هوش محاسباتی:
شبکه های عصبی مصنوعی

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Self Organizing Networks

Introduction

- A supervised network tries to obtain a mapping between input and output
- A SO algorithm tries to discover important and meaningful features from input data
- Such an algorithm has a set of *local rules* (changes in weights are made in a neighborhood of neurons)

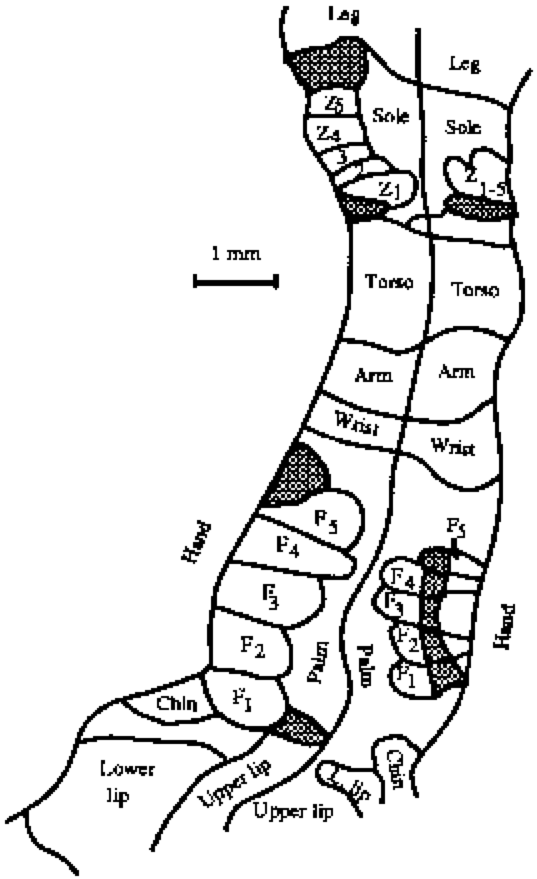
Question :

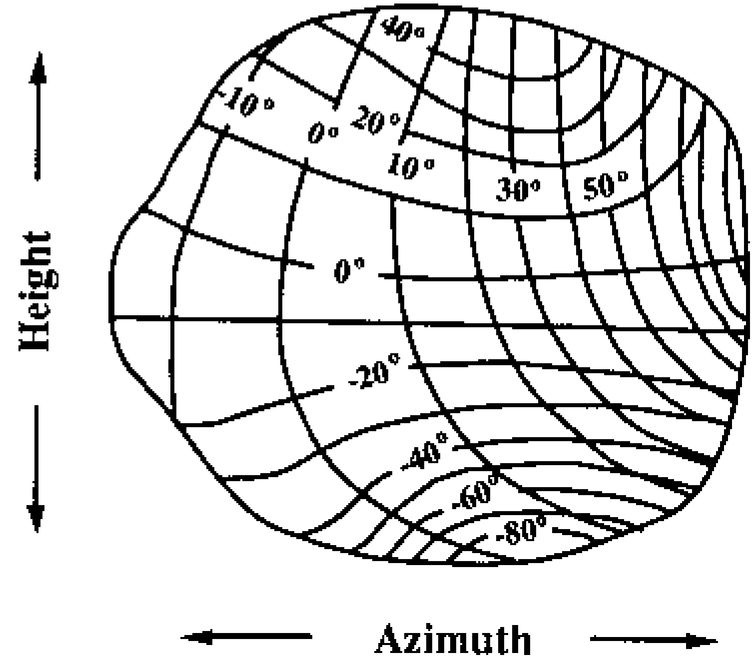
How a useful configuration can finally develop from self organization ?
Answer can be lied in Turing observations (1952) :

