SEGMENTATION OF TEXTURED IMAGES USING NETWORK OF SYNCHRONISED OSCILATORS

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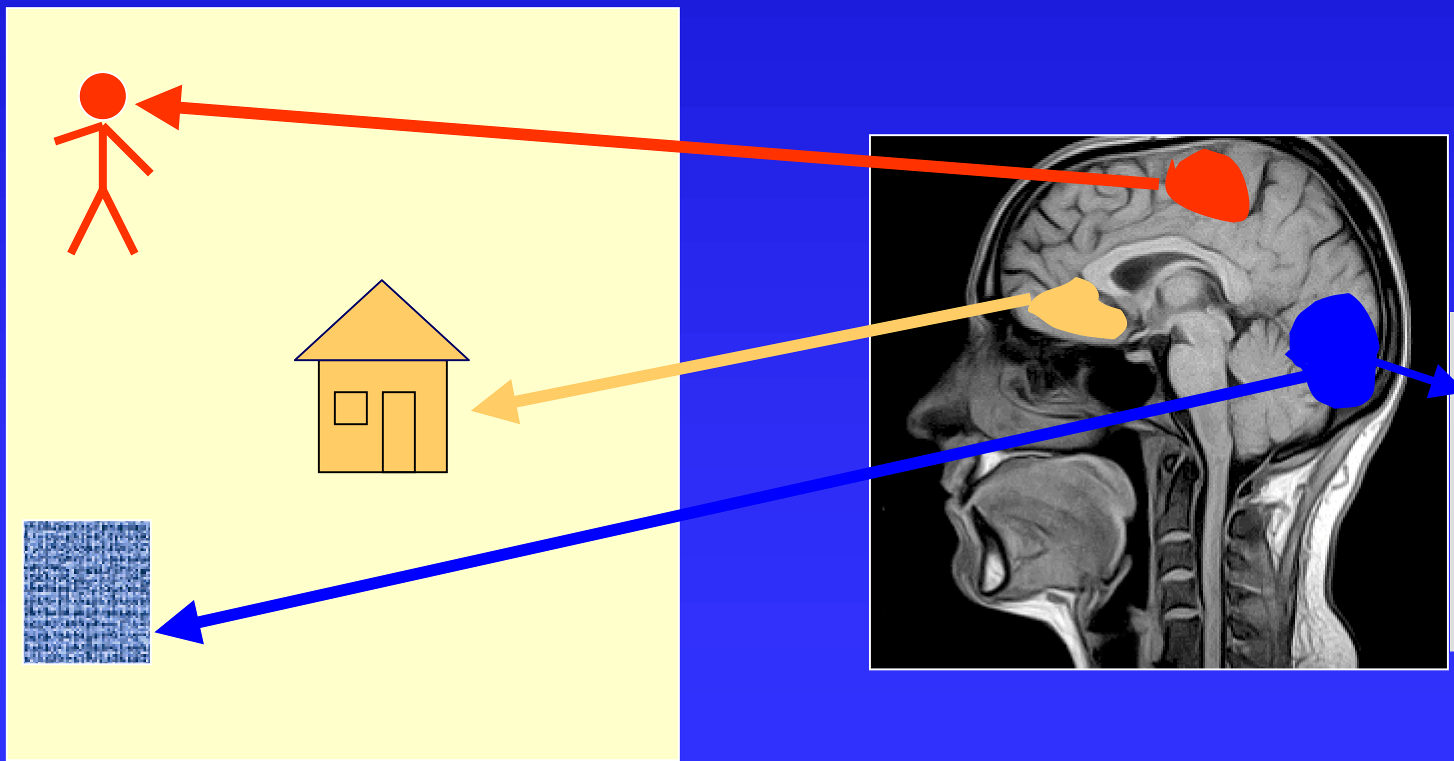
COST B11, 2-4 MAY 2002, BERGEN

<u>„Temporary correlation"</u> theory (von der Malsburg, 1981) tries to explain how the image scene segmentation is performed by human brain.



object features:
{ color,
shape,
texture,
...}

The network of synchronous oscillators

(Wang & Teman 1995, Linsay & Wang 1998)

LEGION - Locally Excitatory Globally Inhibitory Oscillator Network

- **network of locally connected oscillators, each image point is represented by one oscillator**
- **oscillators connected to a given object are simultaneously synchronised**
- **other oscillators are disabled**
- **after same time active synchronised oscillators are desynchronised, while the other oscillator group starts synchronisation (this group represents a different object)**

The mathematical model of single oscillator

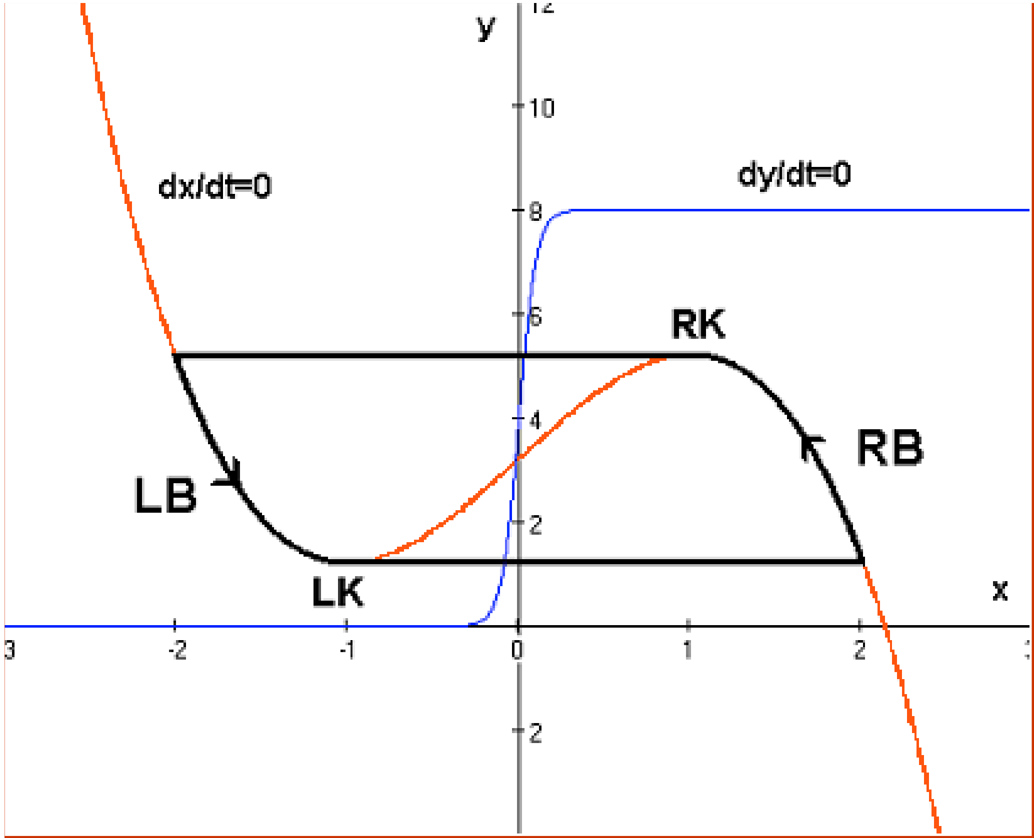
x - excitatory variable, y - inhibitory variable

