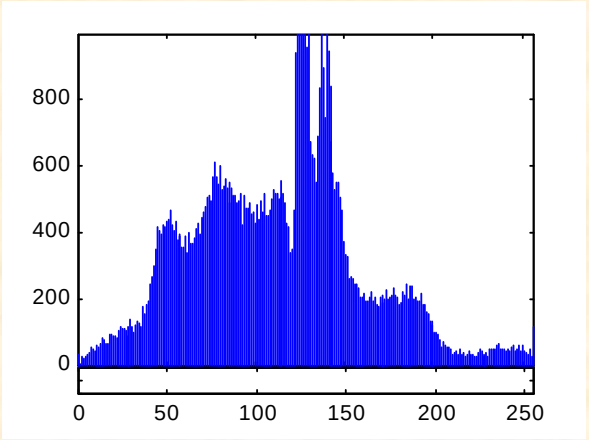
(partition of image into disjoint regions containing homogenous textures)

Texture feature extraction

- statistical
  - image intensity domain
  - mathematical models
  - transform based
- structural
- signal processing

Statistical approach

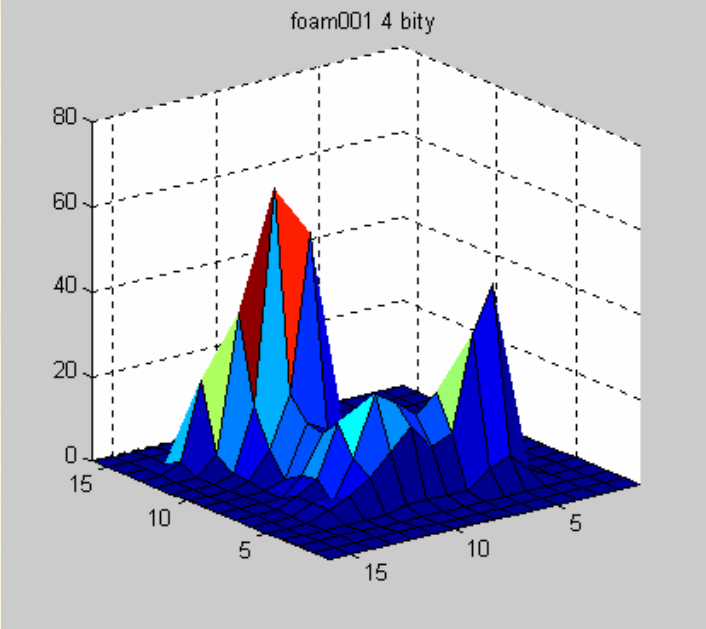
feature extraction in image intensity domain



- histogram
- co-occurrence matrix

  2nd order histogram, [Haralick et al.1973]
- higher order statistics

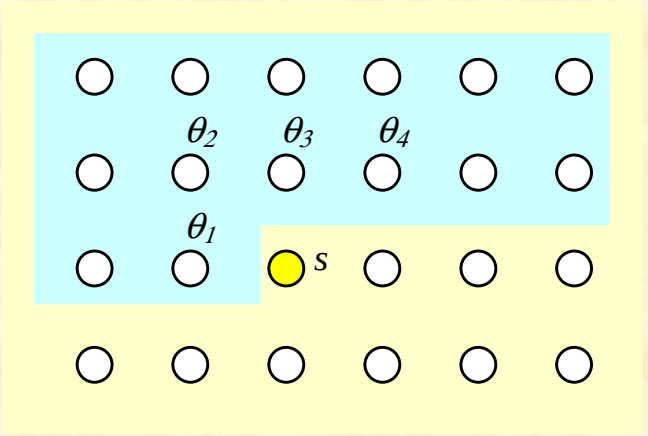
  [Kovalev and Petrou 1996]
- run-length matrix [Haralick 1979]
- gradient matrix
- …

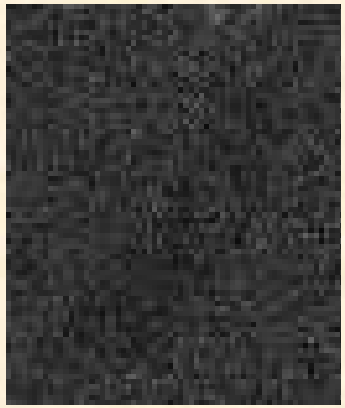


Statistical approach

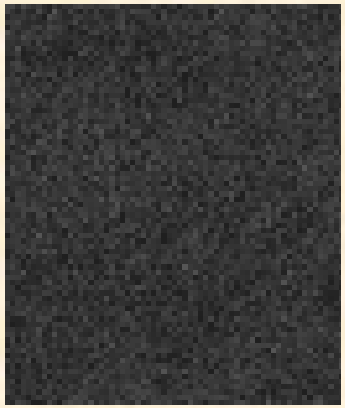
mathematical model parameter estimation

- Markov random fields
  [Geman & Geman 1984]
- autoregressive model
  [Chelappa et al. 1985]
- fractals [Chen et al. 1990]