Global order can arise from local interactions

Biological justifications exist

Biological system

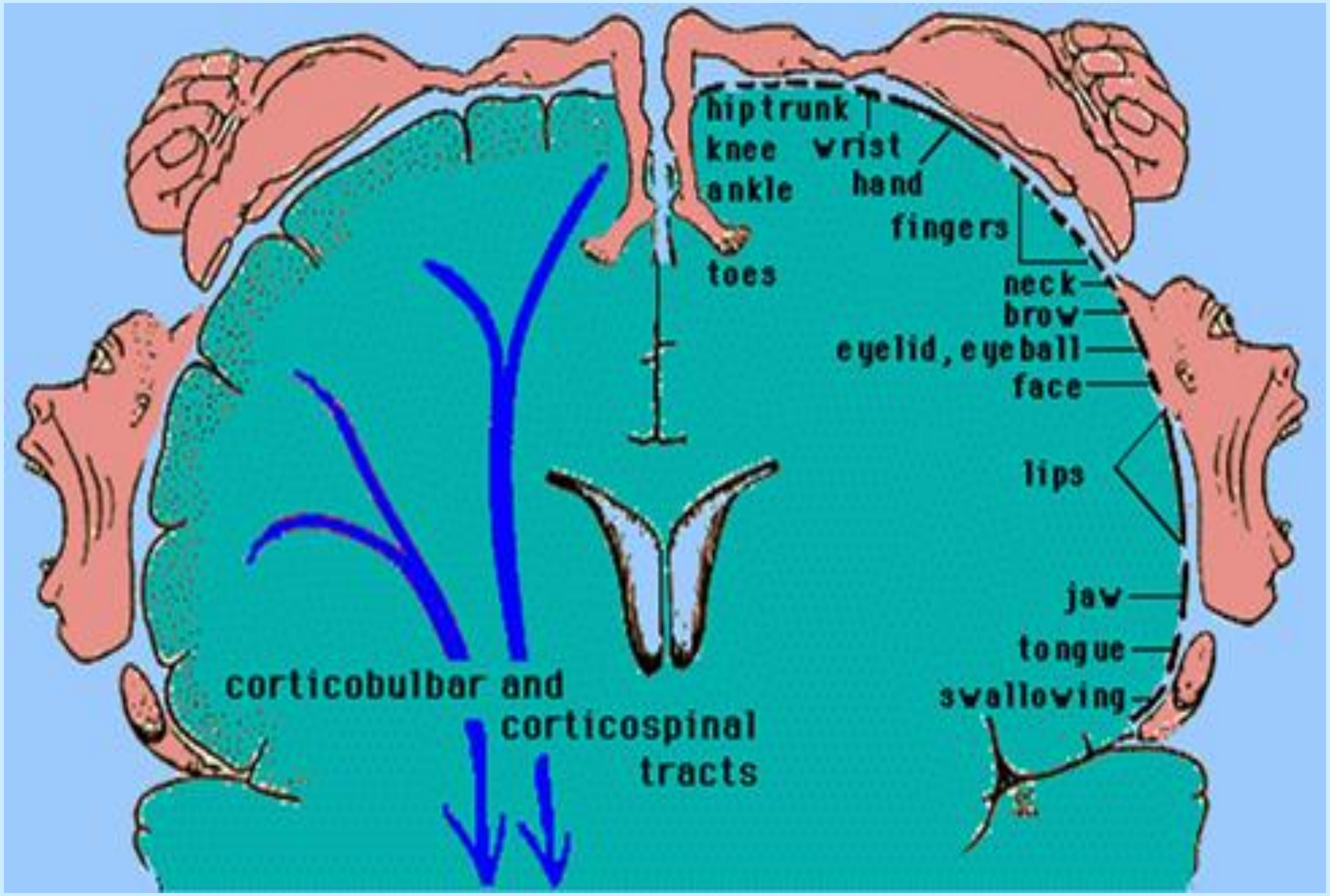




Map of part of the body surface in the somatosensory cortex of a monkey

Direction map for sound signals in the so-called “optical tectum” of an owl

Biological system (cont'd)



Map of the body surface in the human motor cortex : *(Homunculus precentral Gyrus)*

Biological system (cont'd)

Is it probable that in biological systems such map is genetically determined?

The brain is estimated to have ~10^{14} synapses (connections), so it would be **impossible** to produce this organization by specifying each connection in detail

the genome does not contain that much information

(i) wiring diagram would require $\geq$ **10^{14}** bits of information

(ii) genome carries about **5×10^{9}** bits of information

(iii) human genome is about one meter of DNA

(iv) 4 types of base pairs

(v) separation of **4×10^{-8}** cm between base pairs

(vi) much of genome is junk

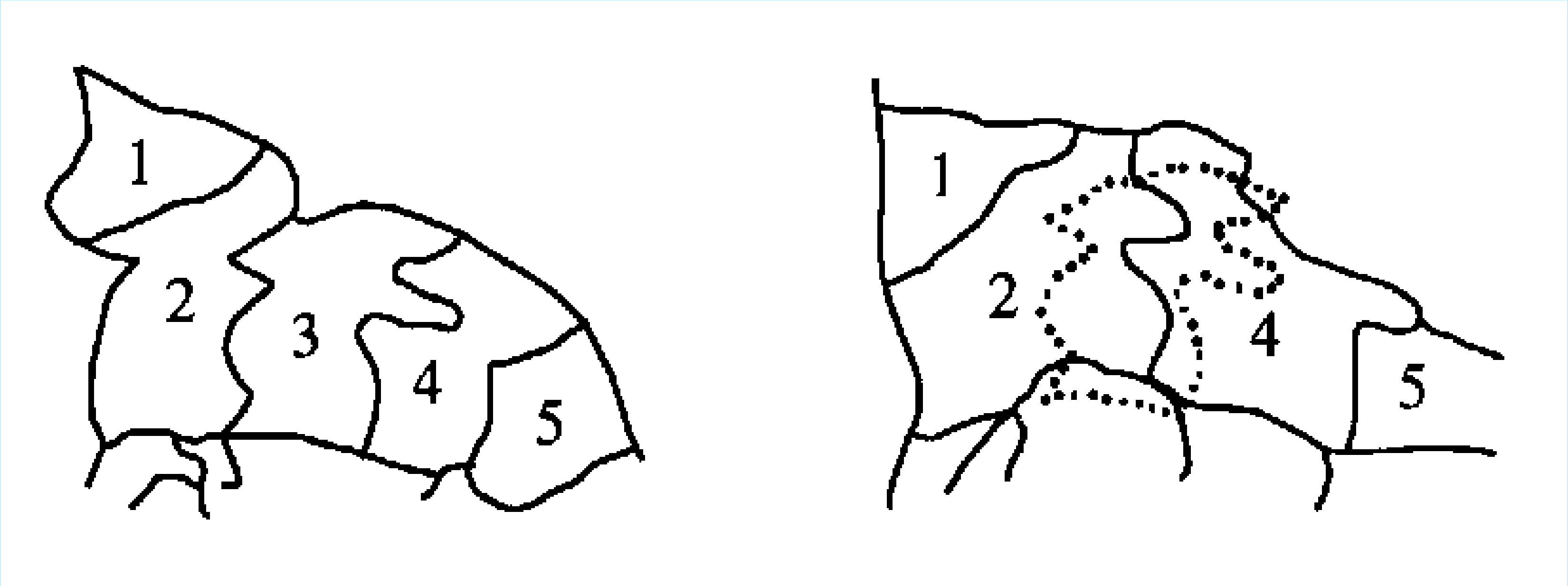
Biological system (cont'd)

-A more likely scenario is that there are genetically specified ***mechanisms of structure formation*** that result in the creation of the desired connectivity

- These could operate before birth, or as part of later maturation, involving ***interaction with the environment***

- There is much evidence for such changes:
    - -the normal development of edge-detectors in the visual cortex of newborn kittens is suppressed in the absence of sufficient visual experience
    - -the somatosensory maps of adult monkeys have been observed to adapt following the amputation of a finger

Biological system (cont'd)



Readaptation of the somatosensory map of the hand region of an adult nocturnal ape due to the amputation of one finger. Several weeks after the amputation of the middle finger (3), the assigned region has disappeared and the adjacent regions have spread out. [Ritter et al., p. 117]

