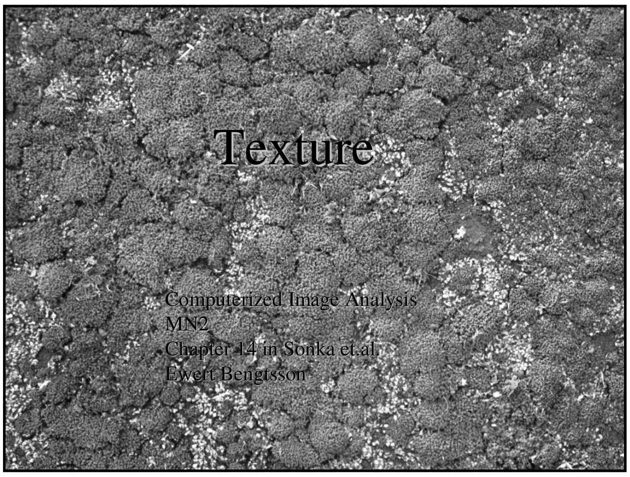
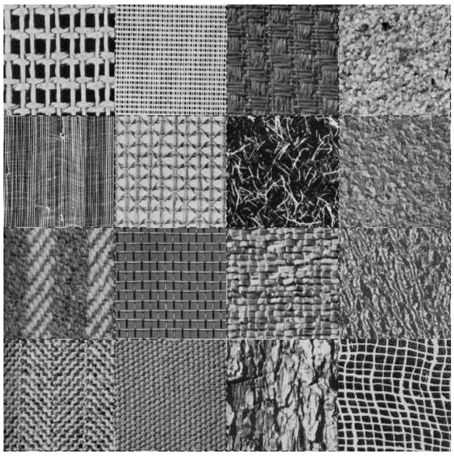
Texture

Computerized Image Analysis MN2
Chapter 14 in Sonka et.al.
Ewert Bengtsson



What is texture?

- An essential concept in image analysis
- Texture consists of texture **primitives** or **elements** called **texels**
  - a contiguous set of pixels with some tonal and/or regional property
- A texture can be characterized by **tone** (intensity properties) and **structure** (spatial relationships)
- Textures are highly **scale dependent**, we may have **hierarchical** textures



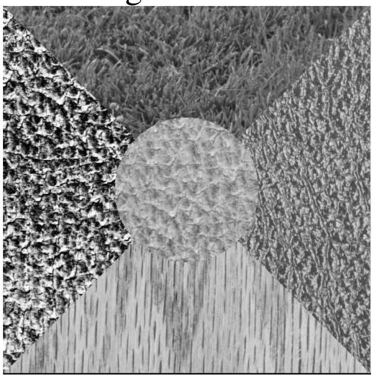
No precise definition of texture exists

- “An image region has a constant texture if a set of its local properties in that region is constant, slowly changing, or approximately periodic.”

What texture analysis is used for

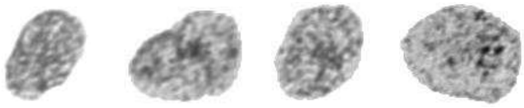
- To **segment** an image into regions with the same texture, i.e. as a complement to greylevel or color
- To recognize or **classify** objects based on their texture

Typical test image for texture based segmentation

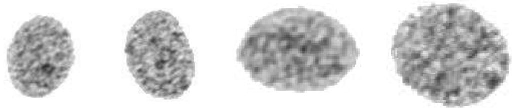


Typical application for texture analysis

Cells from a tumour with poor prognosis



Cells from a tumour with good prognosis



How can we differentiate between these?

Texture description approaches

- Statistical
  - each texture is characterized by a feature vector
- Structural (or contextual)
  - the texture elements are seen as meaningful regions
- Syntactic
  - the texels are combined through a grammar
- Hybrid
  - a combination of syntactic and statistical

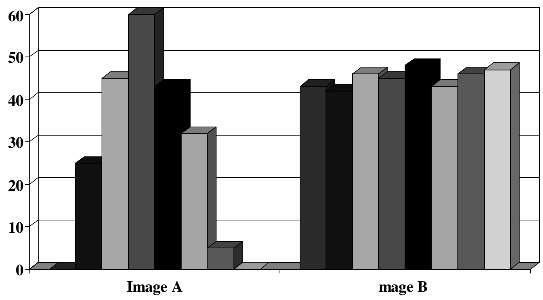
Statistical texture analysis

- First order statistics
- Second order statistics
- Higher order statistics

Texture based on first order statistics

- Anything that can be computed from the greylevel (or color) histogram
- Mean (hardly a texture measure)
- Standard deviation (often quite useful)
- Higher order moments
  - Third order - skew
  - Fourth order - curtosis