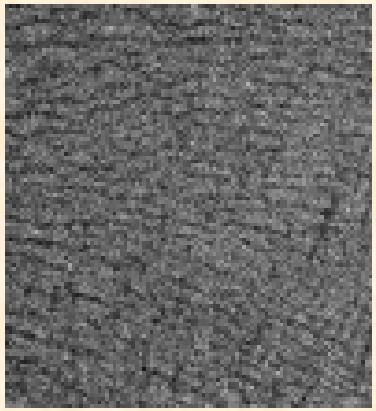




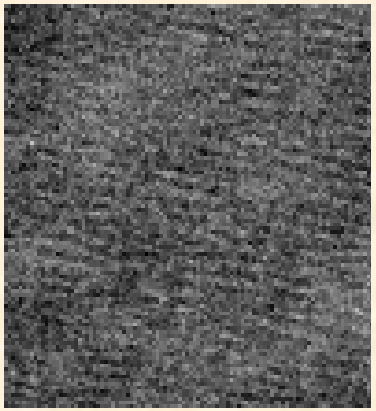
metatarsus tissue



GMRF model



bone tissue

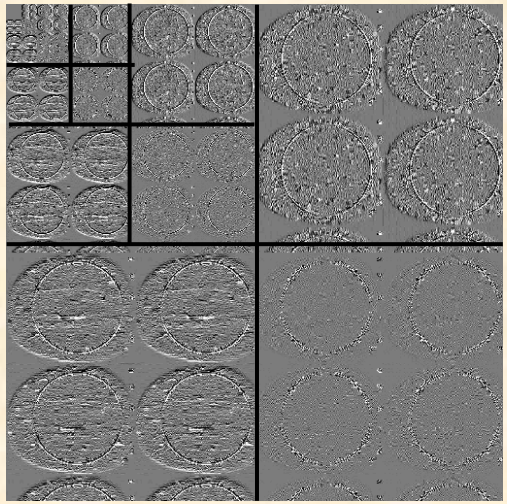


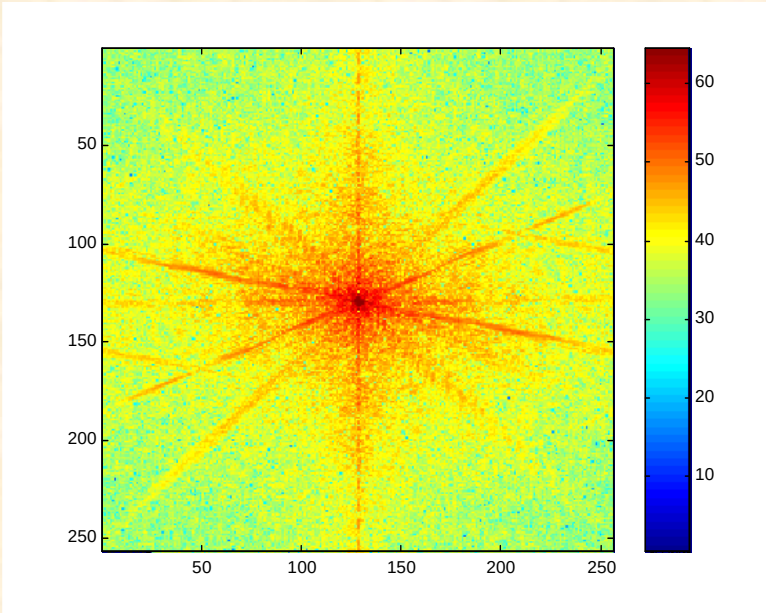
GMRF model

Statistical approach

- Fourier transform
- Gabor filters [Dunn et al. 1994]
- Wavelet transform

  [Choi & Baraniuk 2001]

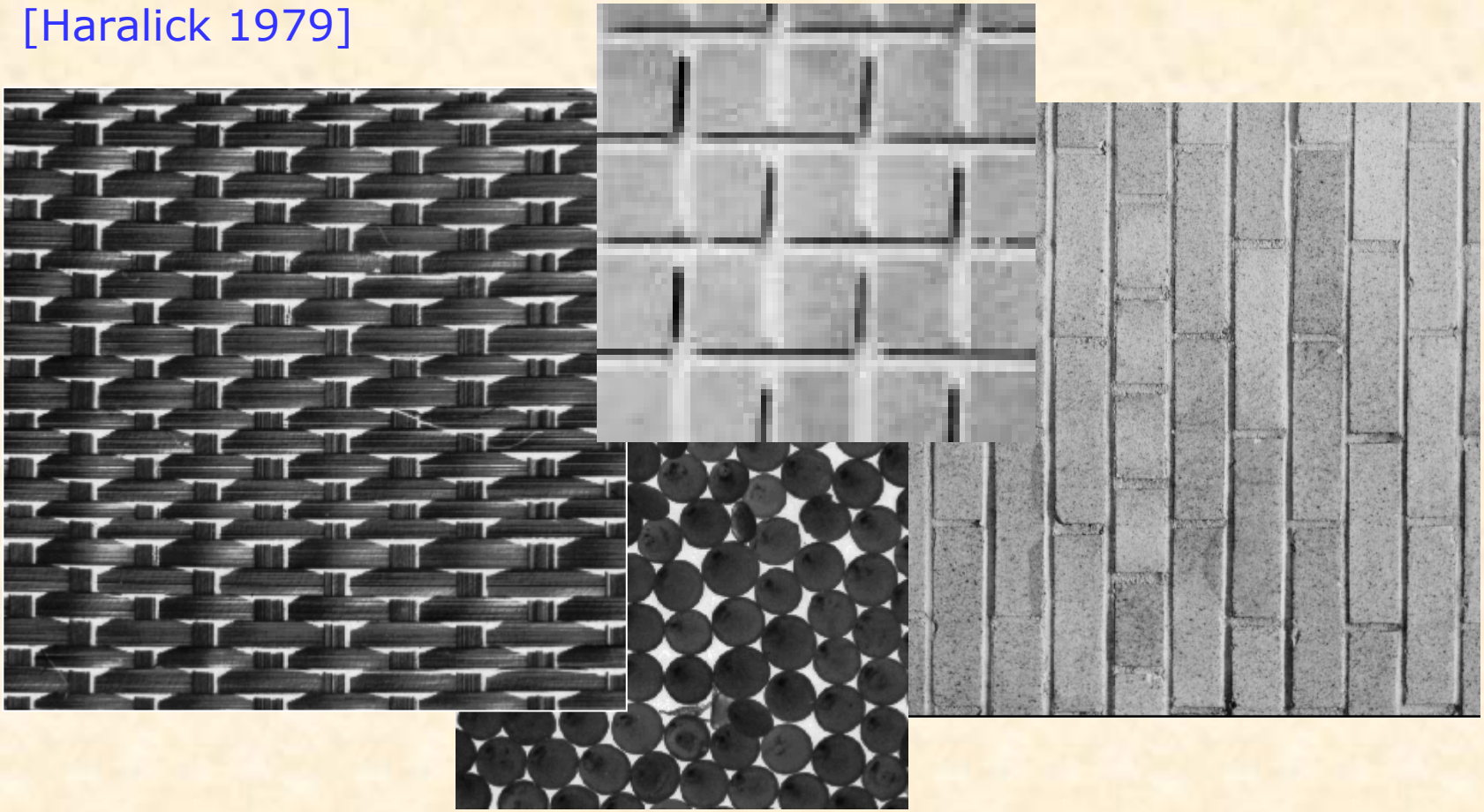




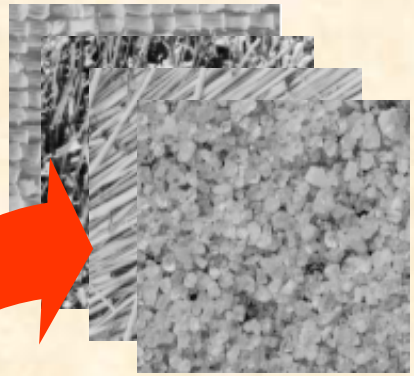
Structural approach

- texel – a basic, repetitive texture element
- placement rules

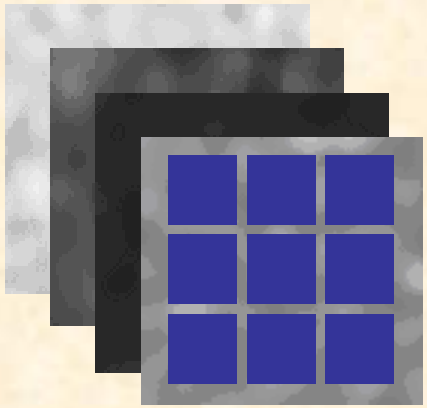
[Haralick 1979]



