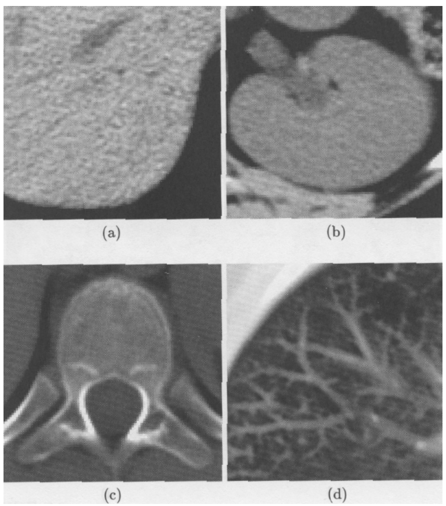
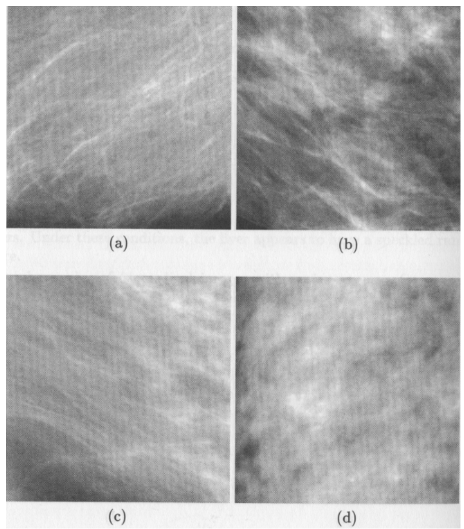
Analysis of Texture

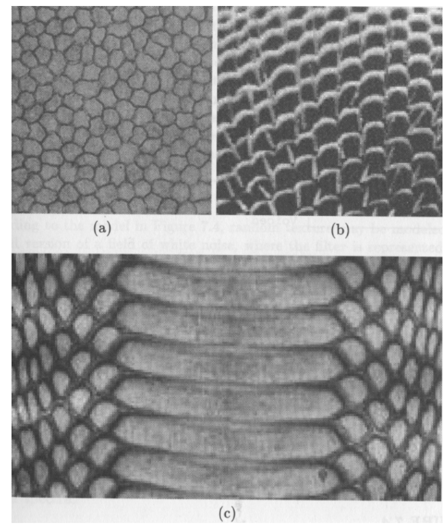
- Random textures in biomedical images



(a) Liver/parenchyma cluster
(b) Kidney (c) Spine (d) Lung



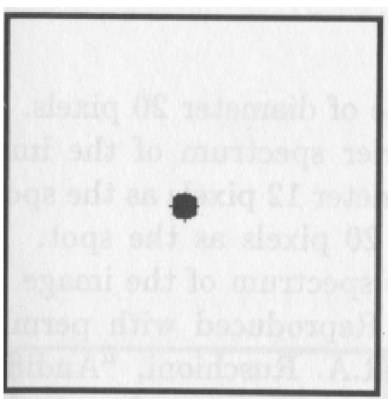
Oriented texture: mammograms



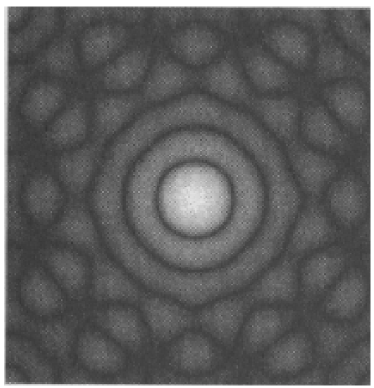
(a) Edothelia cells in cornea
(b) drosophila's eye (c) Skin
of cobra

Texture Modelling (Random)

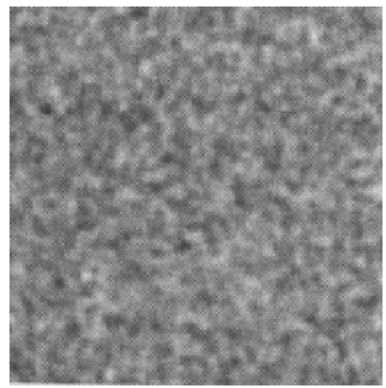
- Convolve spot or spots of a certain shape with a random field of white noise



