SEGMENTATION OF TEXTURED IMAGES USING NETWORK OF SYNCHRONISED OSCILATORS

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Image segmentation is a very important step in image analysis.

Segmentation divides an image into disjoint regions according to appropriate criteria.

Sample image segmentation methods:

- thresholding
- gradient methods
- image splitting/merging
- application of Artificial Neural Networks

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

An object is represented by a group of synchronously active neural cells, which encode a given features of the object.

Different objects are represented by different active cell groups, its activities are changing during the time.

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 with 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

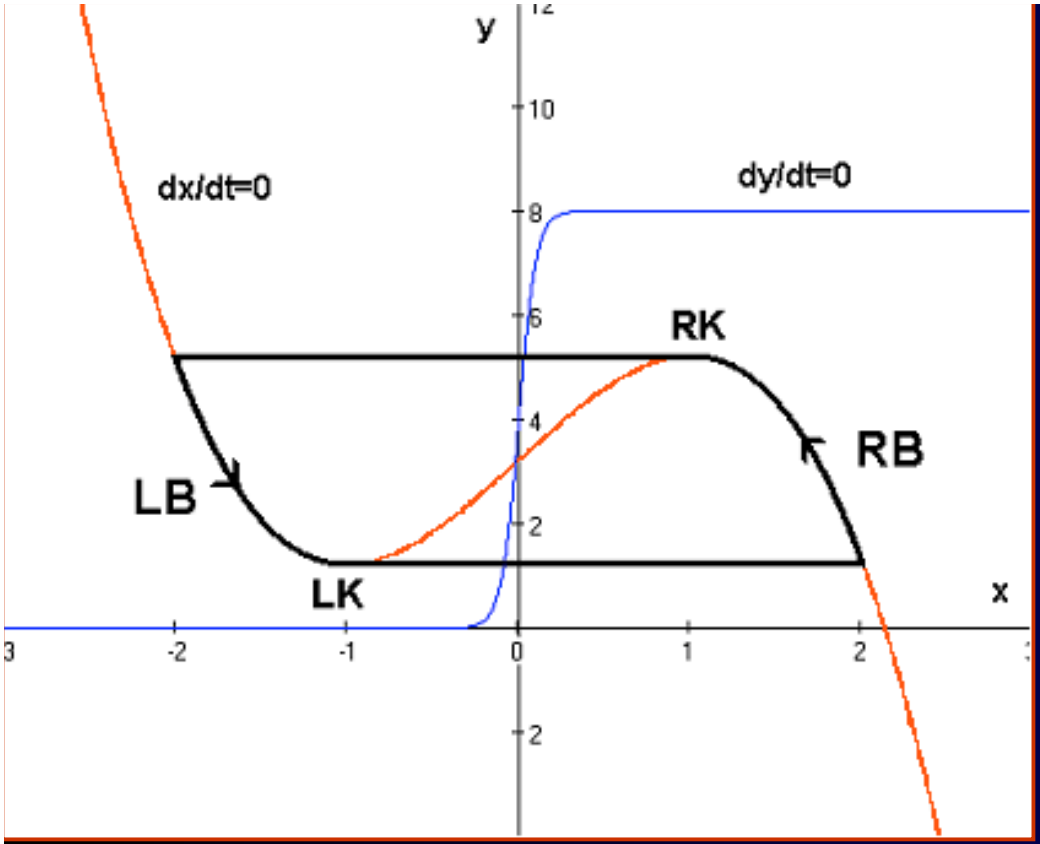
$$\frac{dx}{dt} = 3x - x^3 + 2 - y + I_T$$

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

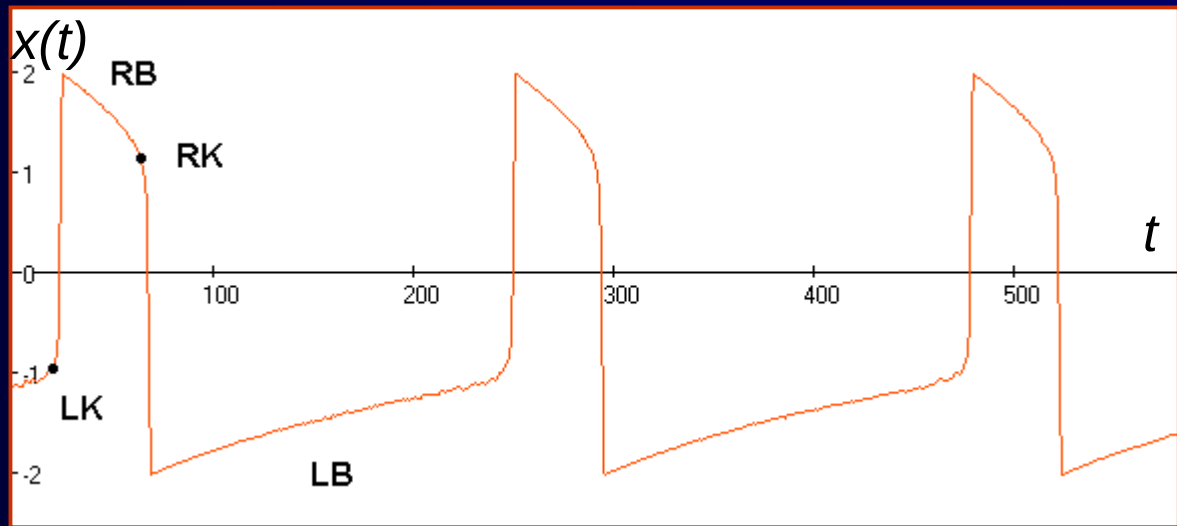
I_T - excitation of oscillator x:

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

$I_T = I_{in}$ *- gray level of image point represented by a network oscillator* x

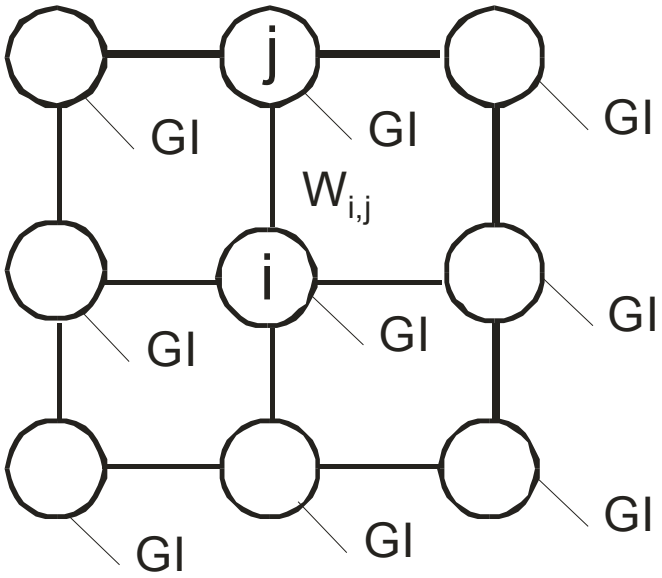


Nullclines (*dx/dt=0*, *dy/dt=0*) and trajectory of an oscillator *x*



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

The network of locally connected oscillators



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

W_{ij} - weight between oscillators i and j

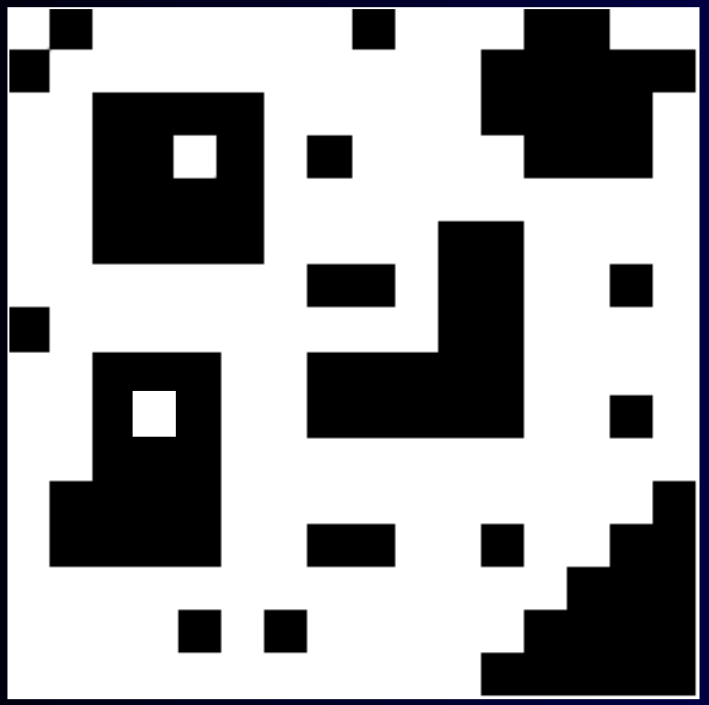
Appropriate weight setting provides synchronisation of oscillators group which represent a given object.