Signal processing approach



linear filter
h



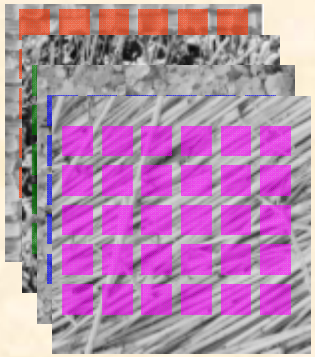
optimisation of
h to increase *F*

$$F(h) = \frac{\frac{1}{K-1}\sum_{k=1}^{K}\sum_{j=1}^{K}\left|\boldsymbol{\mu}_k - \boldsymbol{\mu}_j\right|^2}{\sum_{k=1}^{K} V_k^2}$$

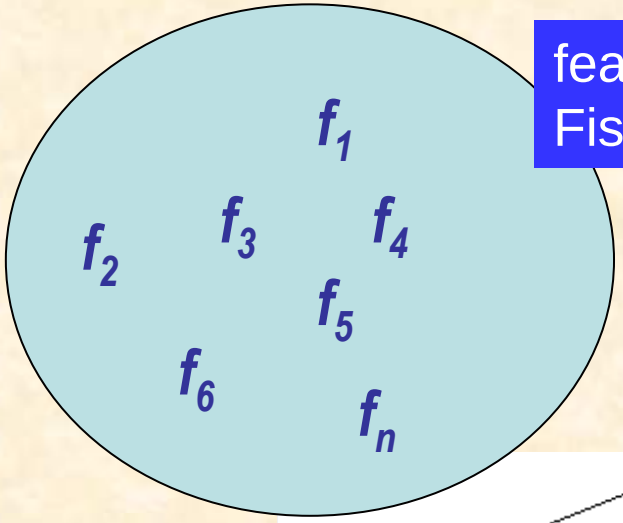
estimation of mean
and variance for ROI

[Randen & Husoy 1999]

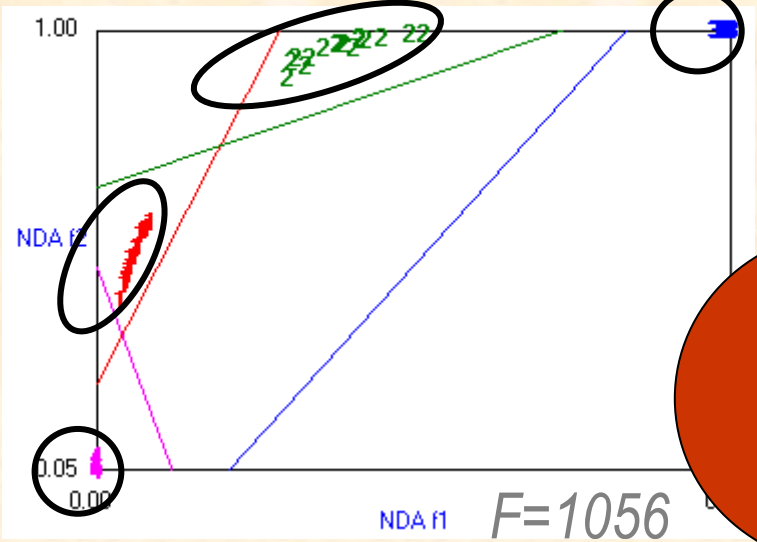
Feature selection for classification

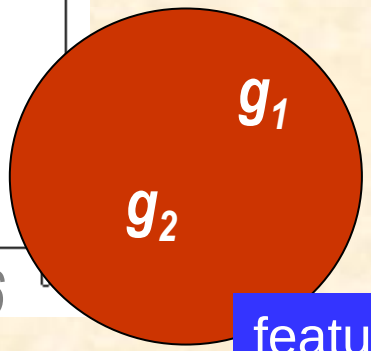


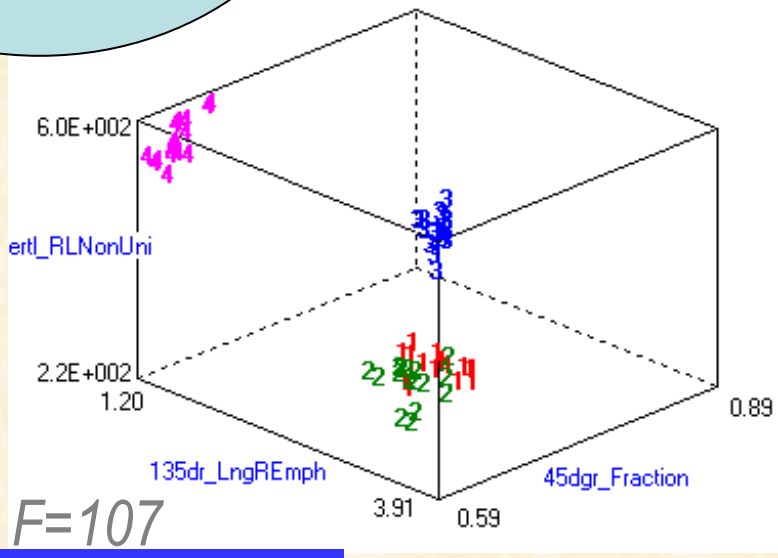
feature evaluation



feature selection:
Fisher, POE, MI



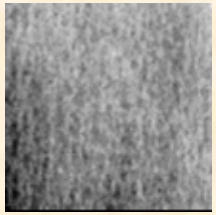




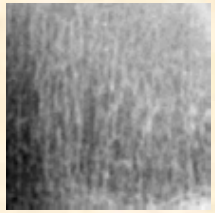
feature projection:
LDA, PCA, NDA

Texture classification

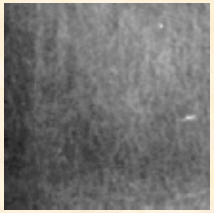
wrist bone X-ray images



healthy (1)

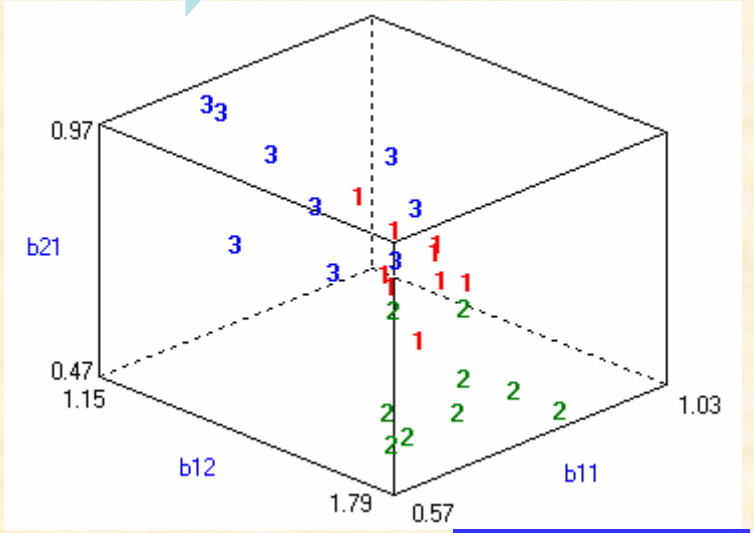


osteopenia (2)