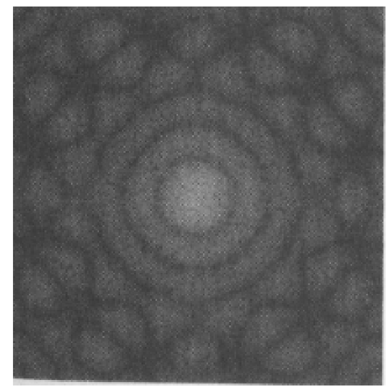
Circle diameter=12 pixel



FFT of the pixel (texon)



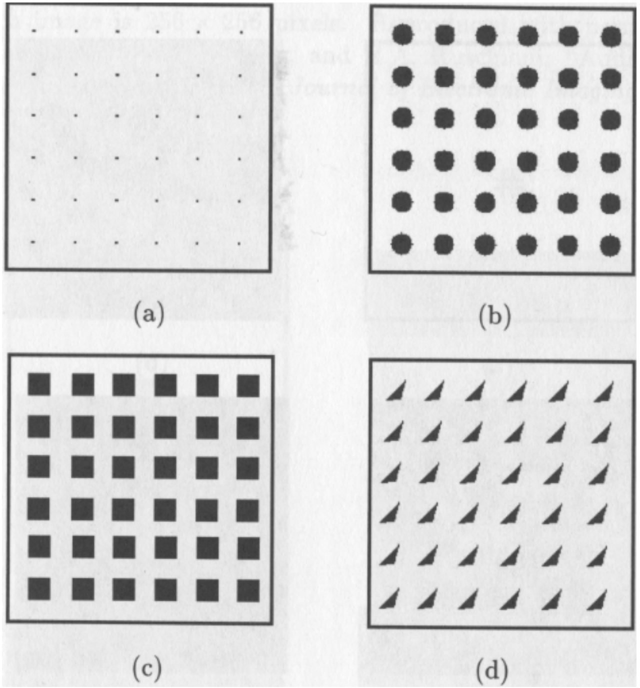
Convolution of white noise with circle



FFT of the whole texture

Texture Modelling (Ordered)

- Convolve texture patch (texton) with a field of (quasi-) periodic impulses
- Oriented textons are possible
- Spectral Properties of the texton would be seen in FFT



(a) Position determined by Diracs (b) circular texon (c) square texon (d) triangle texon (oriented)

Statistical Analysis of Texture

- Moments of the gray-level Probability Distribution Function (PDF)
- k^{th} central moment of the PDF $p(l)$ is

$$m_k = \sum_{l=0}^{L-1} (l - m_f)^k \, p(l)$$

where l=0,1,2,...,L-1 are the gray levels in the image f, and m_f is the mean gray level

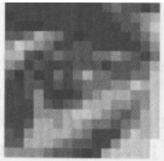
Central Moments

- Serve as one descriptor for the whole image (no spatial information)
- m_2 is the variance of the gray levels and serves as a measure of inhomogeneity
- skewness = $m_3/(m_2)^{3/2}$ indicates asymmetry
- kurtosis = $m_4/(m_2)^2$ indicates uniformity
- Skewness of mammograms was found to be useful in predicting risk of development of breast cancer

Gray-level co-occurance matrix (GCM)

- Commonly used statistical measure of texture proposed by Haralick et al.
- GCM $P_{(d,q)}(l_1,l_2)$ represents the propability of occurence of a pair of gray-levels (l_1,l_2) separated by a given distance d at angle q
- Commonly for unit pixel distances and the four angles 0°, 45°, 90° and 135°.