$$\frac{dx}{dt} = 3x - x^3 + 2 - y + I_T$$

$$\frac{dy}{dt} = \varepsilon\{\gamma[1 + \tanh(\frac{x}{\beta})] - y\}$$

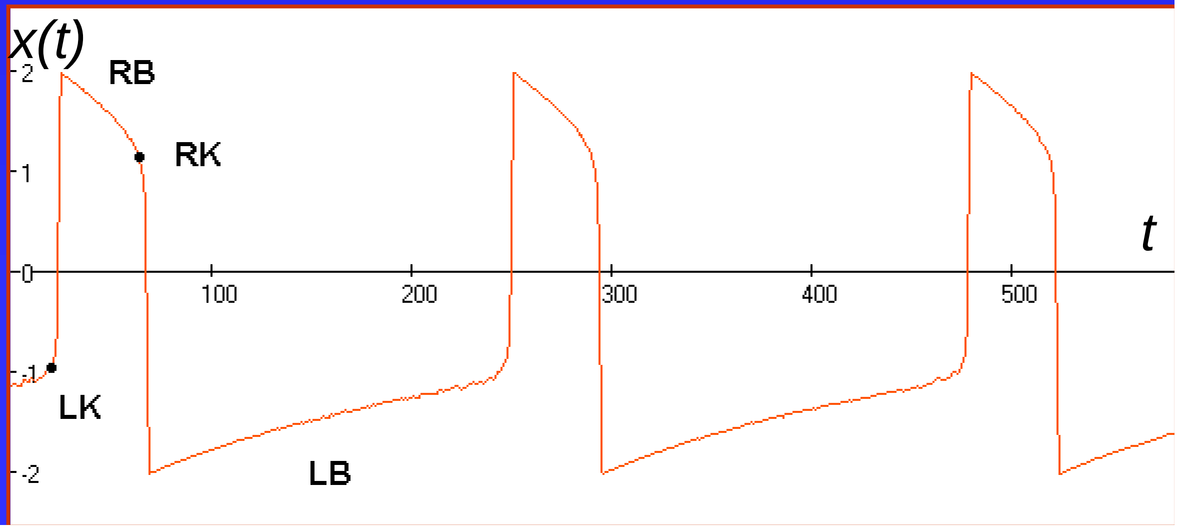
I_T - excitation of oscillator x:

$I_T > 0$ - activated (oscillatory), $I_T \leq 0$ - disabled

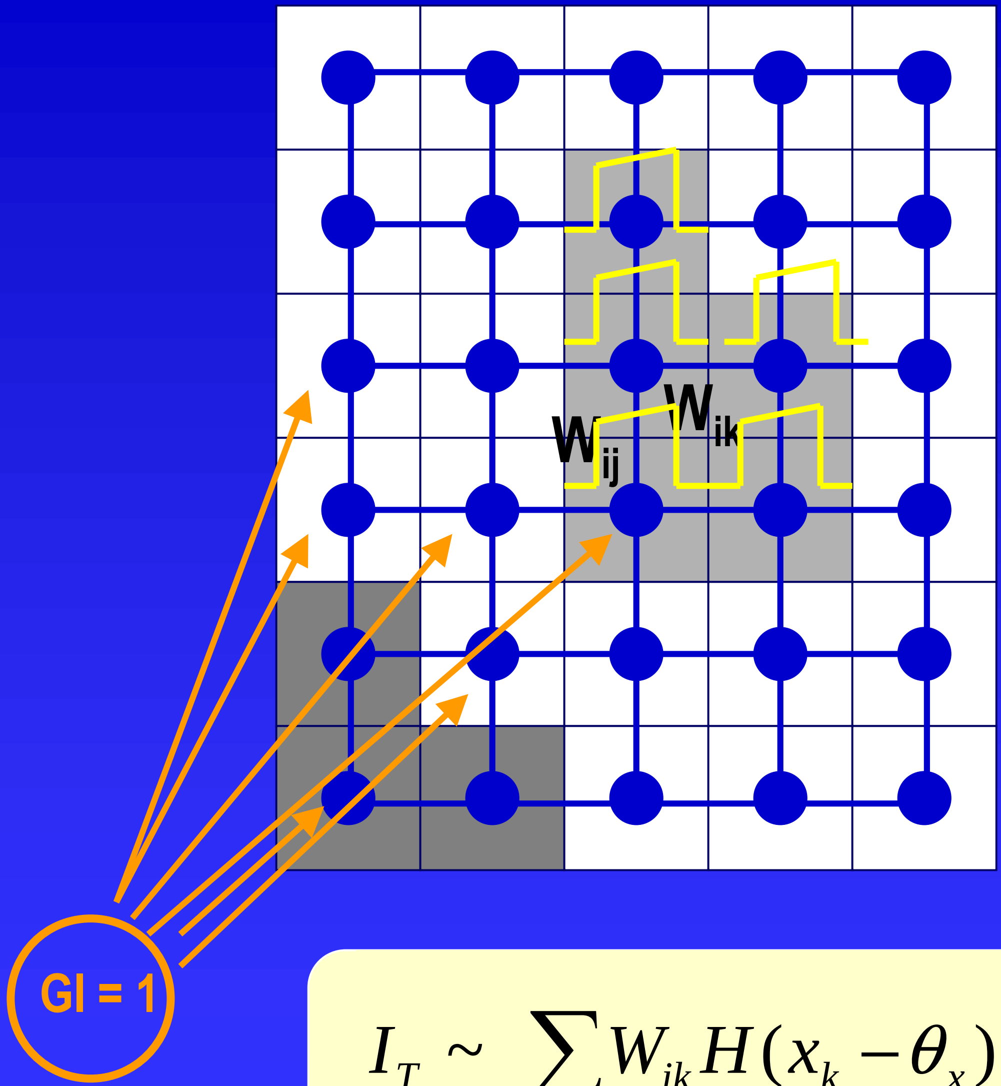


Nullclines (*dx/dt=0, dy/dt=0*) and trajectory of an oscillator *x*

The output waveform *x(t)* of an oscillator *x*



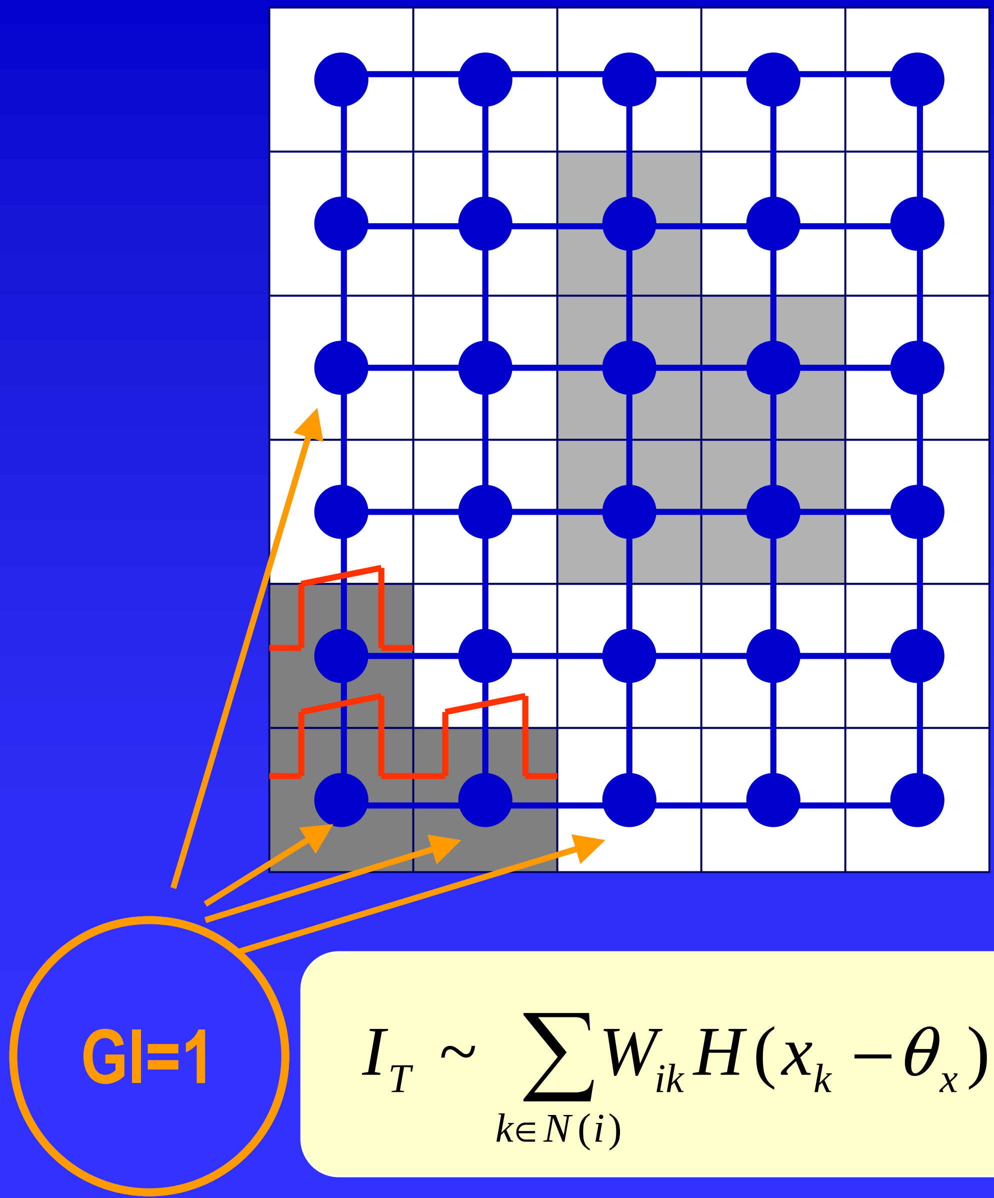
The network of locally connected oscillators



GI - global inhibitor,
equal to 1 when
at least one oscillator
is activated
and 0 otherwise

$$I_T \sim \sum_{k \in N(i)} W_{ik} H(x_k - \theta_x) - GI \cdot W_z \qquad H(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$