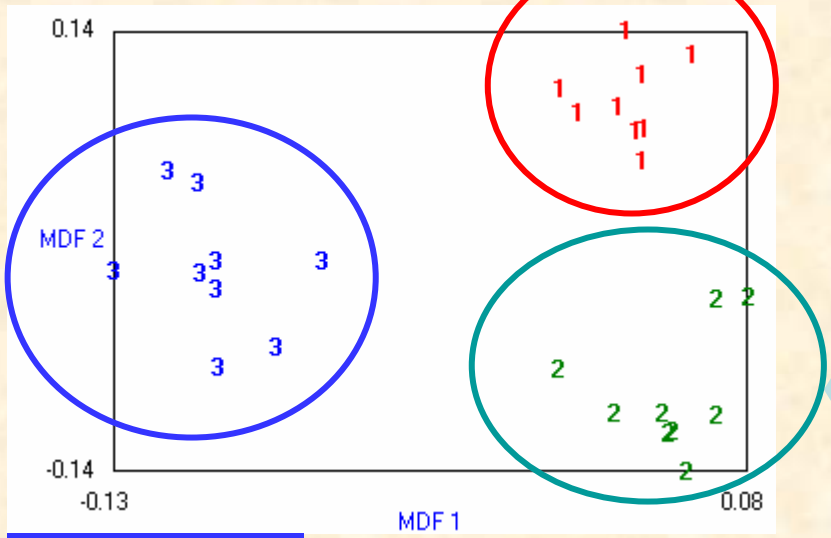
osteoporosis (3)

2nd order MRF features



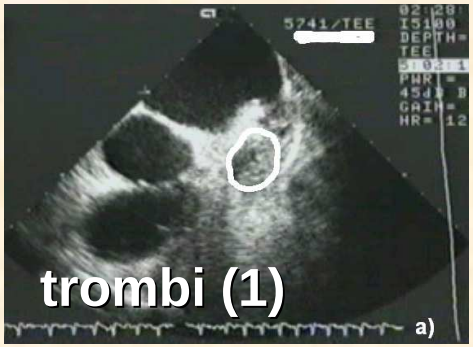
1-NN: 2/27

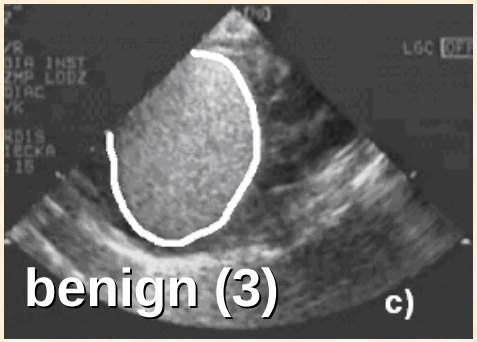
LDA



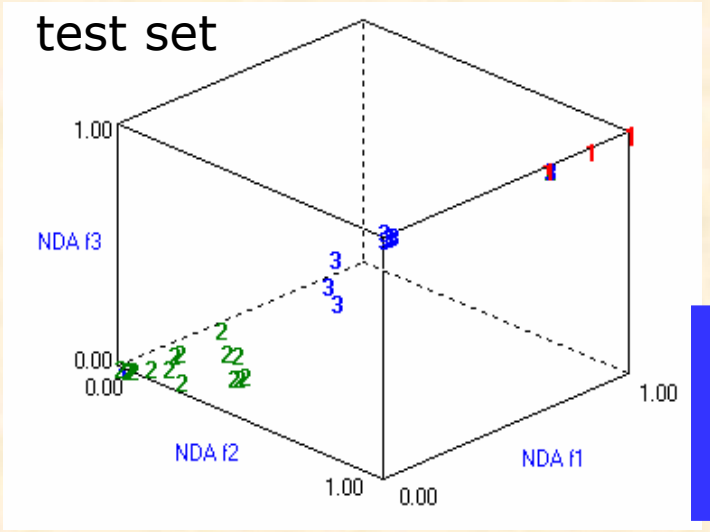
1-NN: 0/27

Texture classification



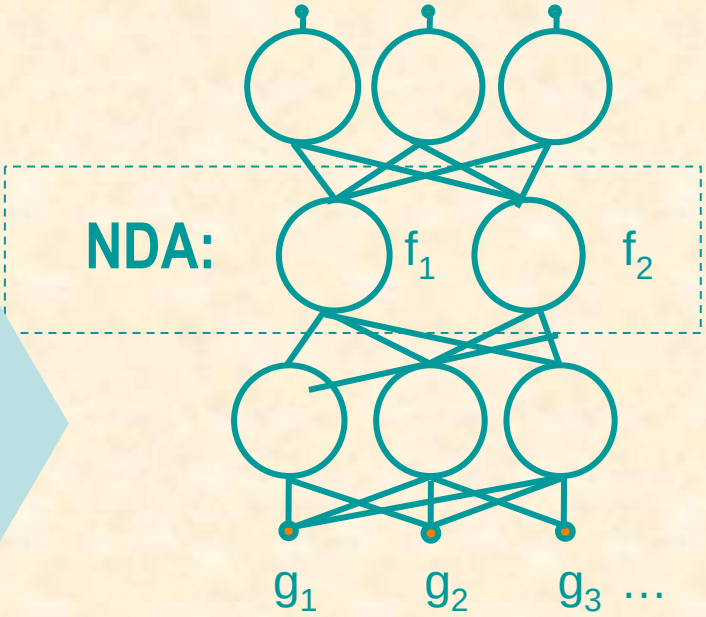


heart masses (USG)