GI - Global Inhibitor

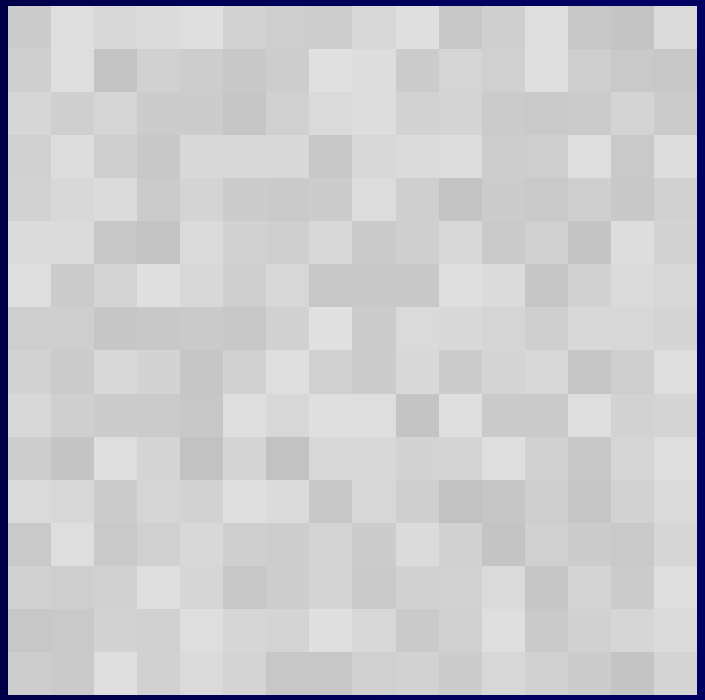
It is connected to all oscillators with a weight W_z. z(t) is equal to 1 when at least one oscillator is active and 0 otherwise. GI provides desynchronisation of oscillators not related with a given object.

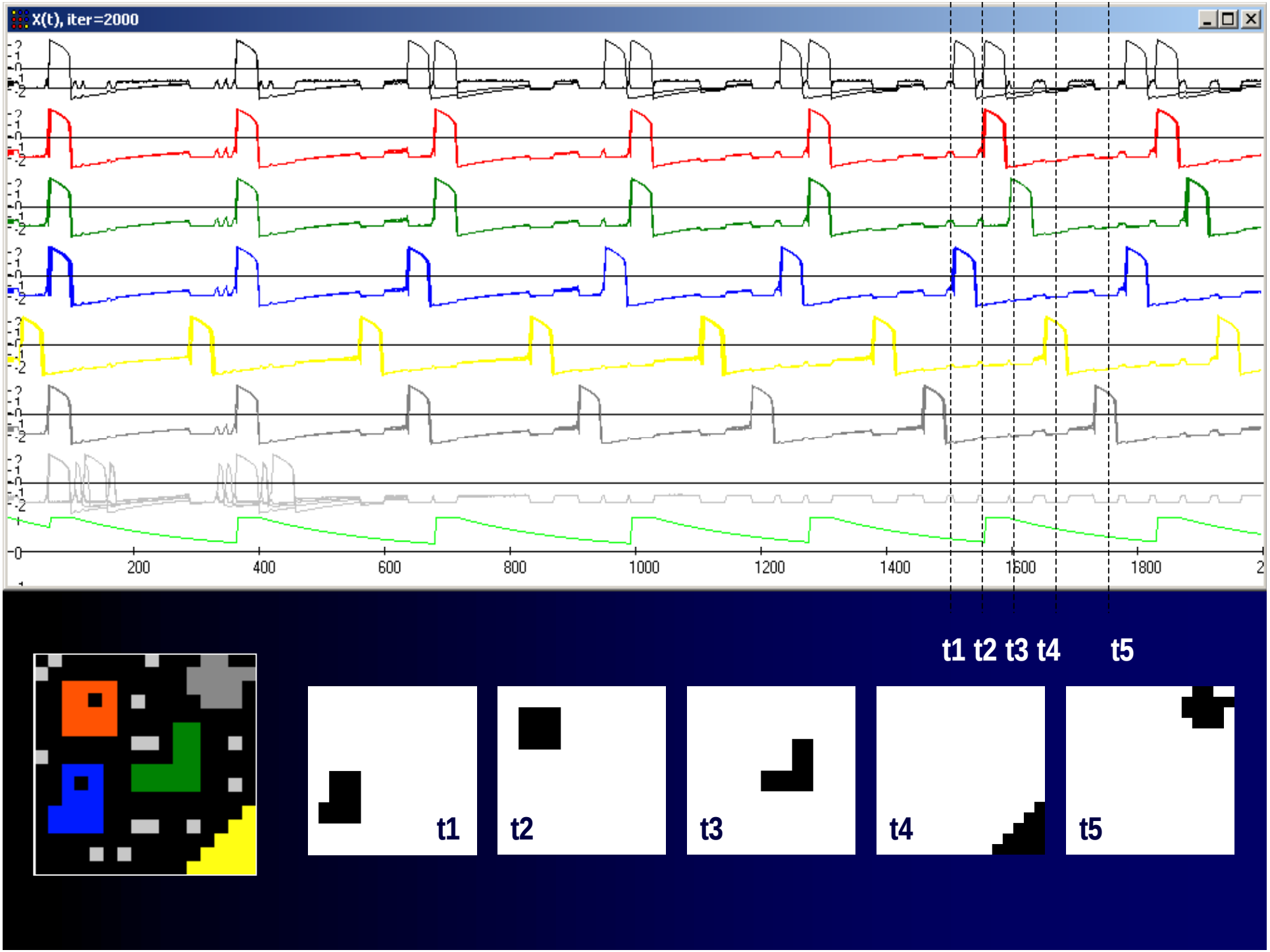
Example of binary image segmentation corrupted by pulse noise