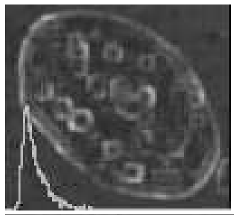
First order texture statistics

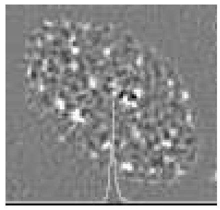


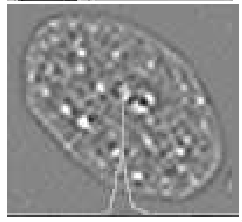
Texture feature transforms

- For texture analysis image transforms are usually quite useful:
  - Gradient image, magnitude of 3x3 gradient
  - Laplace image, laplace operator values
  - Flat texture image, image – median image, parameter R, size of median window
  - Rice field image, based on topological gradients through watersheds

Examples of transforms, removing average graylevel (Gradient image, Laplacian image, Flat texture image)







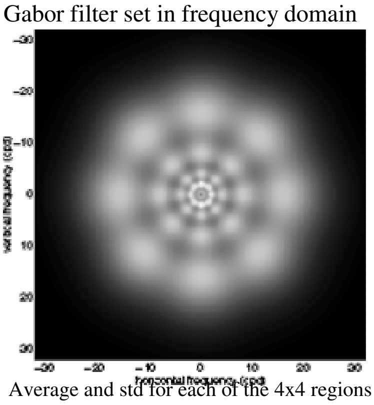
Texture features from the transformed images

- All the histogram and moment features extracted from the transformed images express texture.
- Some features found particularly useful:
  - Skewness of gradient value distribution
  - Total integrated gradient intensity
  - Standard deviation of laplace image
  - Average of flat texture image show unbalance in light/dark particle distributions, std quantifies contrast, the moments of the flat texture image are often quite useful

Texture based on second order statistics

- Autocorrelation function
  - can evaluate for different distances in x and y or r
- Spatial frequencies
  - integrate over annular rings or wedges in Fourier space
  - can be computed optically
  - Gabor filters combines orientation and frequency
- Edge frequency
- Co-occurrence matrices
  - by far the most frequently used texture descriptor

Gabor filter set in frequency domain



Average and std for each of the 4x4 regions gives a feature vector that classifies the texture

Co-occurrence matrix

3	0	1	1
0	0	1	1
0	2	2	2
2	2	3	3

<- Image

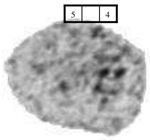
$P_{0,1}$

	0	1	2	3
0	1	2	1	0
1	0	2	0	0
2	1	0	3	1
3	1	0	0	1

$P_{135,1}$

	0	1	2	3
0	0	1	3	0
1	0	1	1	0
2	0	0	0	2
3	1	0	0	0

Texture measure: GLCM



	0	1	2	3	4	5
0	**22**	**8**	**4**	**3**	**5**	**1**
1	**12**	**18**	**10**	**9**	**7**	**2**
2	**8**	**16**	**19**	**9**	**5**	**4**
3	**7**	**14**	**20**	**21**	**13**	**9**
4	**5**	**8**	**14**	**19**	**24**	**11**
5	**3**	**6**	**13**	**18**	**20**	**21**

Gray Level Co-occurrence Matrix

Co-occurrence matrix considerations

- Will have the size of the # of graylevels squared
  - Often reduces graylevels to 16, 32 or 64
- Depends on absolute graylevel
  - use normalization e.g. Histogram equalization
- Depends on texture orientation
  - use average, min, max or max-min over all orientations
- Generates very many strongly correlated features
  - needs large data sets for evaluation and validation

How to use co-occurrence matrices

- Gives a high-dimensional texture description
- Can use directly to measure statistical distances between different textures
- Usually used by extracting secondary features
  - The Haralick features, the first and most popular
  - Extended and modified by many others

Co-occurrence matrix features

- The classical way of expressing texture according to Haralick
  - 14 features defined
  - Based mainly on extinction and texture image
  - Normalized by
    - Histogram equalization
    - Linear stretch
- Typically done with reduced orientation dependence by summing over different directions

Haralick texture features

1.angular 2nd moment	8.sum entropy
2.contrast	9.entropy
3.correlation	10.difference variance
4.variance	11.difference entropy
5.inverse 2nd diff. moment	12.measure of correlation 1
6.sum average	13.measure of correlation 2
7.sum variance	14.local mean