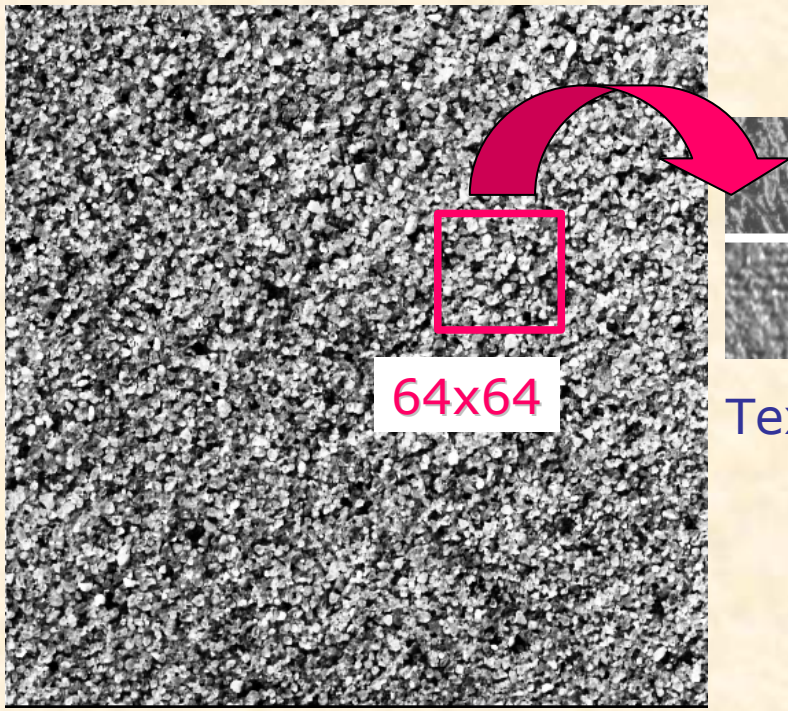
class. errors:
training: 10/108
test: 5/55

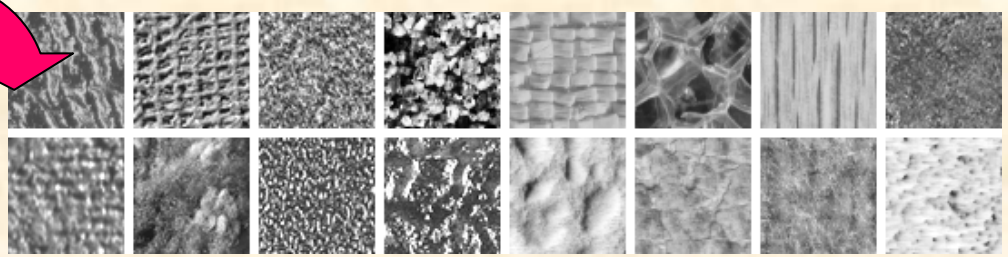
statistical features



Texture classification

- 16 textures from Brodatz album,
- each image was divided into 64 squares (64x64)
- 1024 samples of 16 texture classes altogether





Texture samples

Texture classification

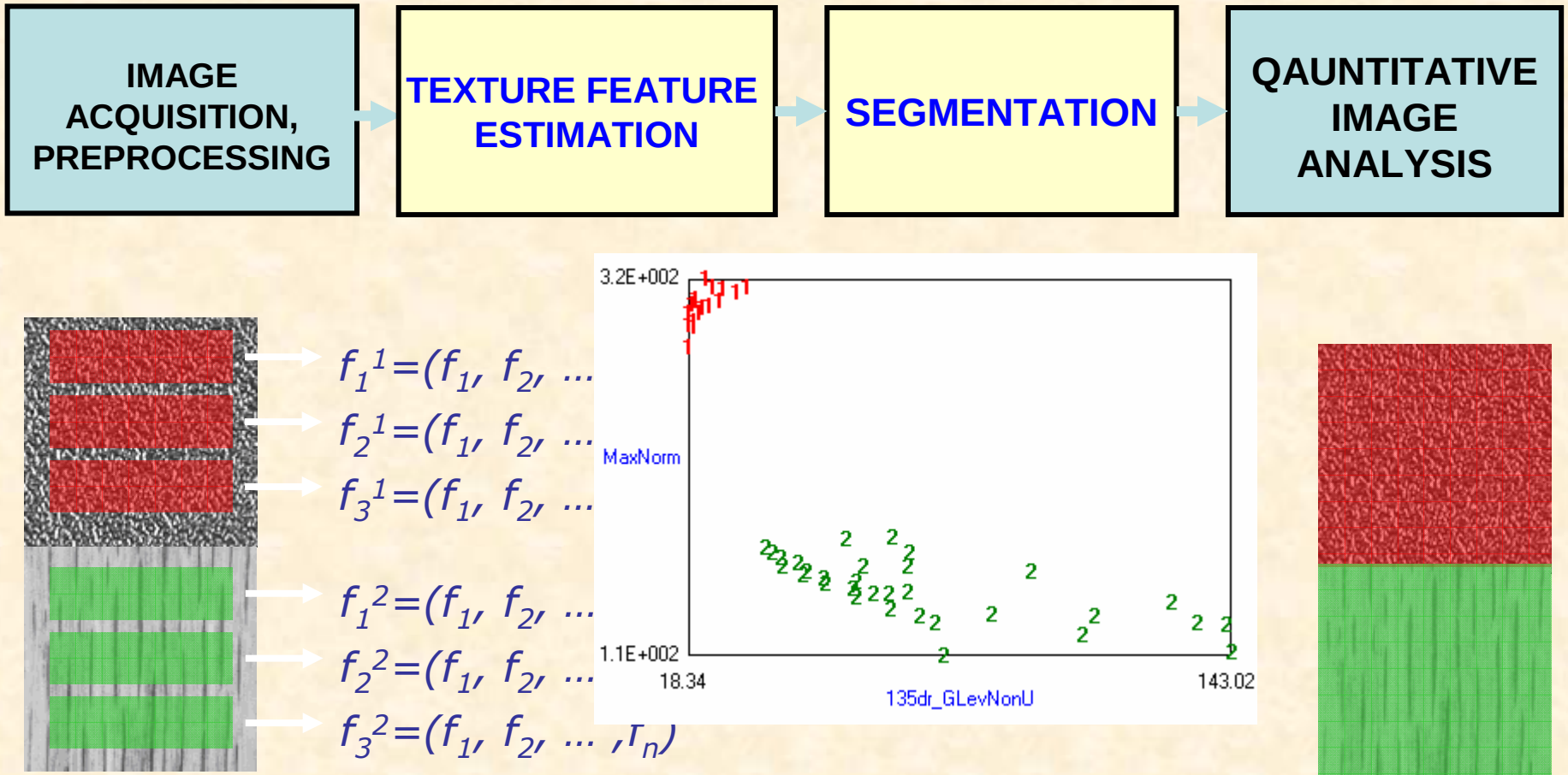
1-NN classification results for
different feature selection methods

optimal subset*	MI		Fisher		POE	
raw	raw	LDA	raw	LDA	raw	LDA
0	**16**	**8**	**79**	**59**	**145**	**147**
Number of misclassiedfied samples (total no. of samples: 1024)						

* Optimal subset with 4 features:
(*Sigma, MinNorm, GrMean, S(0,2)Correlat*)
found based on exhaustive search