Principles of SO

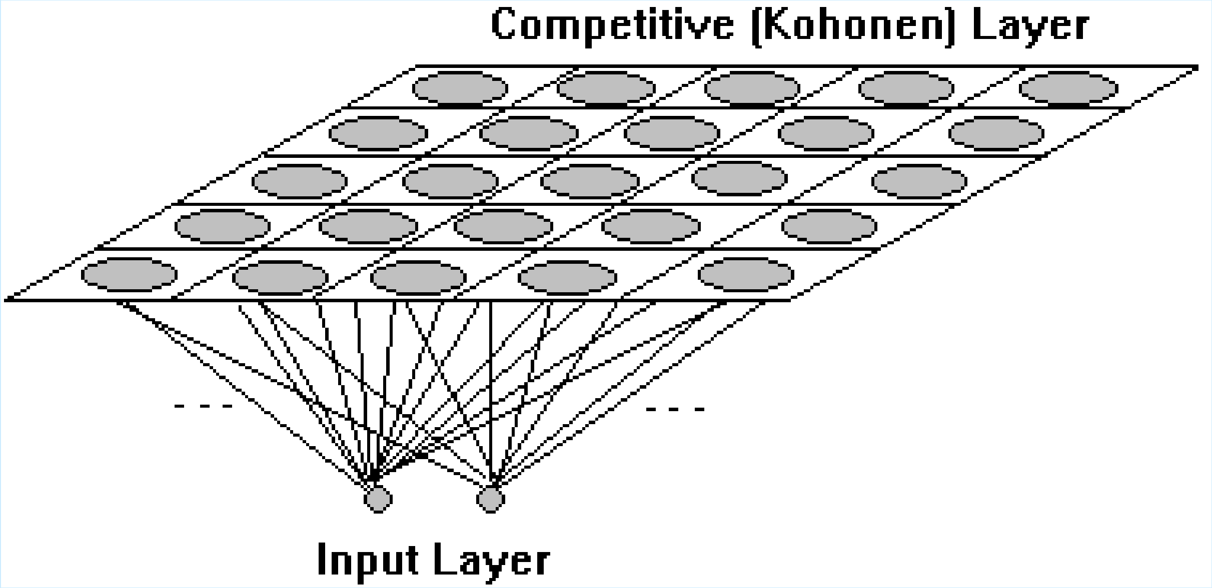
Some intuitive principles of SO:

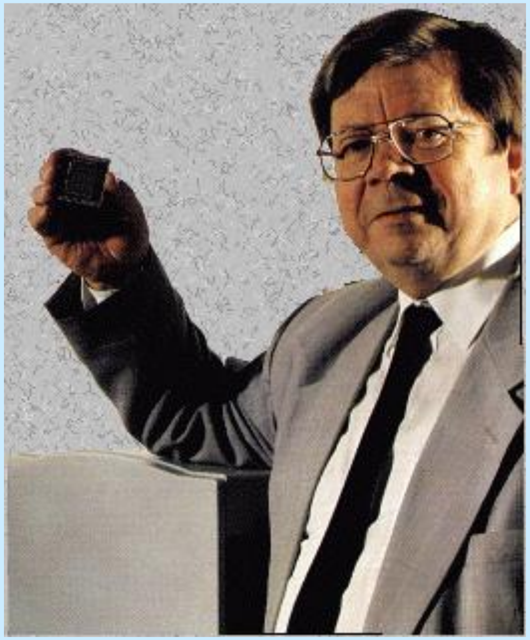
- Modifications in synaptic weights tend to self amplify
- Limitation of resources leads to competition among synapses
- Competition leads to the selection of the most vigorously growing synapses at the expense of the others
- Modifications in synaptic weights tend to cooperate

Two Basic models of SO

1- Willshaw von del Malsburg

2- Kohonen model (SOFM):





A continuous input space of activation patterns is mapped to a discrete output space of neurons by a process of competition among the neurons in the network

Formation of SOM

Essential processes of a SOFM are:

1. Initialization
2. Competition
3. Cooperation
4. Synaptic Adaptation

1- Initialization of the synaptic weights is done by assigning ***random small values*** in order to impose no prior order on the map

2- Competition

- An input vector ***x*** selected at random and presented to the network

    - Input vector: $X=[x_1, x_2,..., x_m]^T$

    - Weights vector: $W_j=[w_{j1}, w_{j2},..., w_{jm}]^T$

- A neuron is selected as the winner based on a best matching criterion

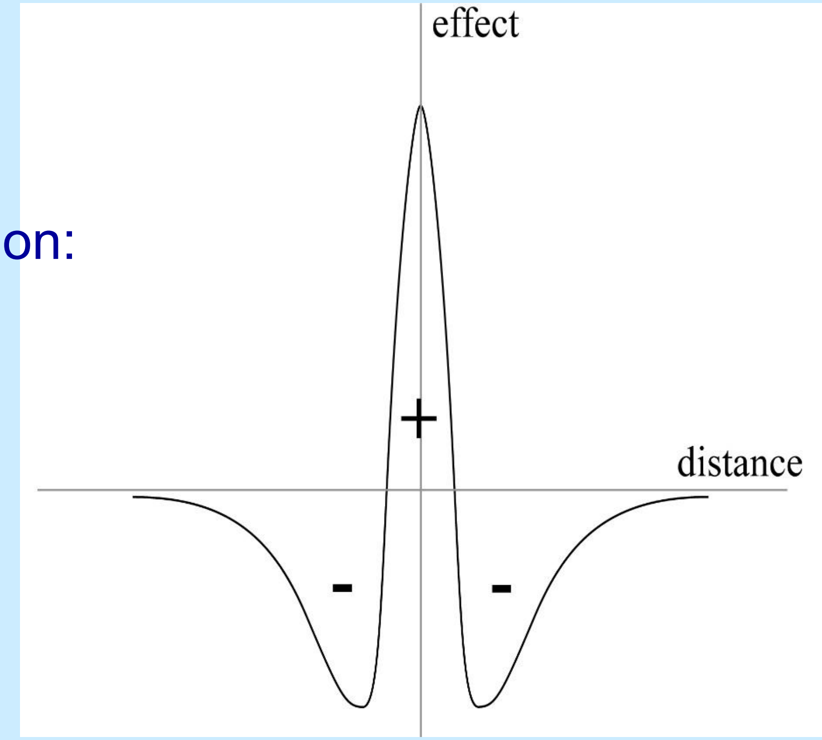
    The Euclidian distance: $i(x)=\arg\min ||X-W_j||$