16×16

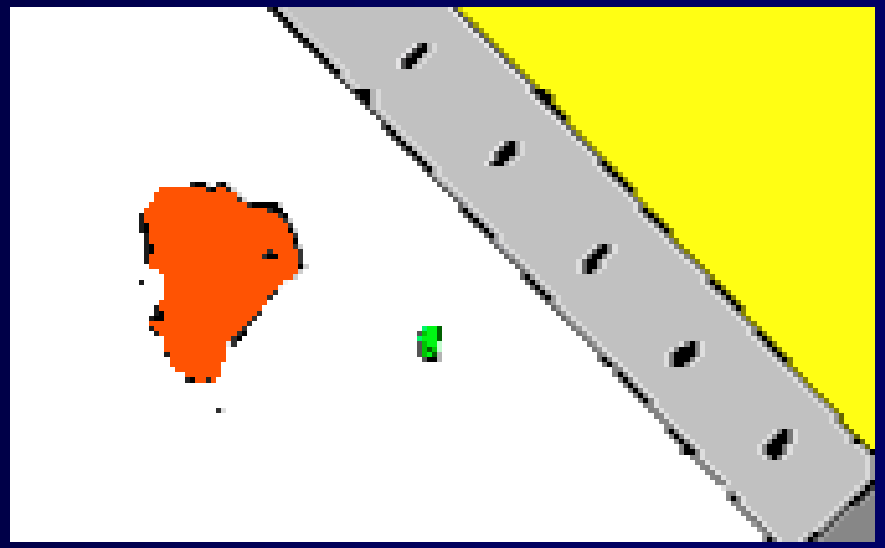


iterations




X(t), iter=2000
200
400
600
800
1000
1200
1400
1600
1800
t1 t2 t3 t4 t5
t1
t2
t3
t4
t5

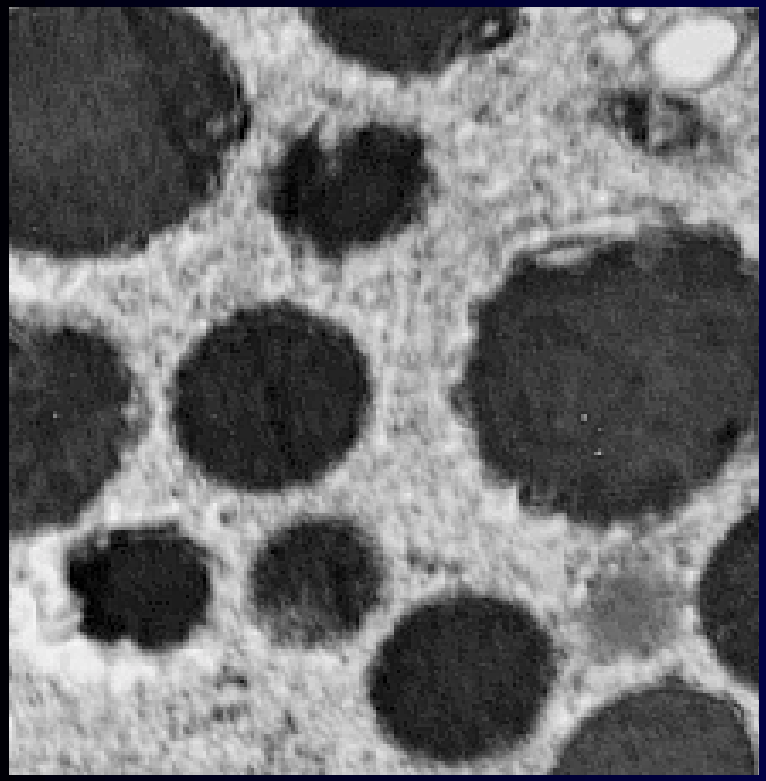
Example of biomedical image segmentation