Texture segmentation

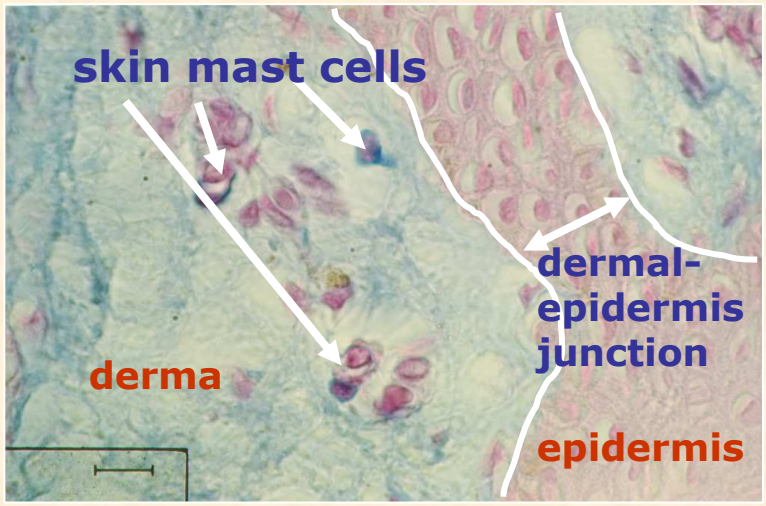
- splitting of the image into disjoint, homogeneous regions

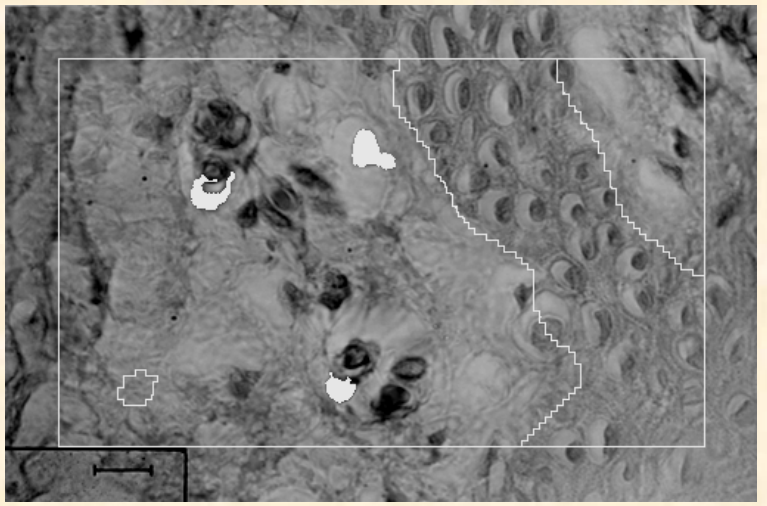


Texture segmentation

Example of biomedical image analysis:

- detect skin mast cells
- calculate their parameters
  (eg. area, distance from D-E junction





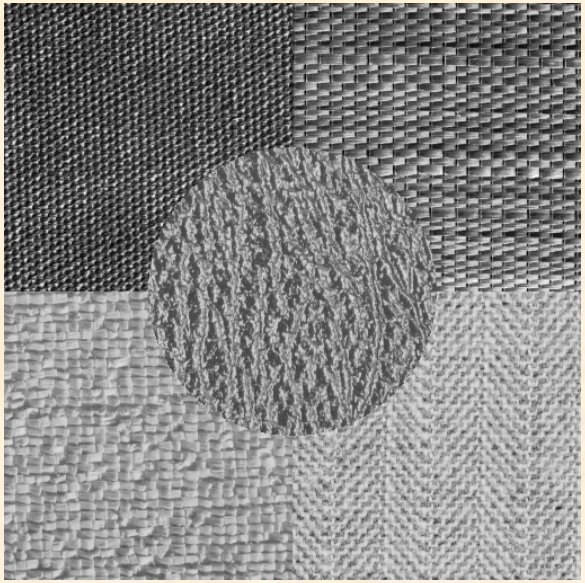
Texture segmentation

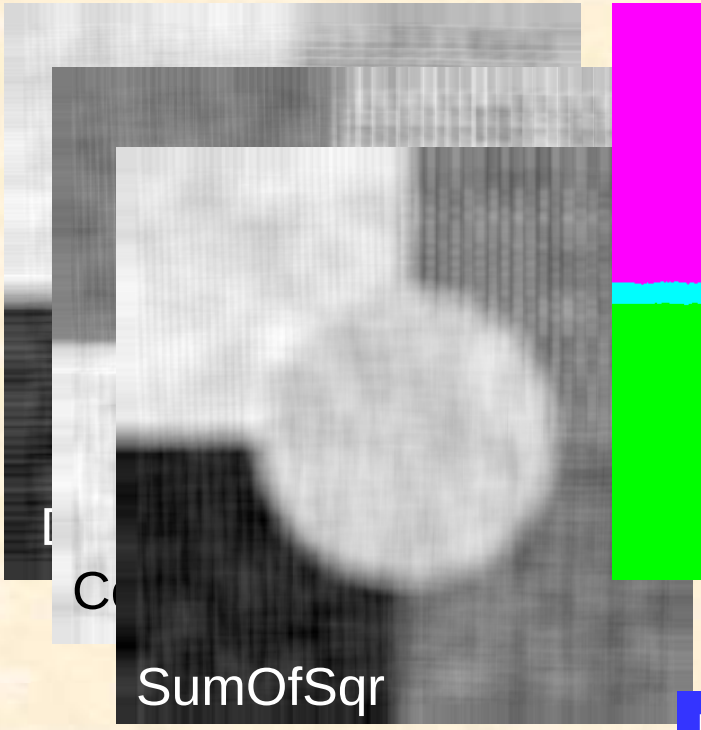
Image texture segmentation techniques:

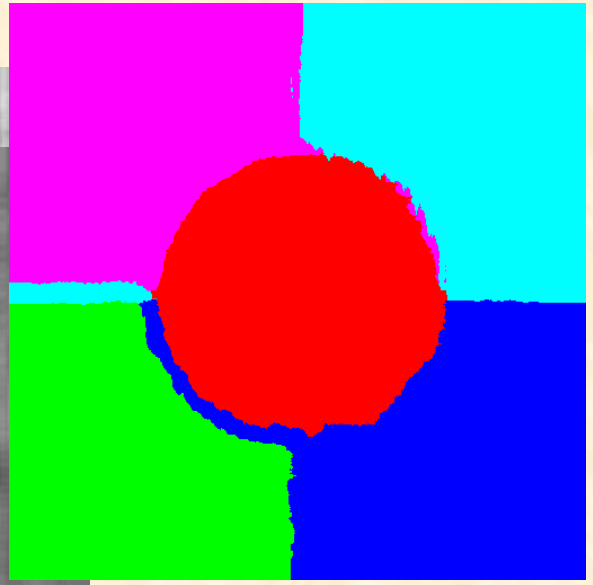
- "classical" approaches (region- and gradient based methods) [Reed et al. 1990, Yhann & Young 1995]
- Bayes estimation (MRF models) [Cohen i Cooper 1987]
- artificial neural networks (Hopfield, multilayer perceptrons, network of synchronized oscillators) [Raghu & Yegnanarayana 1998, Augusteijn 1995, Hu & Hwang 2002, Wang 1995, Strzelecki et al. 2006]
- unsupervised segmentation (k-means, Kohonen, AHC) [Yin & Allinson 1994, Klepaczko 2006]