3- Cooperation

- A topological neighborhood of the winning neuron is selected

$$h_{j,i(x)}$$

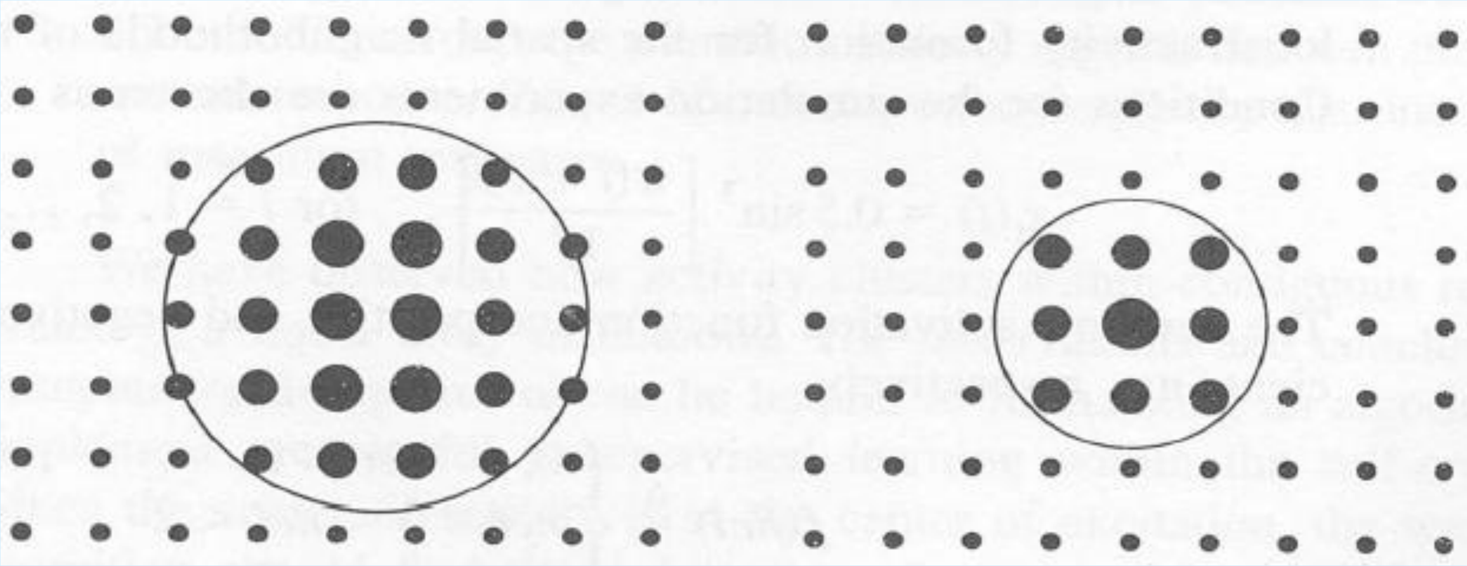
The best form is a Mexican hat function:



A simpler typical choice can be a Gaussian function:

$$h_{j,i(x)} = e^{\frac{-d_{j,i}^2}{2\sigma^2}}$$

Neighborhood function



Selected neurons in
a large neighborhood

Selected neurons in
a small neighborhood

4- Adaptation

Synaptic weights are modified according to :

$$\Delta w_j = \underbrace{\eta y_j x}_{\text{Hebb Rule}} - \overbrace{g(y_j)\, w_j}^{\text{Forgetting term}}$$

By choosing :

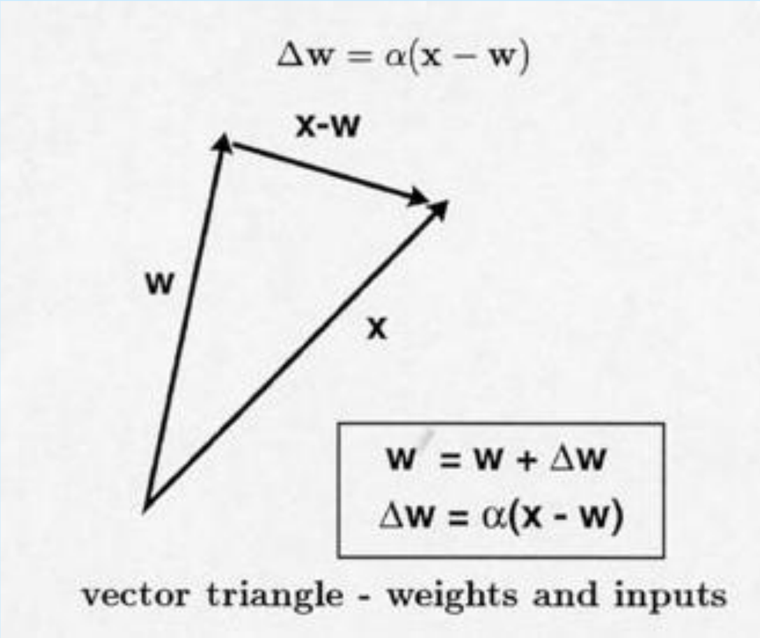
$$g(y_j) = \eta h_{j,i(x)}$$

and:

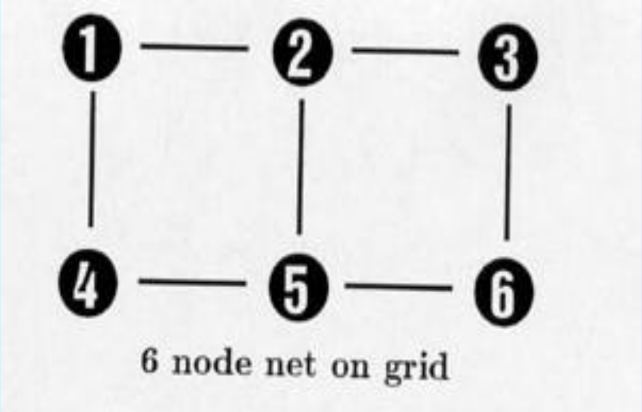
$$y_j = h_{j,i(x)}$$

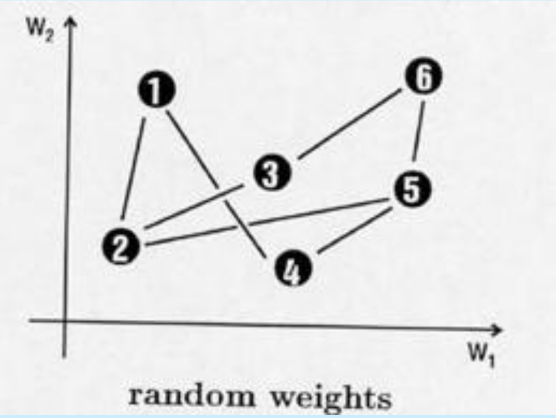
We obtain :