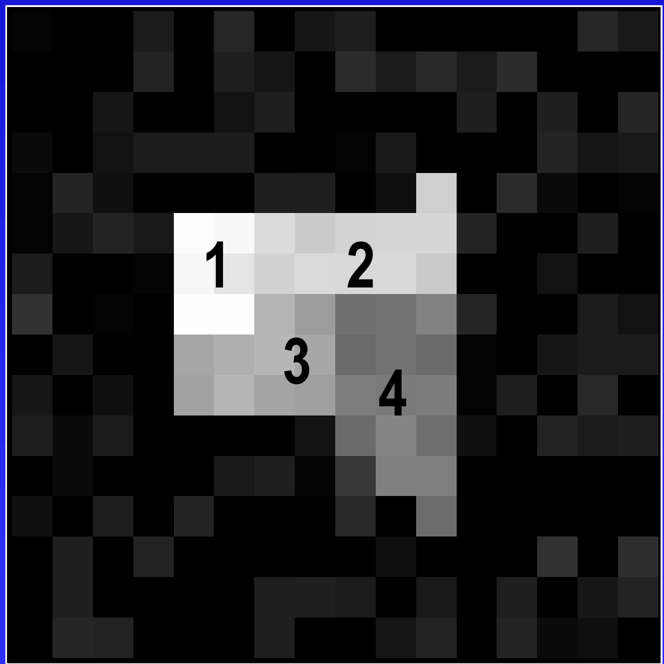
The network of locally connected oscillators



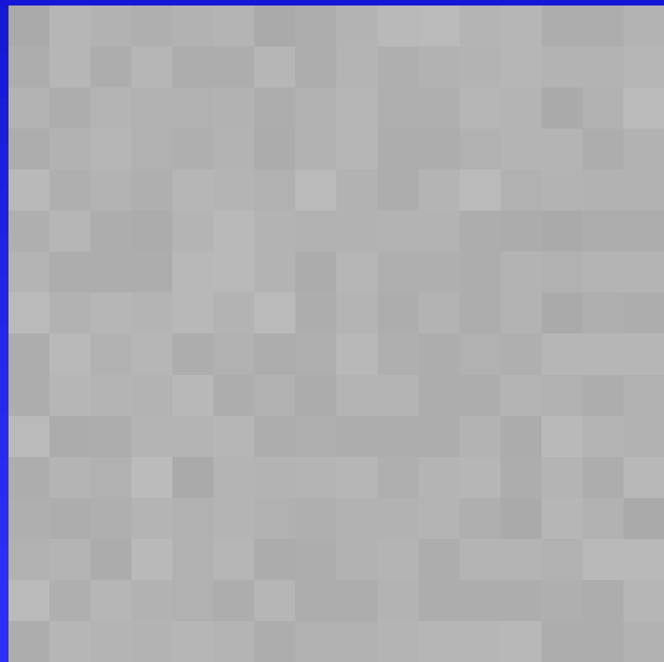
$$I_T \sim \sum_{k \in N(i)} W_{ik} H(x_k - \theta_x) - GI \cdot W_z \qquad H(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$

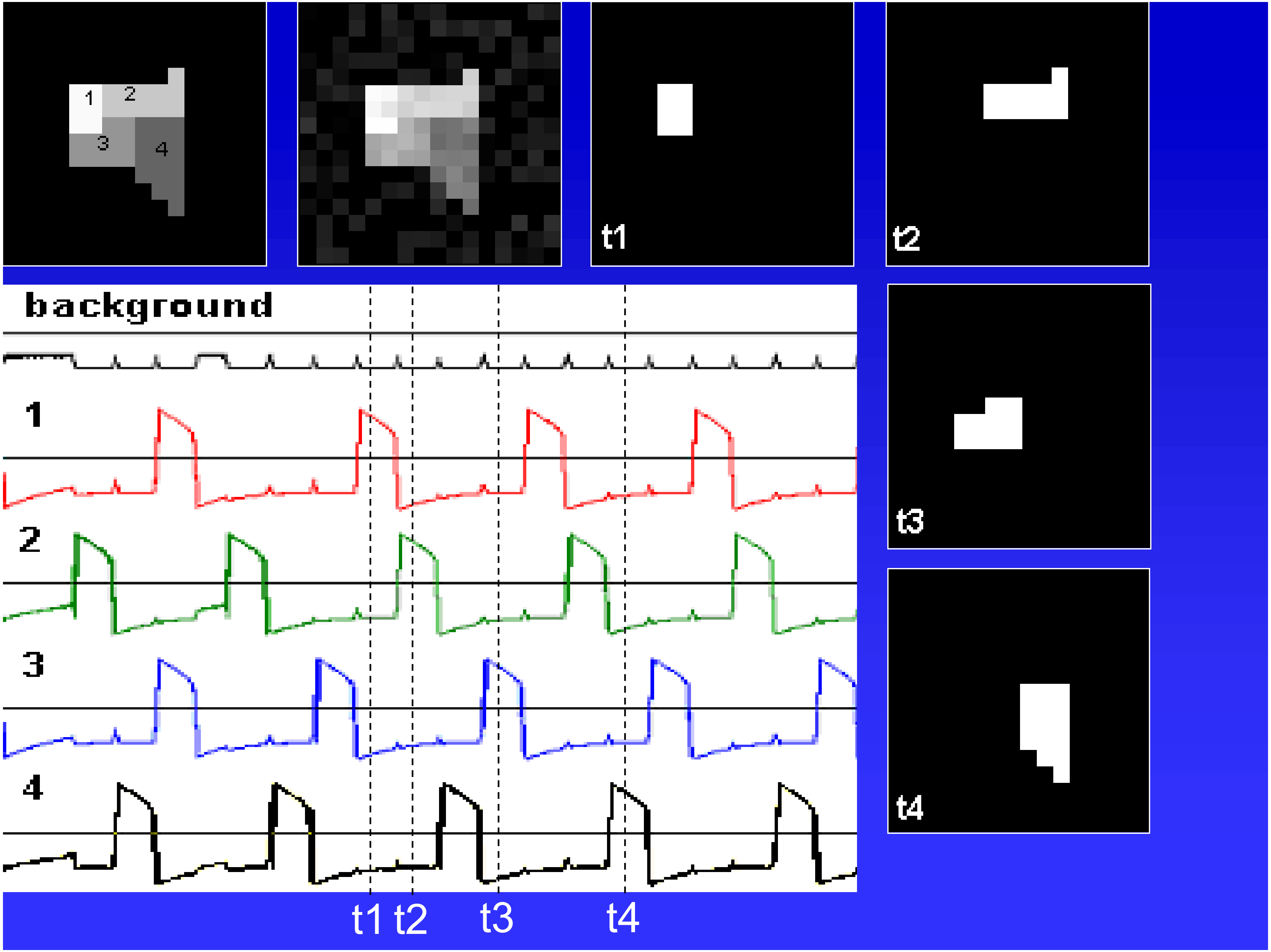
Example of grey-level image segmentation corrupted by Gaussian noise