Texture segmentation

Brodatz texture mosaic







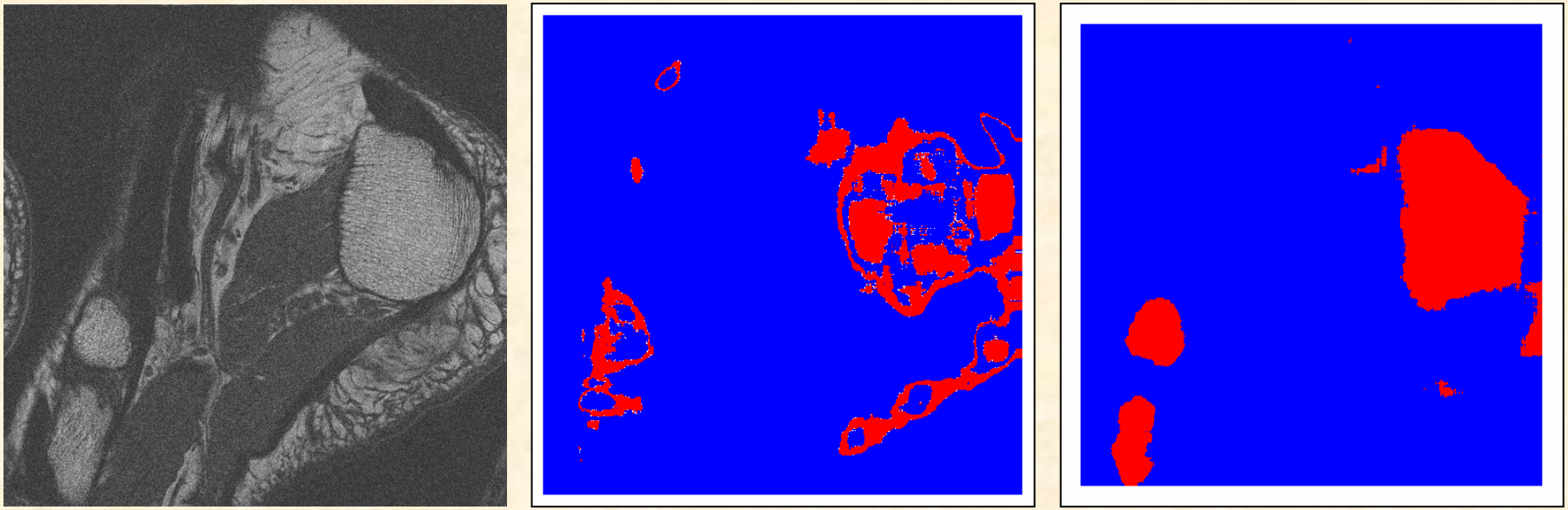
statistical features

feature maps

k-means segmentation results

Texture segmentation

MR image of foot cross-section



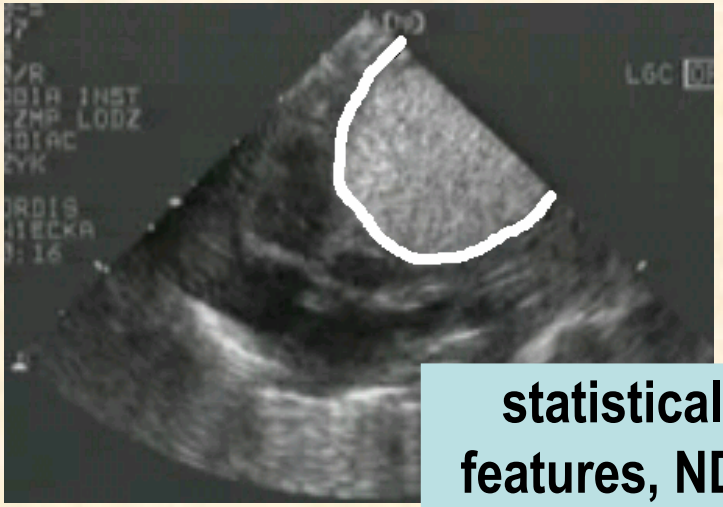
statistical features

GMRF model parameters

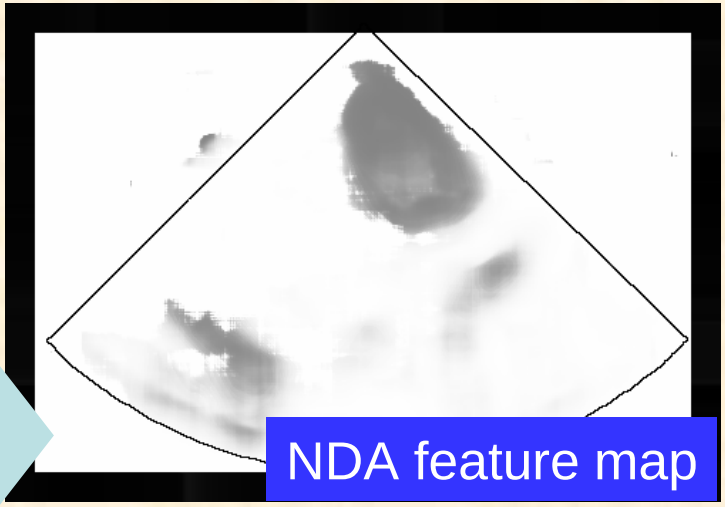
multilayer perceptron (MLP) segmentation results