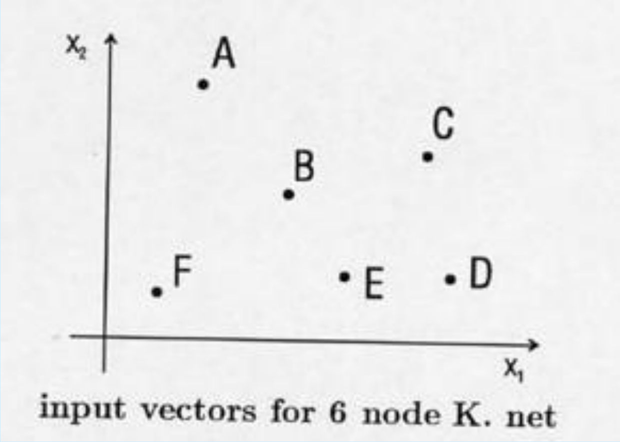
$$\Delta w_j = \eta h_{j,i(x)} (x - w_j)$$

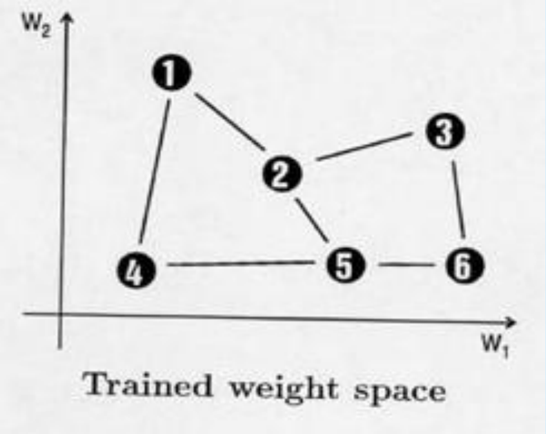


Example 1

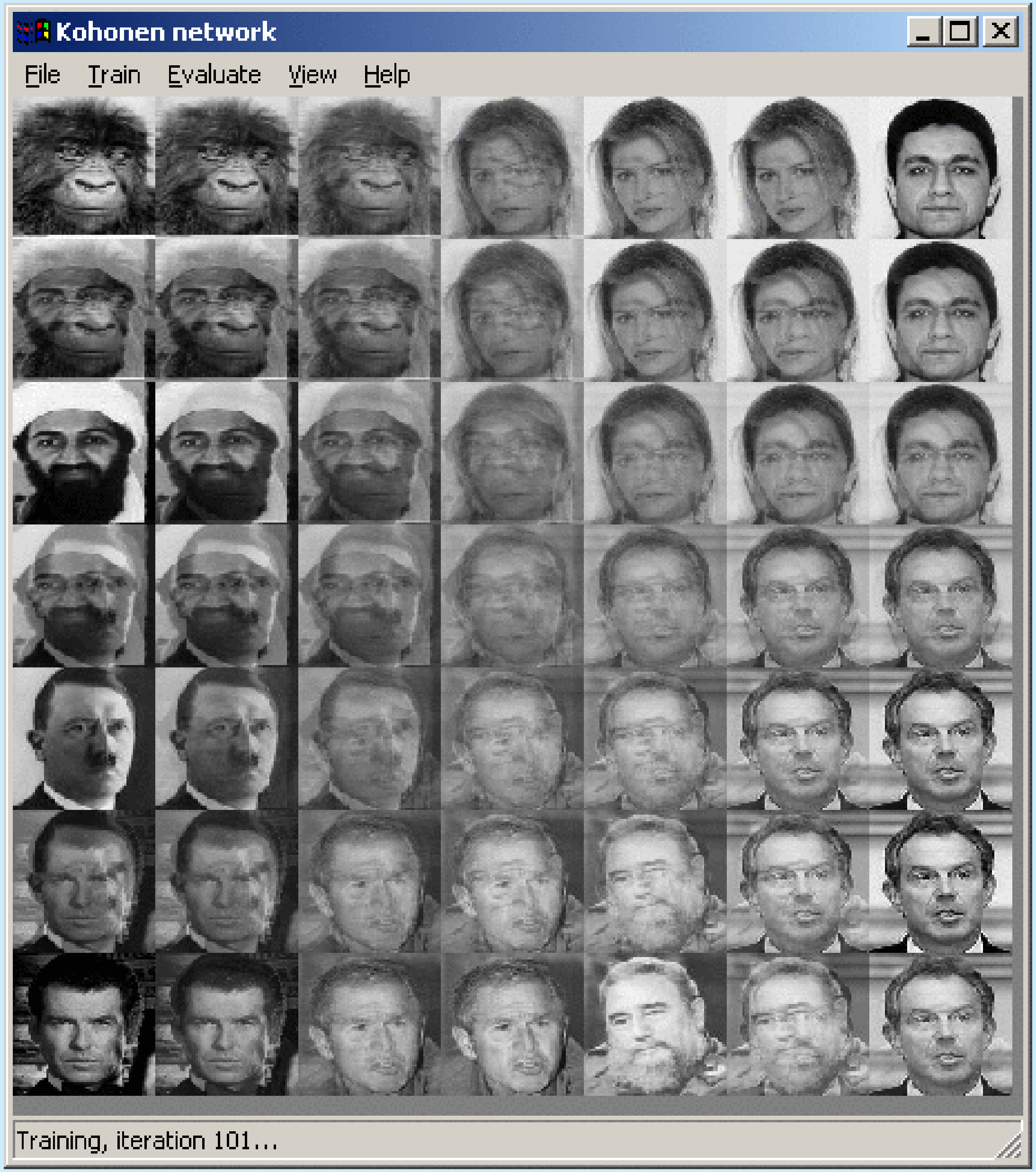

1
2
3
4
5
6
6 node net on grid


W2
W1
1
2
3
4
5
6
random weights

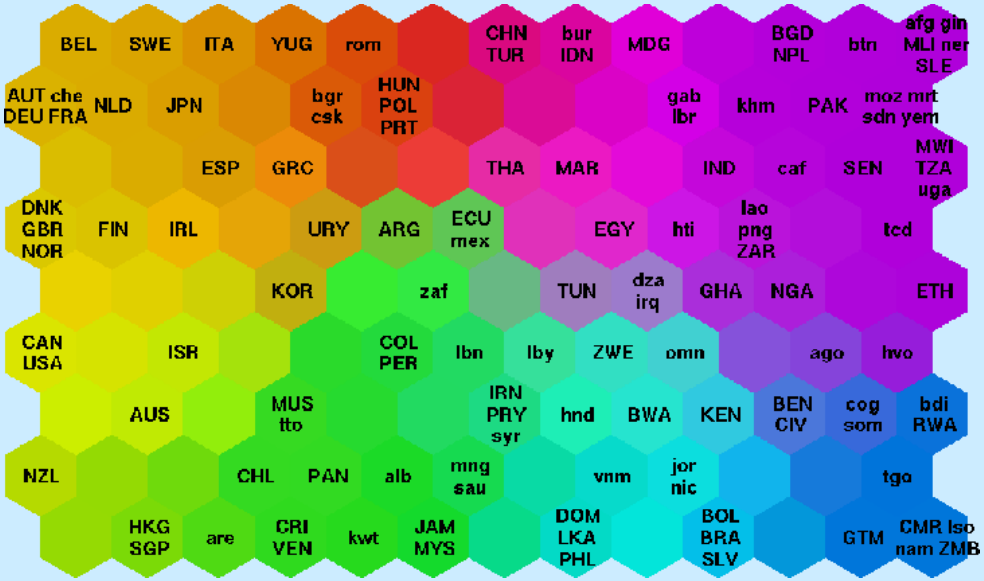

X2
X1
A
B
C
D
E
F
input vectors for 6 node K. net