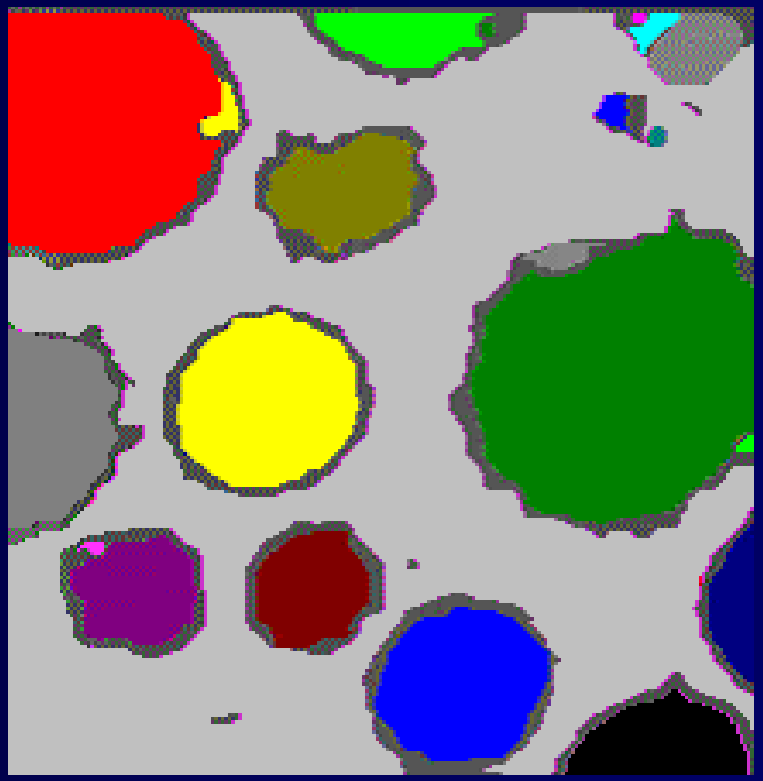


Skin abscess

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 biomedical image segmentation