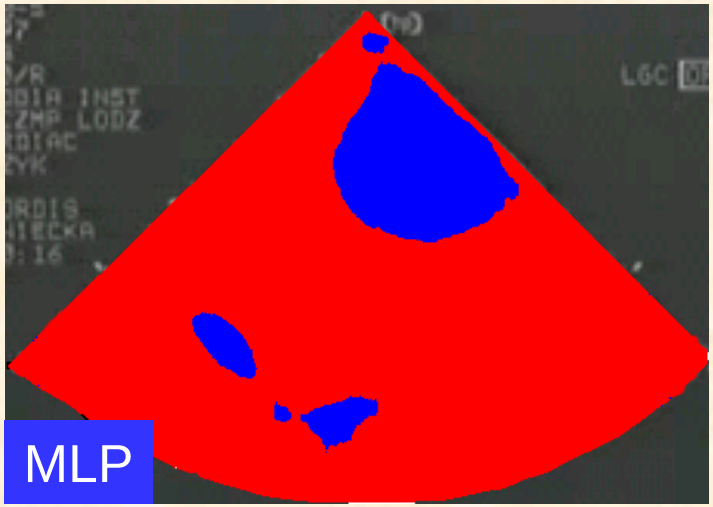
Texture segmentation

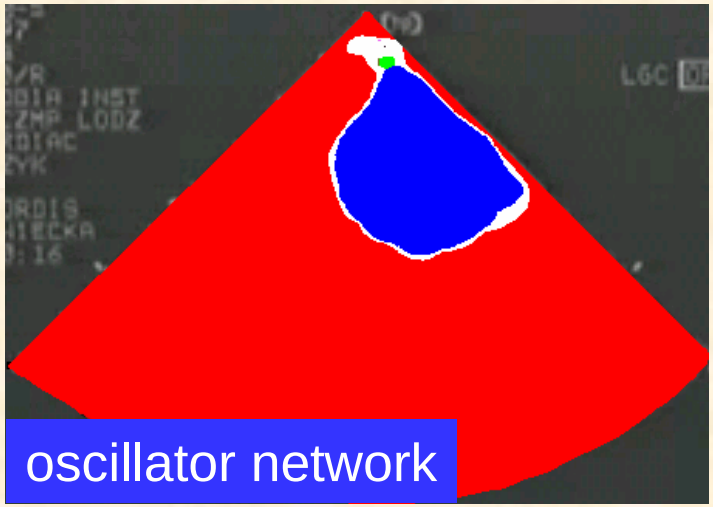
Heart mass echocardiogram (benign tumor)



statistical features, NDA

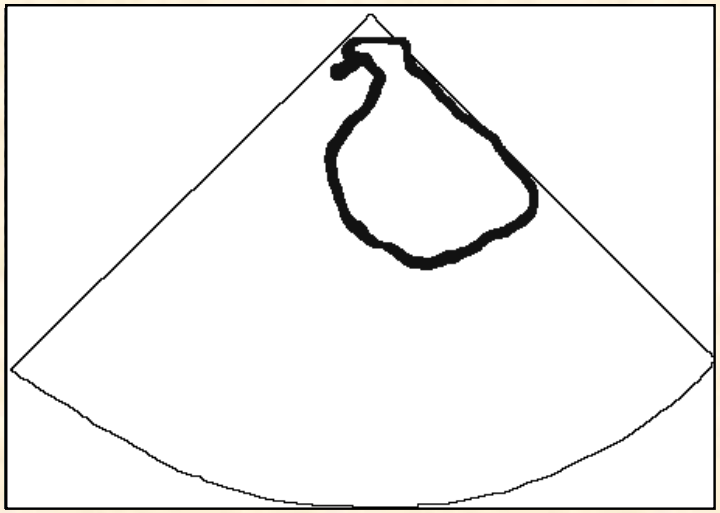






Texture segmentation

Detection of texture edges



oscillator network

References

Brodatz P., “Textures - A Photographic Album for Artists and Designers”, Dover, 1966.

Hajek M., Dezertova M., Materka A., Lerski R. (Ed.), “Texture analysis for Magnetic Resonance Imaging “, Med4 publishing, 2006

Tamura H., Mori S., Yamawaki T., “Textural Features Corresponding to Visual Perception, IEEE Trans”. on Systems, Man, and Cybernetics, **SMC-8**, pp. 460-473, 1978

Haralick R., “Statistical and Structural Approaches to Texture”, Proc. IEEE, **67**, 5, 1979, 786-804.

Haralick R., Shanmugan K., Dinstain I. , “Textural Features for Image Classification”, IEEE Transactions on Systems, Man and Cybernetics, **3**, 6, 1973, 610-622.

Kovalev V., Petrou M., “Multidimensional Co-Occurrence Matrices for Object Recognition and Matching”, GMIP, **58**, 3, 1996, 187-197.

Geman S., Geman D., “Stochastic Relaxation, Gibbs Distribution and the Bayesian Restoration of Images”, IEEE Trans. Pattern Analysis and Machine Intelligence, **6**, 11, 1984, 721-741.

Chellappa R., Chatterjee S., Bagdazian R., “Texture Synthesis and Compression Using Gaussian-Markov Random Field Models, IEEE Trans. on Systems, Man, and Cyber., **15**, 2, 1985, 298-303.

Dunn D., Higgins W. E., Wakeley J., Texture Segmentation Using 2-D Gabor Elementary Functions, IEEE Trans. on Pattern Analysis and Machine Intelligence, **16**, 1994, pp. 130-149.

Chen C-C., Daponte J., Fox M., “Fractal Feature Analysis and Classification in Medical Imaging”, IEEE Trans. Medical Imaging, **8**, 2, 1990, 133-142.

Choi H., Baraniuk R., “Multiscale Image Segmentation Using Wavelet-Domain Hidden Markov Models”, *IEEE Trans. on Image Processing*, **10**, 9, 2001, 1309-1321.

Randen T., Husoy J., “Filtering for Texture Classification: A Comparative Study”, IEEE on Pattern Analysis and Machine Intelligence, **21**, 4, 1999, 291-310.

Yhann S., Young T., “Boundary Localisation in Texture Segmentation”, IEEE Trans. Image Processing, 4, 6, 1995, 849-856.

Augusteijn M., “Texture Segmentation and Classification Using Neural Network Technology”, Applied Mathematics and Computer Science, 4, 1995, 353-370

References

Cohen F., Cooper D., “Simple Parallel Hierarchical and Relaxation Algorithms for Segmenting Noncausal Markovian Random Field”, IEEE Trans. Pattern Analysis and Machine Intelligence, 9, 2, 1987, 195-219.

Wang D., “Emergent Synchrony in Locally Coupled Neural Oscillators”, IEEE Trans. on Neural Networks, 6, 4, 1995, 941 – 948

Hu Y., Hwang J. (Ed.) Handbook of Neural Network Signal Processing, , CRC Press, 2002.

Reed T., Wechsler H., Werman M., “Texture Segmentation Using a Diffusion Region Growing Technique”, Pattern Recognition, **23**, 9, 1990, 953-990

Raghu P., Yegnanarayana B., “Supervised Texture Classification Using a Probabilistic Neural Network and Constraint Satisfaction Model”, IEEE Trans. on Neural networks, **9** 3, 1998, 516-522.

Yin H., Allinson H., “Unsupervised Segmentation of textured Images Using a Hierarchical Neural Structure”, Electronics Letters, **30**, 22, 1994, 1842-1843

Strzelecki M. , Materka A., Drozdz J., Krzeminska-Pakula M., Kasprzak J. D., Classification and segmentation of intracardiac masses in cardiac tumor echocardiograms, Computerized Medical Imaging and Graphics, **30**, 2, March 2006, pp. 95-107

Klepaczko A., Application of clustering algorithms for feature selection for data classification tasks, Ph. D. Thesis, Technical University of Lodz, 2006 (in Polish)