W2
W1
1
2
3
4
5
6
Trained weight space

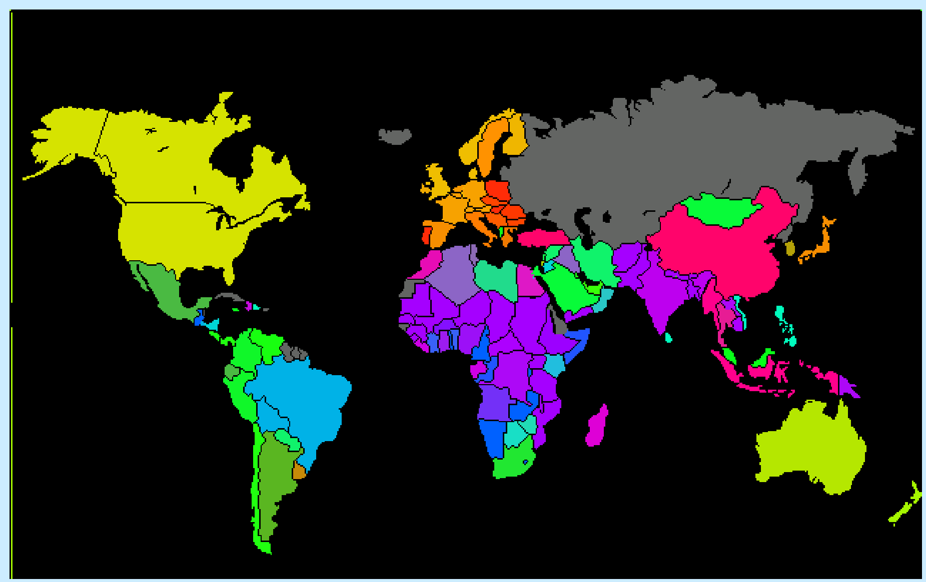
Example 2


Kohonen network
File Train Evaluate View Help
Training, iteration 101...

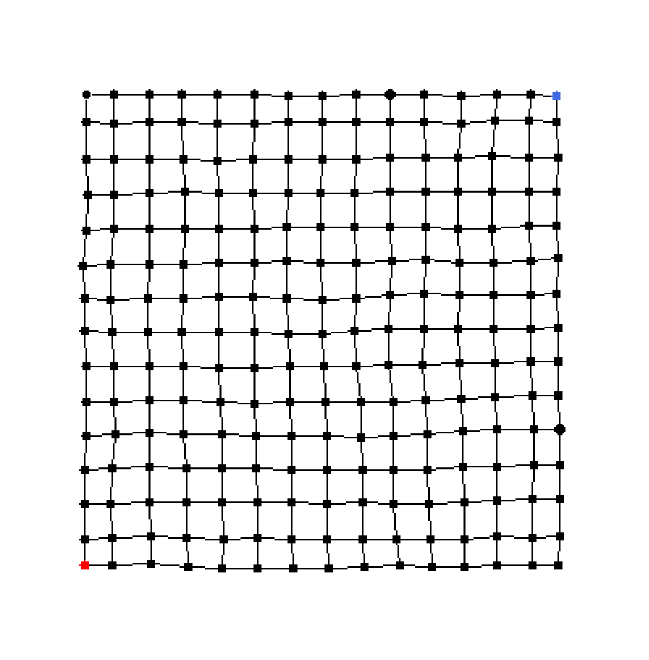
Example 3: Poverty Map



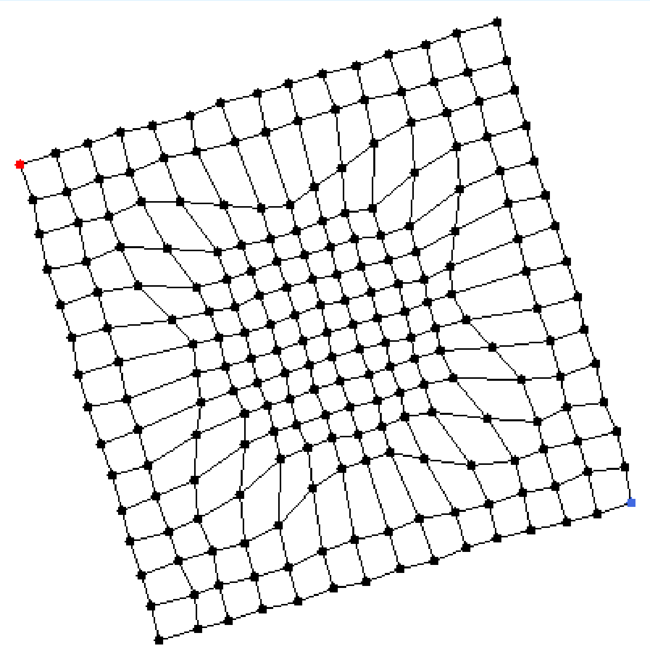
http://www.cis.hut.fi/research/som-research/worldmap.html