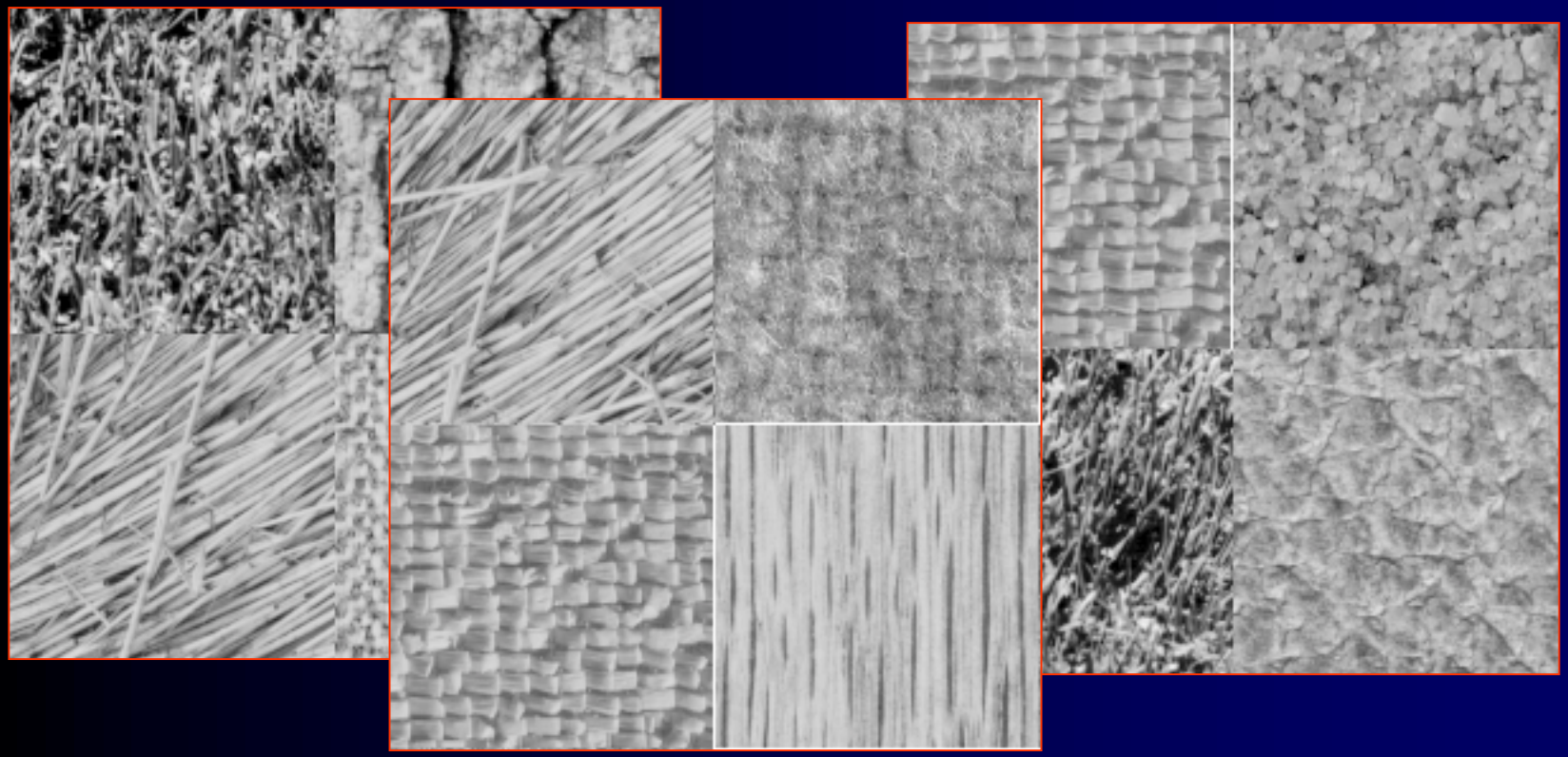




Skin cells

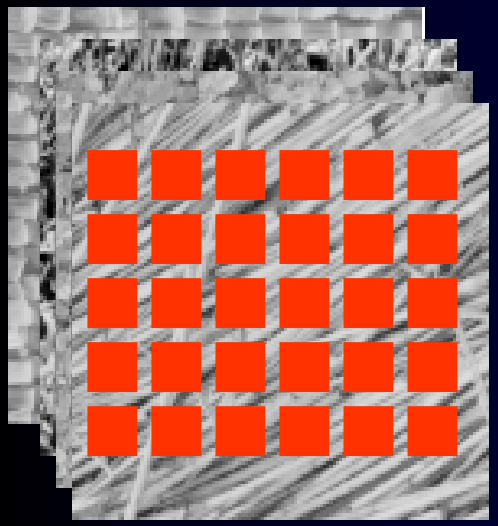
$$W_{ij} = \frac{U_{\max}}{1 + |U_i - U_j|}$$

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 networks.