Some definitions of Haralick features

- Energy: $\sum_a \sum_b P^2(a,b)$
- Entropy: $\sum P(a,b) \log_2 P(a,b)$
- Maximum probability: max P(a,b)
- Contrast: $\sum |a-b|^{\kappa} P^{\lambda}(a,b)$,
  typically $\kappa=2$, $\lambda=1$, also $\kappa<0$ if $a \neq b$
- Correlation: defined as usually
- Many other variants common

Texture based on higher order statistics

- Experiments have shown only 2nd order needed
- Run length codes
  - Histograms of greylevel run lengths in various directions
- Laws texture energy measures
  - five masks based on combined 0,1,2 derivatives
- Fractal texture descriptors
- Mathematical morphology based, openings
- Wavelet based - new promising approaches

Texture measure: GLRLM

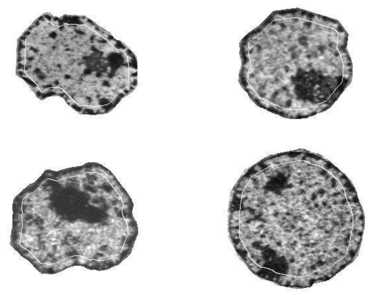
Gray Level Run Length Matrix

	0	1	2	3	4	5	6
1	30	18	34	25	11	9	8
2-3	16	15	18	12	7	3	2
4-N	12	14	19	11	5	2	0

Run-length texture features

- Normalized as for co-occurrence features
- Five features calculated:
  - Short run emphasis (divided by run squared)
  - Long run emphasis (multiplied by --”--)
  - Gray level nonuniformity (run length sum squared)
  - Run length nonuniformity (gray levels sum squared)
  - Run length percentage 1/A * double sum

The region for which a feature is calculated can have great significance: Separating the texture analysis radially gives significantly better discrimination results between these four types of cells



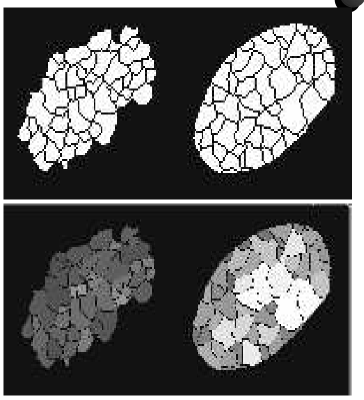
Structure features also called contextual features

- Some transform, typically the flat field image or the rice field images are used to define small texture objects through segmentation
- From each of these objects various intensity measures are obtained from the original (extinction) image
- Statistics describing the distributions of these measures are often useful features

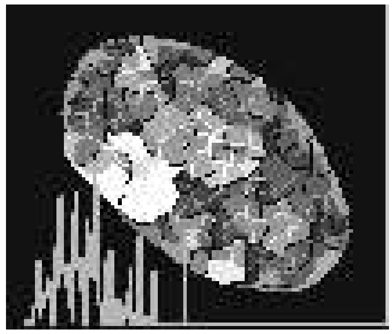
The rice field image

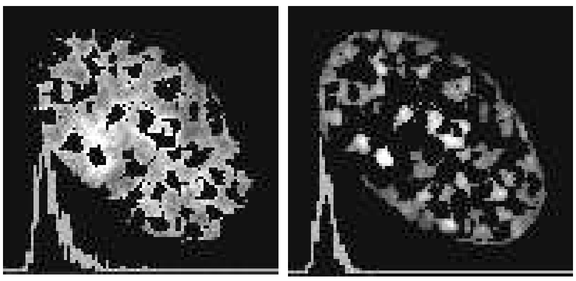
- Carry out a watershed transform
- All pixels in each watershed region is replaced by corresponding extreme value
- Can be generated for 255 – image, resulting in upper rice field (vs lower rice field)
- Topological gradient = RU – RL
- Second difference D2 = (RU+RL)/2-image
  - Threshold at 0 defines HU and HL

Rice field images Upper and lower



The topological gradient image HU - HL





Topological texture regions: HL and HU

Syntactic methods

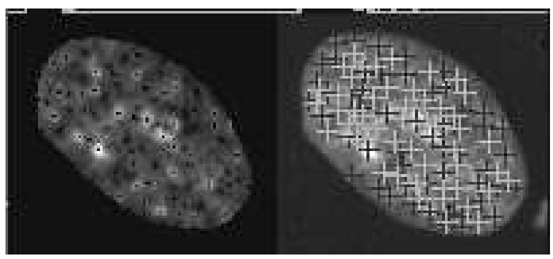
- Shape chain grammars
- Graph grammars
  - The texture recognition is based on graph recognition
- Primitive grouping in hierarchical textures