Example 4



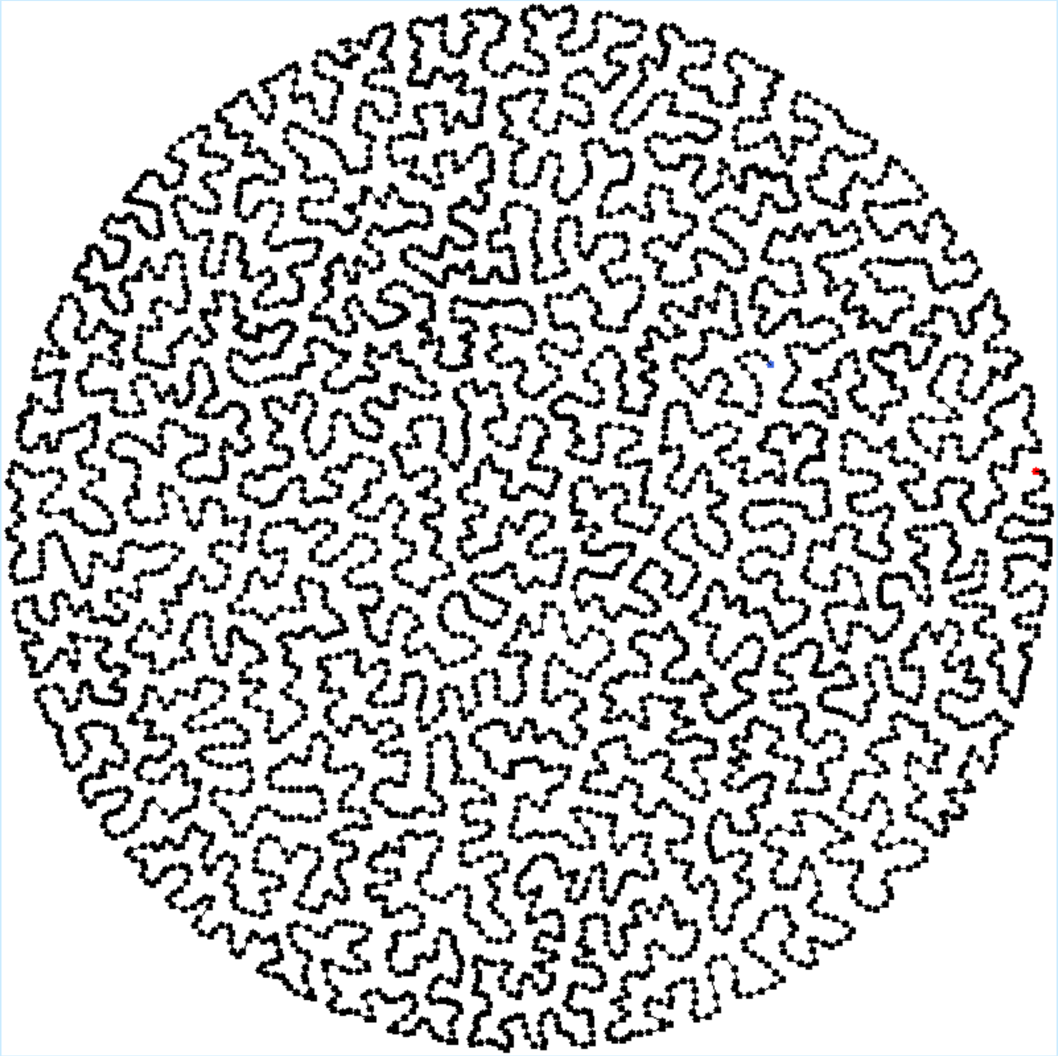
SOM that has learnt data uniformly distributed on a square



SOM that has learnt data on a rotated square, where points are twice as likely to occur in a circle at the centre of the square (relationship to clustering)