16×16



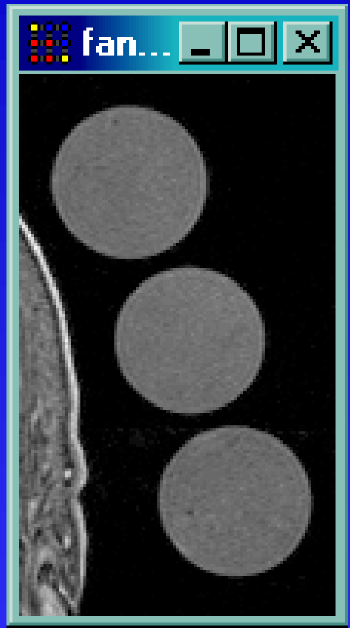
iterations

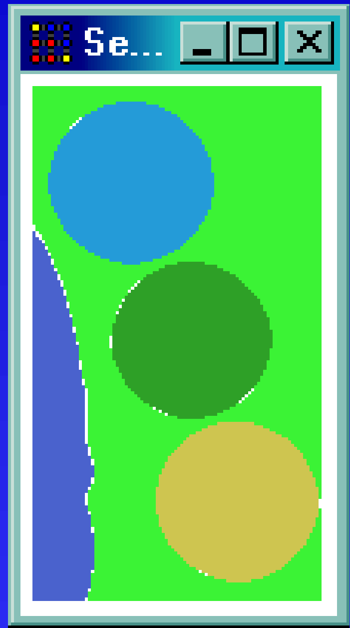



1
2
3
4
t1
t2
t3
t4
background
1
2
3
4
t1 t2 t3 t4

Example of MRI image segmentation

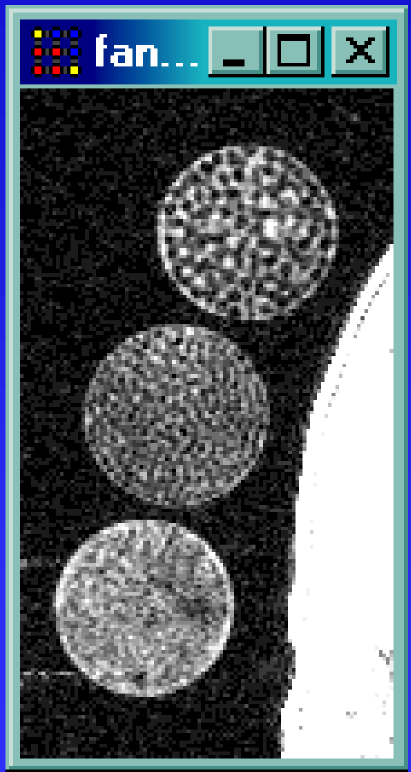
Foam phantoms

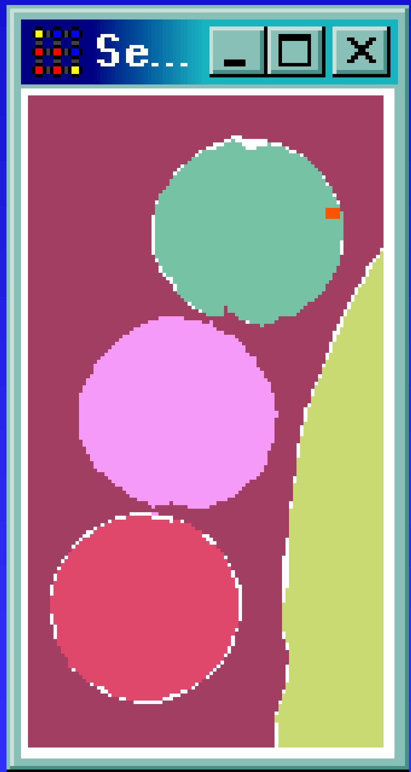




To speed up calculation in the network, it is possible to apply an algorithm, where simplified oscillator model is assumed (Linsay & Wang 1998)