- Usually need to use stochastic grammars to allow for variation and noise
- Much less successful than statistical approaches

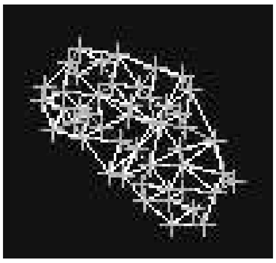
Graph analysis on texture regions

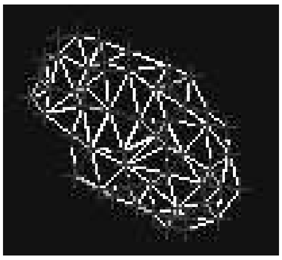
- Various graphs can be generated:
  - Delauney triangulations,
  - nearest neighborhood graphs,
  - minimum spanning trees
  - convex hull of dark and bright particles
- The numbers of nodes, neighboor nodes and variations in these express structure
- Mainly used in histometry, but has potential also in cytometry…

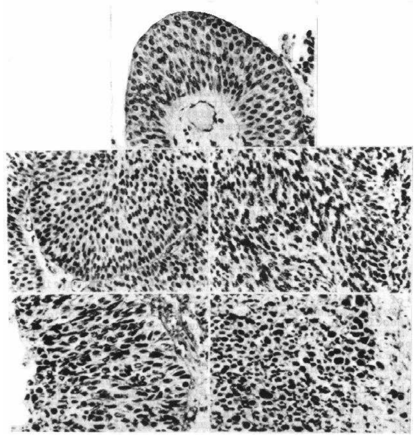
Defining texture particle positions

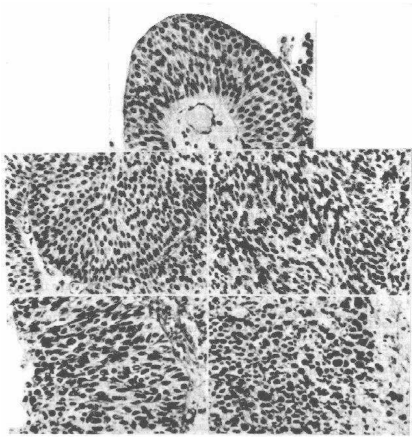


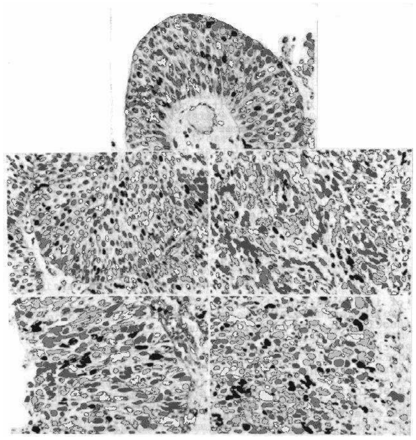
Graph analysis of chromatine topology: EL end EU regions

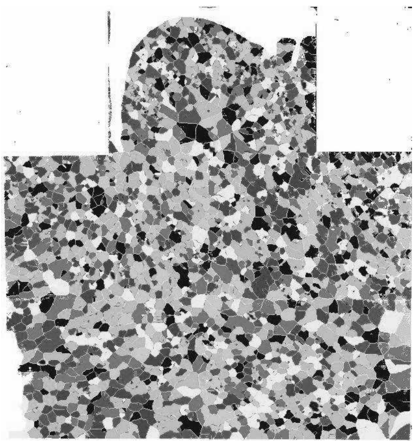






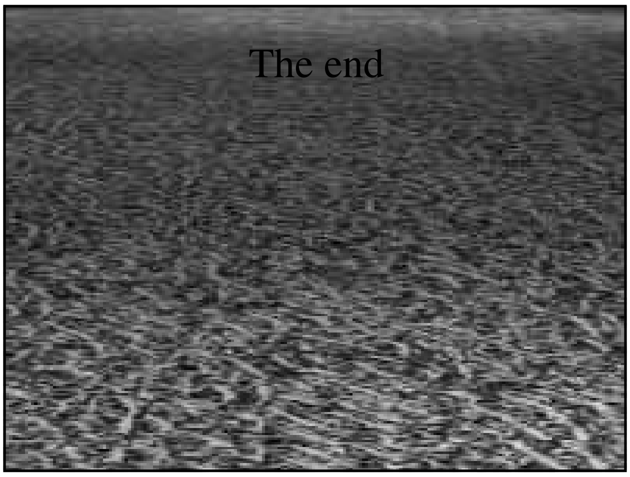






Hybrid methods

- Primitives are defined based on statistical measures
- These are related to each other through syntactical methods


The end