Feature preparation

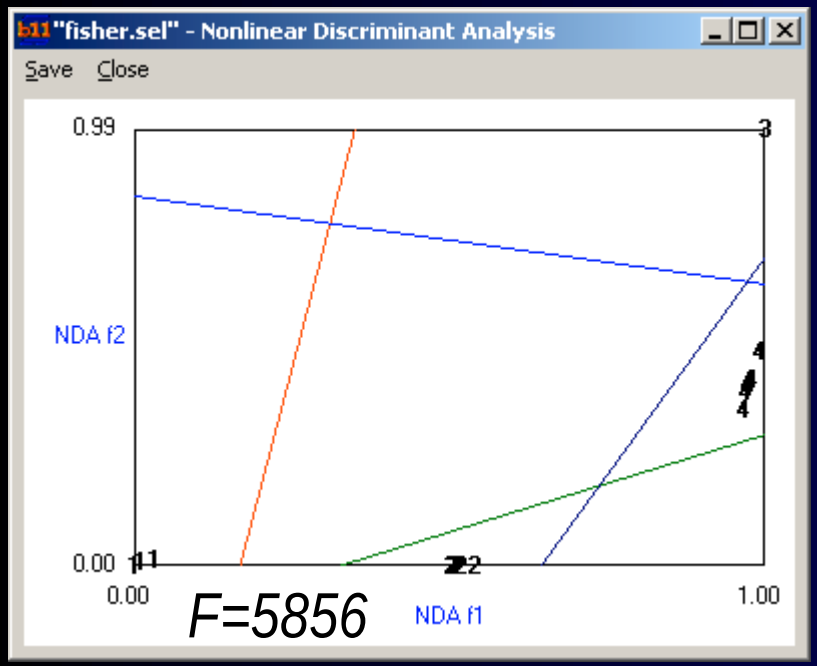


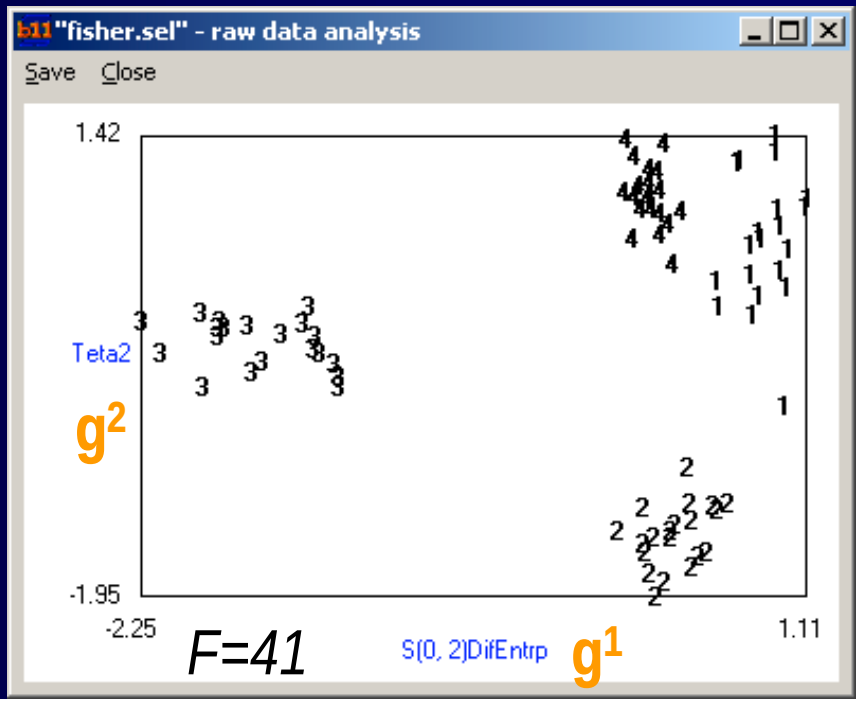
feature calculation

MaZda software, 250 features

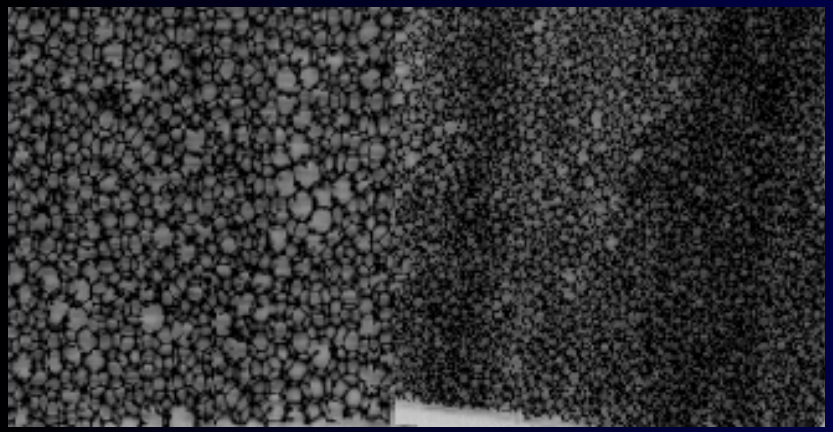
- run-length
- gradient
- co-occurence
- AR model

Feature selection (Fisher coeff.)



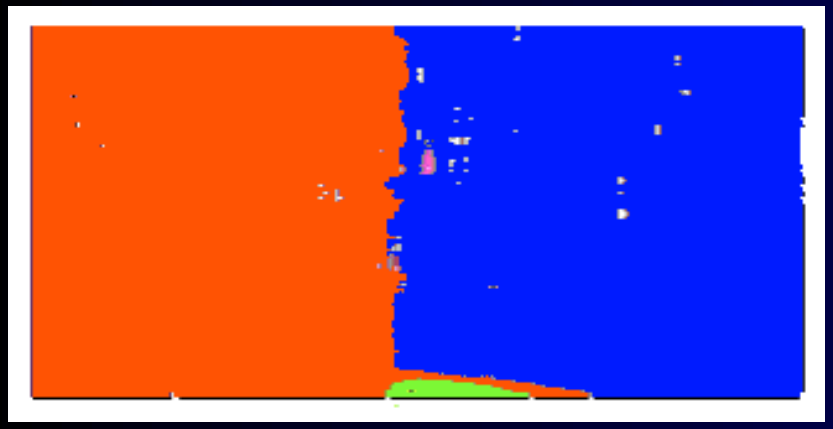


Segmentation example

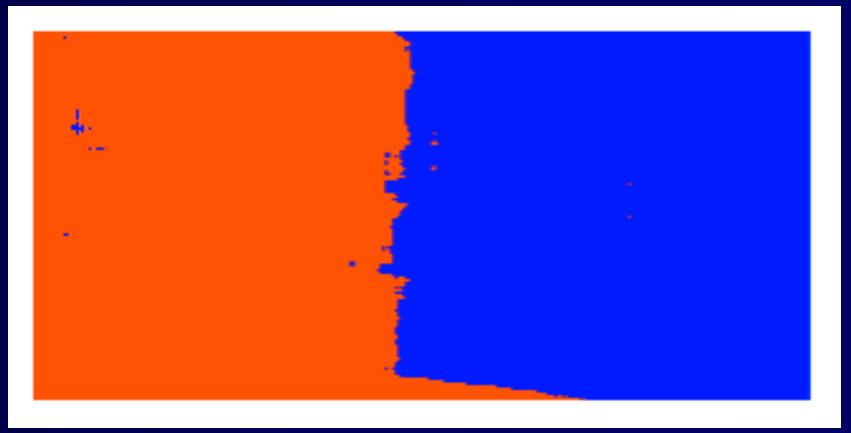


$$W_{ij} = \frac{\sqrt{(f_i^1 + f_i^2)(\overline{f_{N(i)}^1} + \overline{f_{N(i)}^2})}}{\varepsilon + |f_i^1 - f_j^1| + |f_i^2 - f_j^2|}$$