Example of MRI image segmentation



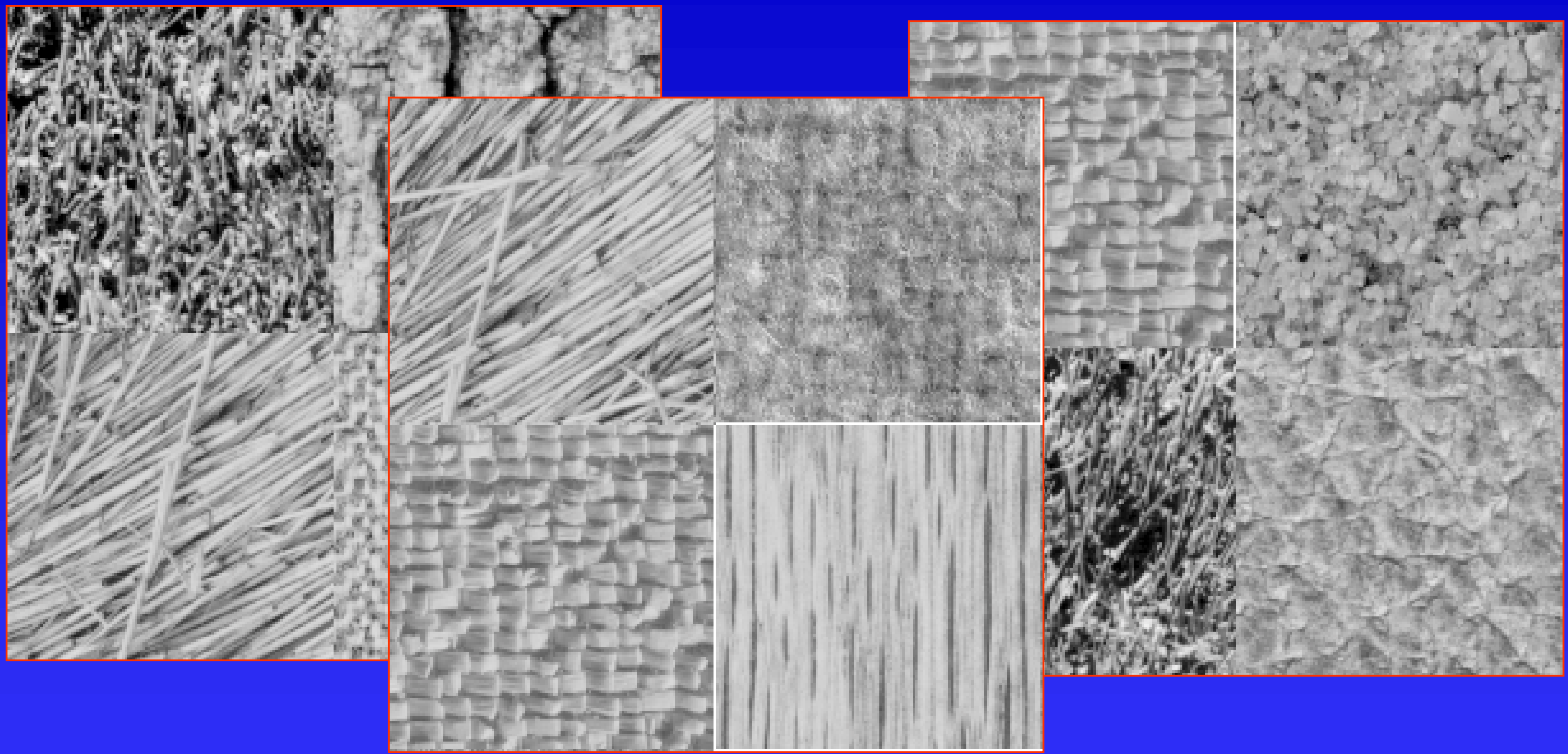


PS phantoms

$$W_{ij} = \frac{U_{\max}}{1 + |U_i - U_j|}$$

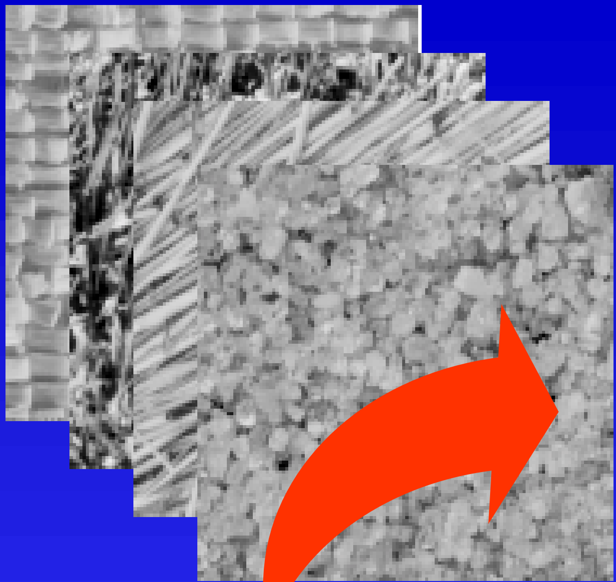
U_i - ***median in 5x5 window***

Segmentation of textured images

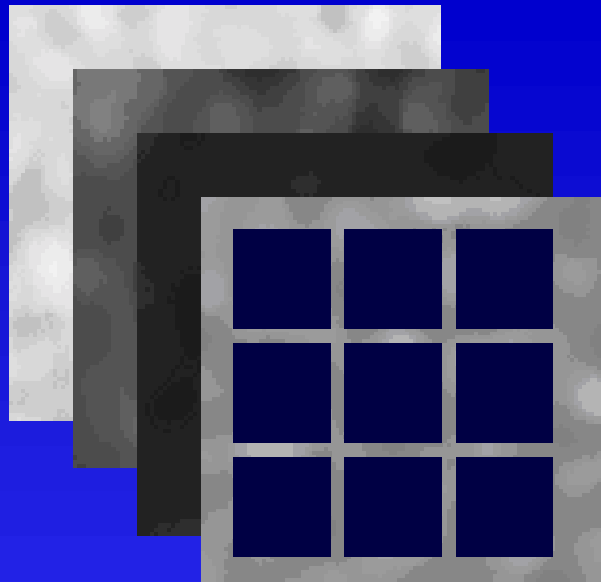


There is a need to find texture features which are able to segment analysed images. These features will be used to form oscillator weights.