GCM example



1	1	1	1	1	1	1	1	1	1	2	3	2	2	1	2
0	1	1	1	1	1	1	1	1	1	1	2	2	3	4	5
1	0	0	0	1	1	1	1	1	1	1	1	2	2	4	6
2	2	3	5	4	3	1	0	1	1	1	1	1	2	3	5
4	6	5	4	3	1	1	2	2	1	1	1	1	1	2	4
5	5	2	1	2	3	2	2	2	3	3	4	3	2	1	3
4	3	1	2	1	1	1	2	2	2	1	2	2	2	3	5
2	0	2	0	1	3	1	3	5	3	3	2	2	3	3	6
1	1	2	2	1	2	1	2	3	3	3	4	4	6	5	6
1	1	2	4	1	0	0	1	3	4	5	5	5	4	4	6
1	1	1	4	2	1	2	3	5	5	5	4	4	3	4	6
1	1	1	4	4	4	5	6	6	5	4	3	2	3	5	6
1	1	2	5	5	4	5	5	4	3	3	2	3	4	5	6
2	1	4	5	5	5	5	4	3	1	1	1	4	6	5	6
2	2	5	5	5	4	3	2	2	1	1	4	6	6	6	7
4	4	4	4	3	2	2	1	0	1	5	6	6	6	6	7

Current Pixel	Next Pixel Below							
	0	1	2	3	4	5	6	7
0	0	3	4	1	0	1	0	0
1	6	44	10	9	5	1	0	0
2	3	13	13	5	8	3	1	0
3	1	5	11	5	3	5	2	0
4	0	1	5	7	5	9	3	0
5	0	0	1	5	11	10	4	0
6	0	0	0	0	2	3	10	1
7	0	0	0	0	0	0	0	1

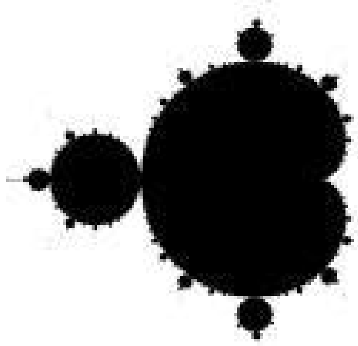
GC Matrix for d=1 and q=270°.

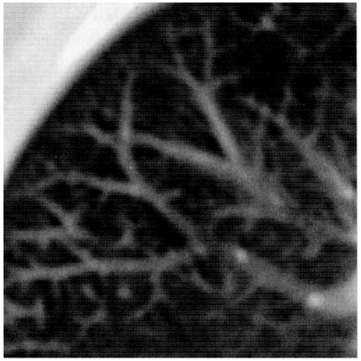
Haralick's measures of texture

- Normalized GCMs are used to define image features F, for example
  - F_1 energy (homogeneity)
  - F_2 contrast
  - F_8 entropy (randomness)
  - F_{14} maximal correlation
- Features used, for example, to distinguish malignant tumours and image classification

Fractal Analysis

- Pattern composed of repeated occurrences of a basic unit at multiple scales of detail (Mandelbrot set).
- Fractal dimension
  - relationship between measured length and the measuring unit.
  - quantifies how a pattern fills space. Pattern of increasing irregularity/roughness have greater fractal dimension d_f.
  - 1 for straight line, 2 for circle and 3 for sphere





Example: Bronchial tree

Methods for estimating fractal dimension

- Relative dispersion
  - Ratio of standard deviation to the mean using varying number of samples
- Intensity difference measure
- Surface area measure (box-counting)
- Hurst coefficient: $d_f = d_E + 1 - H$

Fractional Brownian Motion

- Brownian motion model
  - Expectation of the differences between signal values is

$$E[|\, f(h+\Delta h) - f(h)\, |] = |\, \Delta h\, |^{H}$$

- The psd of a Brownian motion model follows the power law commonly encountered in biological signals.
- Estimation of d_f by approximating expectation with sample mean.
- Machine Learning: Gaussian Process with special Covariance Matrix (parametric estimates possible?).

Applications of fractal analysis

- Benign masses have low fractal dimension then malignant tumors.
- Classification
- Segmentation
- Generally better results than GCM features, fourier spectral features, gray-level difference statistics and Law’s texture energy
- Has a connection to the generation of biological pattern by means of reaction-diffusion system.