original image

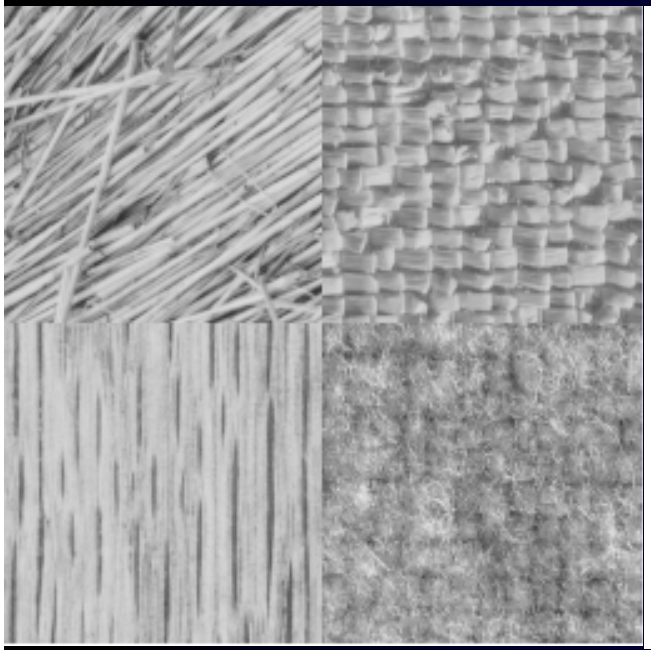


segmented with
oscillator network

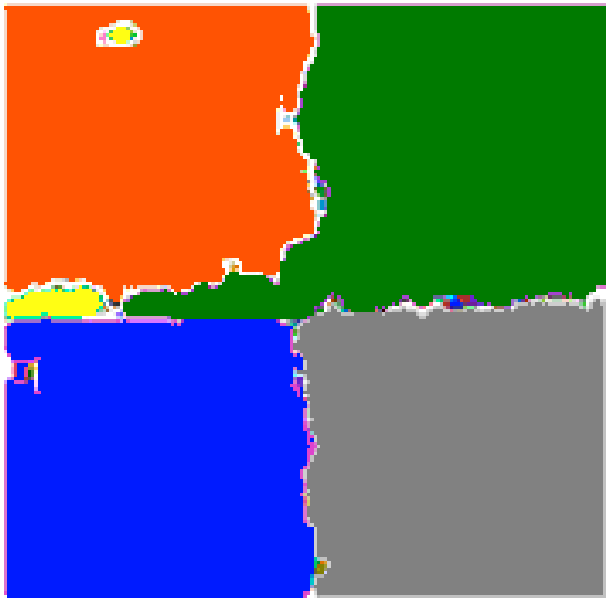


segmented with
ANN (2-2-4)

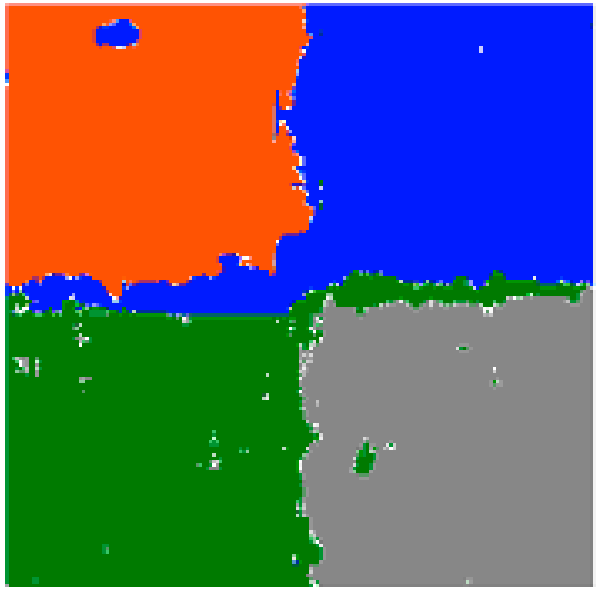
Segmentation example



original image



segmented with oscillator network



segmented with ANN (2-2-4)

$$W_{ij} = \begin{cases} U[\sum_{k=1}^{2} f_i^k / (f_j^k + \varepsilon)]^{-1} & \text{if} \quad f_i^k > f_j^k \\ U[\sum_{k=1}^{2} f_j^k / (f_i^k + \varepsilon)]^{-1} & \text{if} \quad f_i^k \le f_j^k \end{cases}$$

Conclusions

Presented image segmentation method that uses LEGION provides promising results for a class of analysed textures.

The most important problem is to find appropriate texture features. The future research will comprise searching of new features, eg. based on optimised linear filters.

The method is suitable for parallel implementation in hardware realisation.