Features based on linear optimised filtering



linear filter ***h***



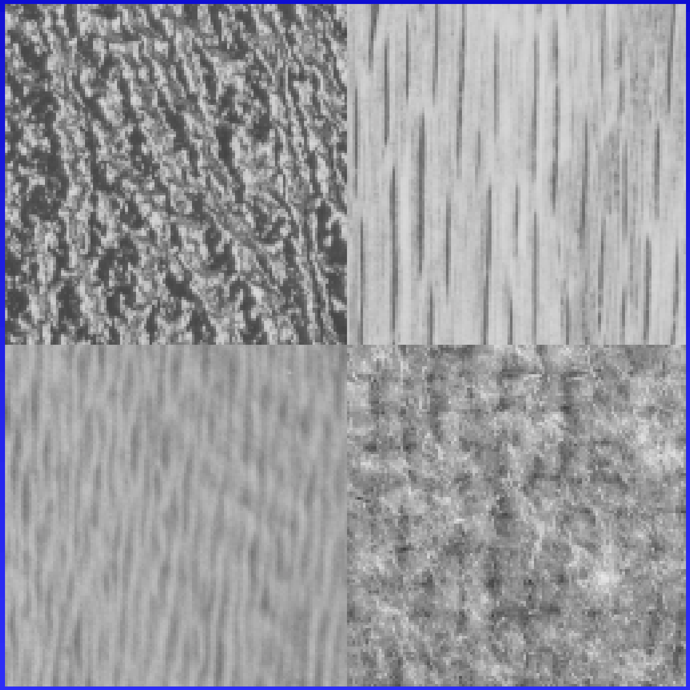
feature extraction

estimation of mean and variance for these features

optimisation of *h* to increase *F*

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

Segmentation example



sample texture from Brodatz album

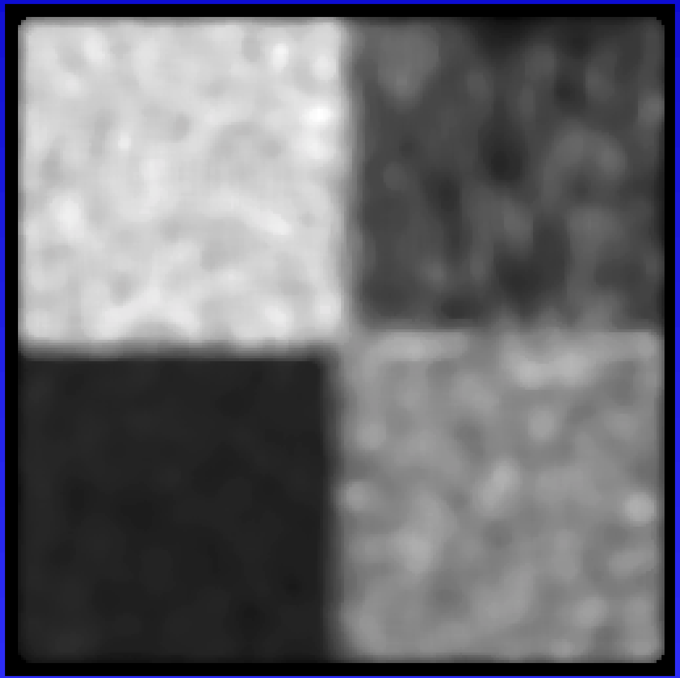
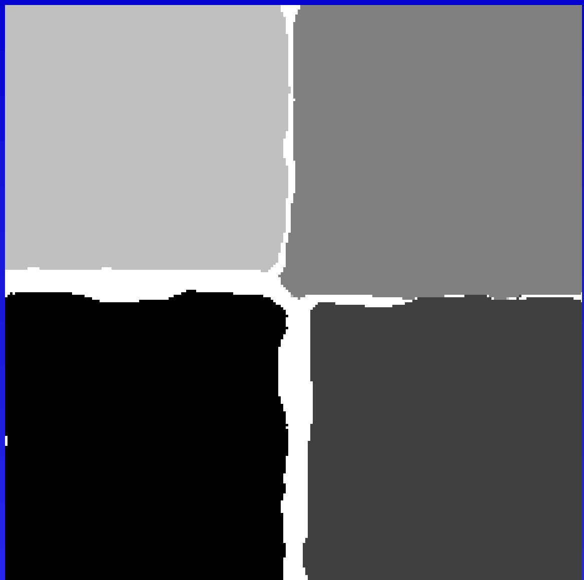
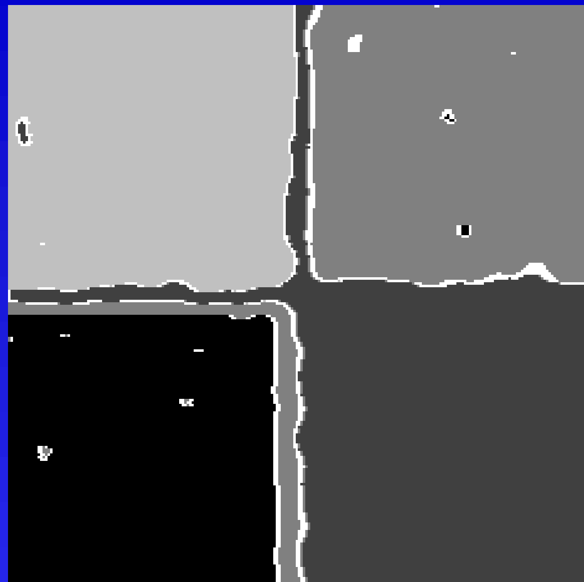


image after filtering, 7x7

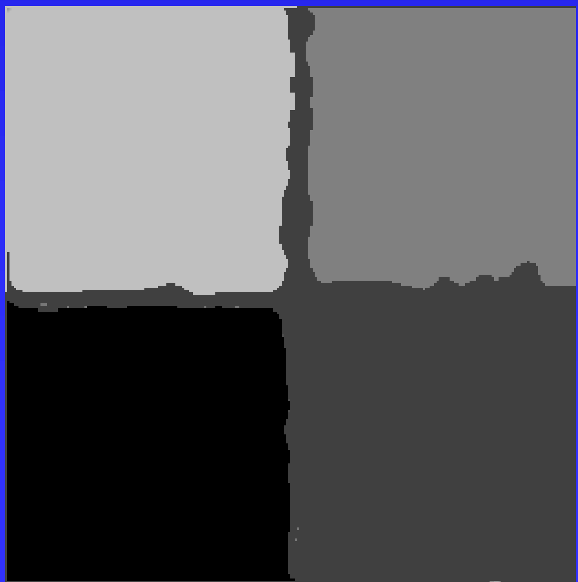
Comparison of different segmentation methods