Structural Analysis

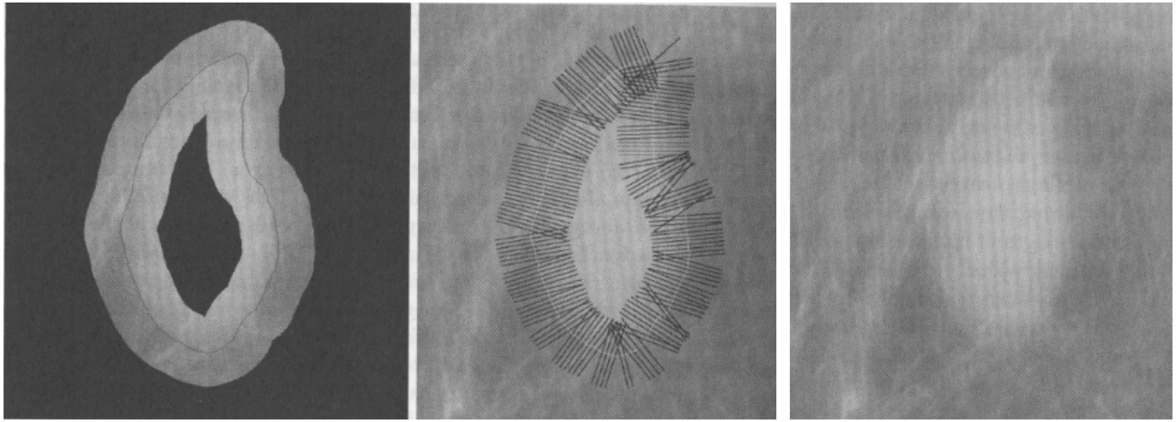
- Statistical methods are suitable for analysis of random or fine texture
- Structural methods are more suited for analysis of large-scale motifs and multitextured images
- Requires image segmentation

Structural Analysis Methods

- Find image textons and their placement maps
  - Describe textures in terms of texture elements and their arrangement from edge repetition data
  - Texture units in terms of 8-connected neighbours
  - Texture primitives assumed to appear as regions of connected pixels
  - Gabor filters
  - Multiple scale methods
  - Homomorhpic deconvolution

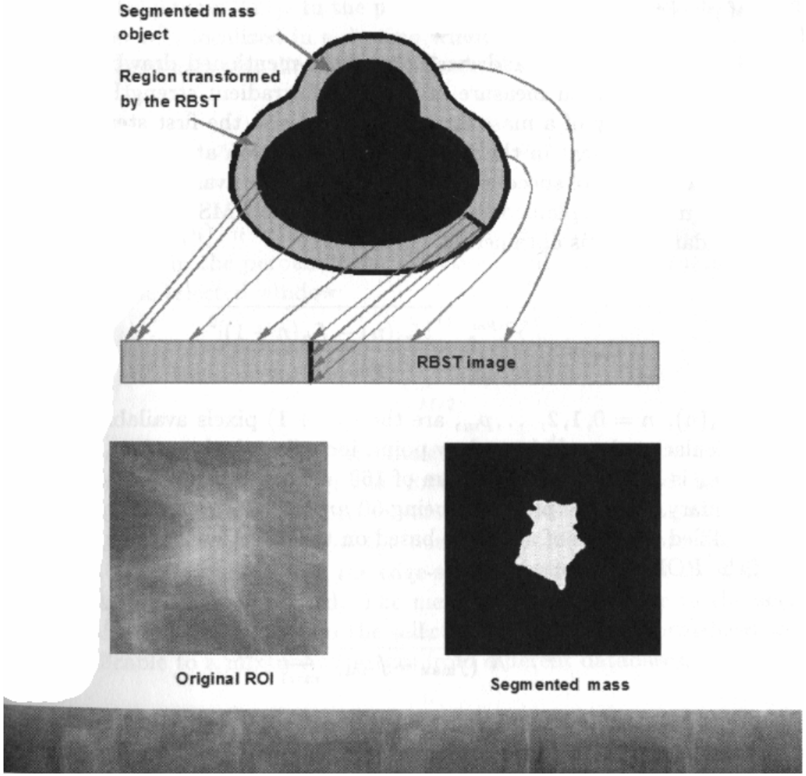
Application

- Analysis of Breast Masses
- Problem: Malignant breast lesions permeate larger areas than apparent on mammograms (infiltration) →large inter-observer variations
- Define a ribbon of uncertainty



Application

- Map the ribbon to rectangular image
- Apply Texture Analysis



Summary

- In practice you need to use combinations of several methods
- Still an active field of study
- More in chapters 8, 9 and 12.