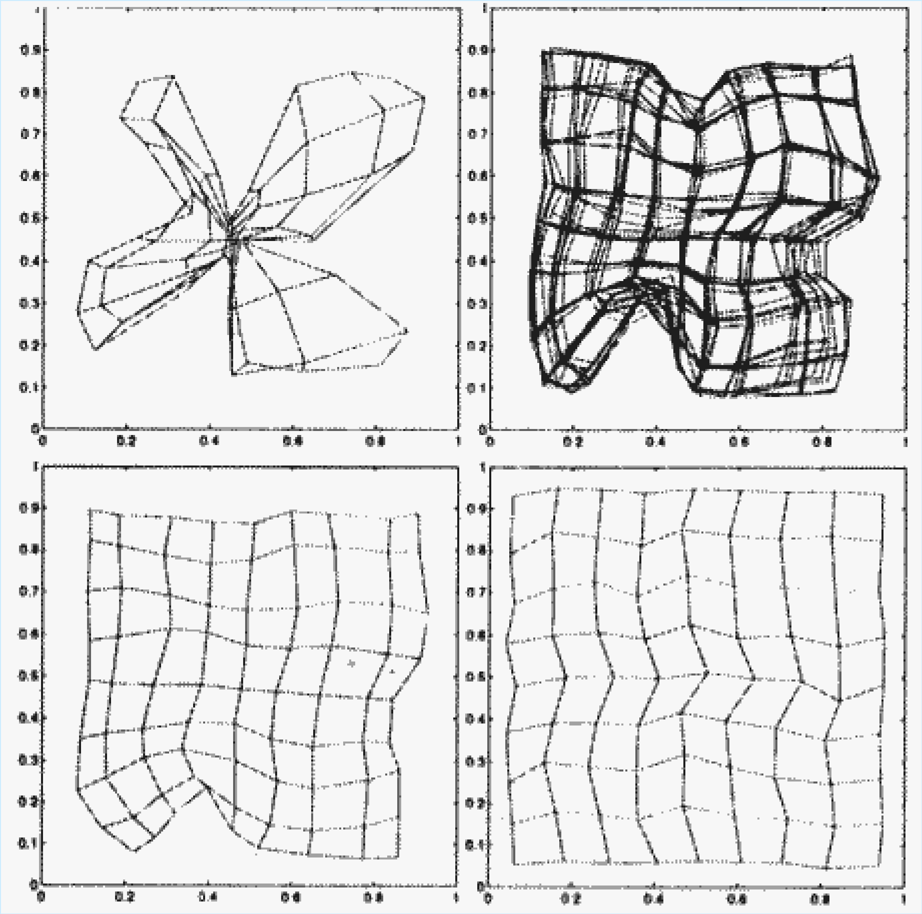
Example 5

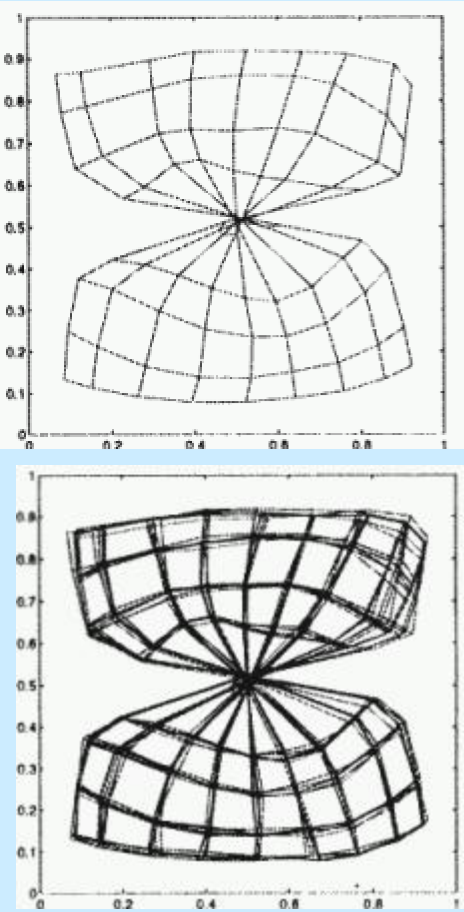
1-dimensional SOM that has learnt data uniformly distributed in a 2-dimensional circle



Example 6

Map distortions

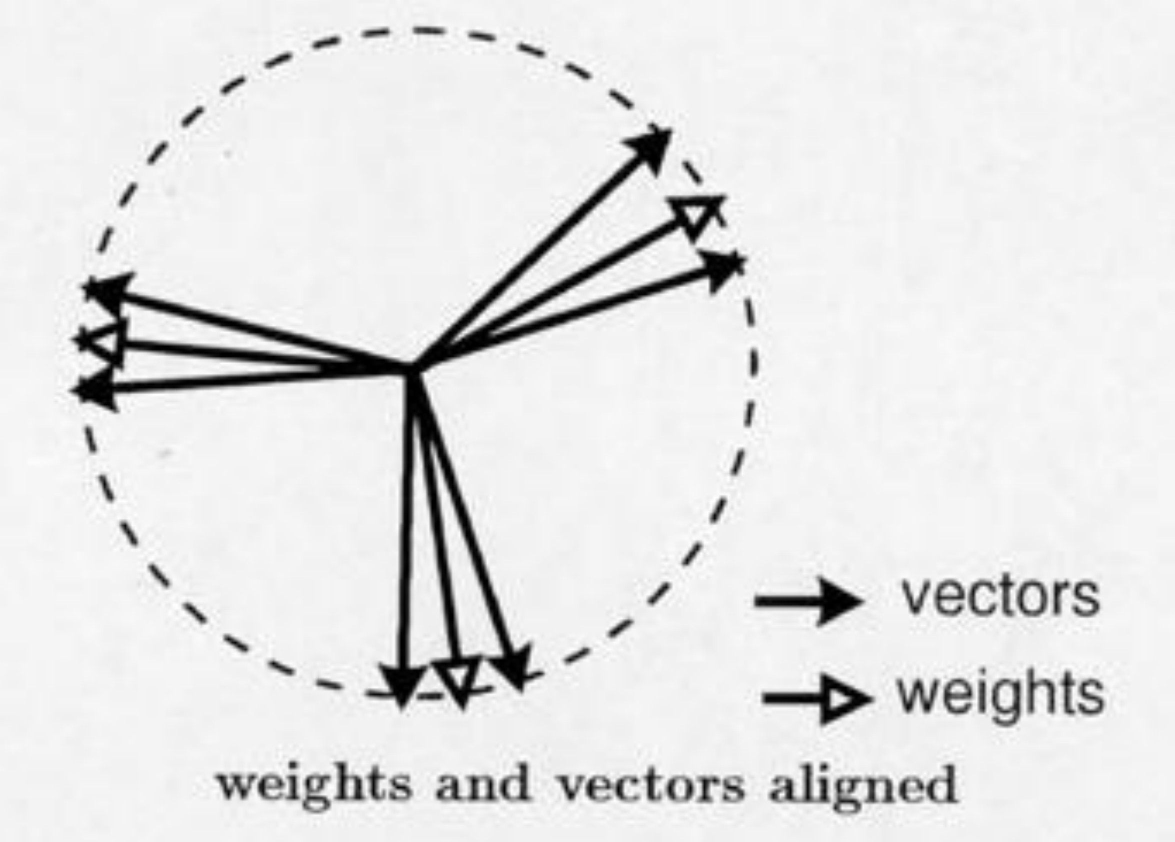




Initial distortions may slowly disappear or may get frozen

Vector representation

A learnt SOFM has a set of weights vector fitted in clusters of input vectors:



Properties of SOFM

- Approximation of the input space
- Feature selection of nonlinear distributed data
- A topographic representation of multi-dimensional input space
- Topological ordering
- Density matching (respecting the input distribution)