LEGION



ANN

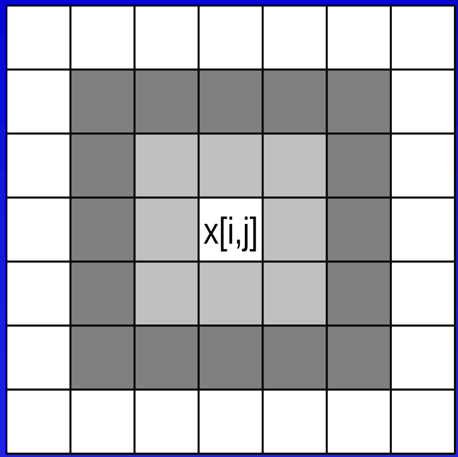


region growing

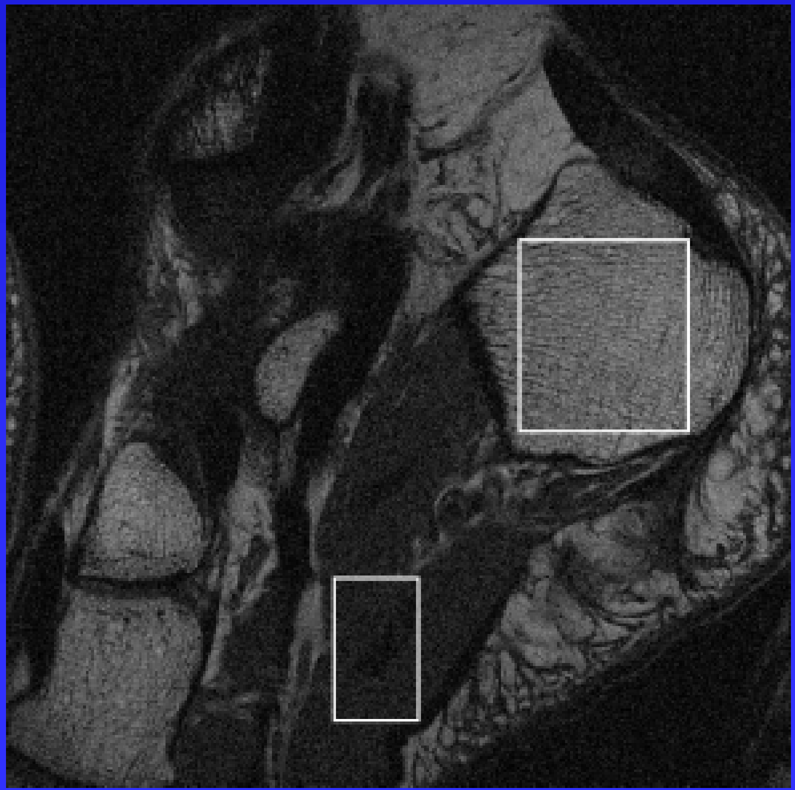
thresholding

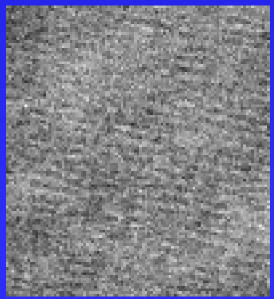
Features based on Gaussian Markov random field model

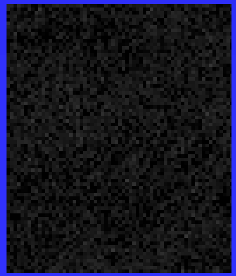
$$X[i,j] = \sum_{(k,l)\in N_v} \theta_{k,l} X[i+k, j+l] + e[i,j]$$



MRI crossection of human foot (Heidelberg)



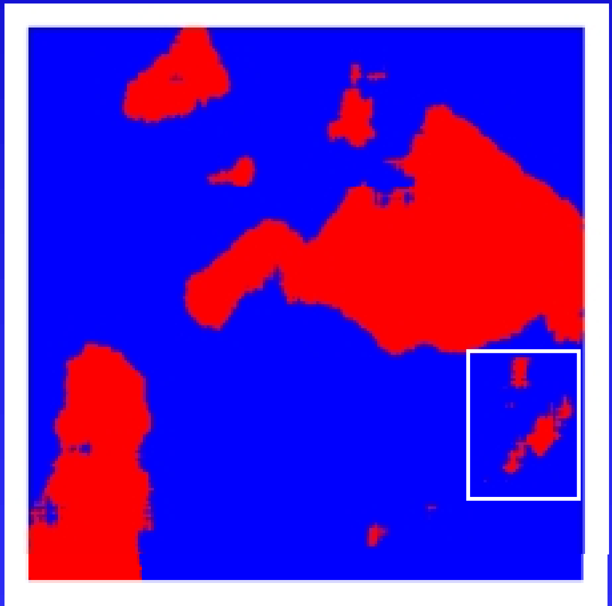




artificial textures generated based on estimated GMRF parameters

Segmentation example of MRI textured image

original image



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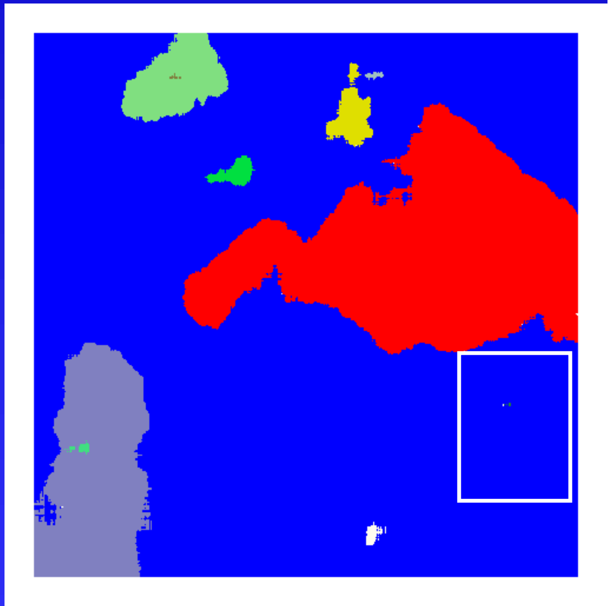

LEGION

Conclusions

Presented image segmentation method that uses LEGION provides promising results for a sample MRI textured images.

The most important problem is to find appropriate texture features. The features based on optimised linear filters and GMRF model are suitable for classification of analysed textures.

The LEGION may be realised in VLSI chip, which would provide parallel image segmentation.