Learning and Forgetting for a Robot Wanderer

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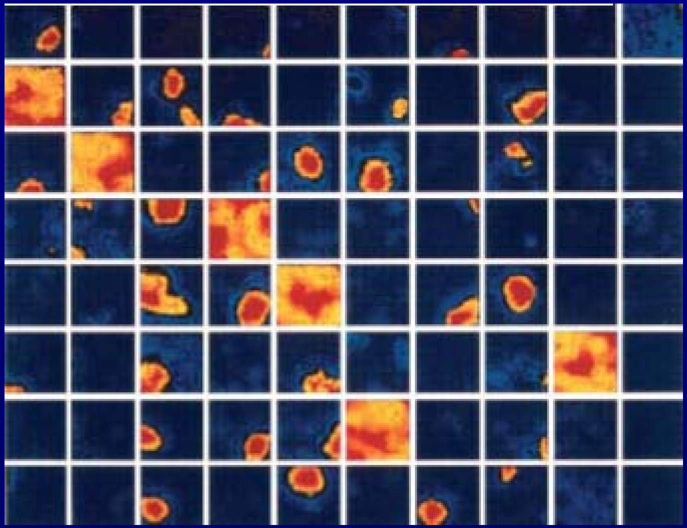
Scope of the Project

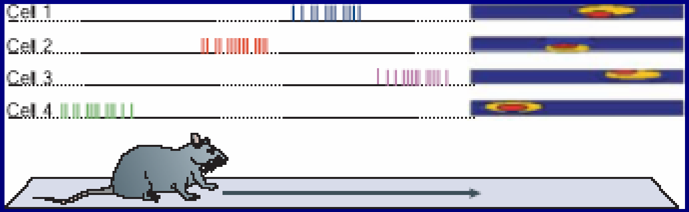
The purpose of this project is to design and implement a mechanism that gives a mobile robot the means to localise itself in an environment, and to keep the robot localised as the robot moves around.

The robot should localise itself by observing its environment and by moving around. This should be performed even if the robot does not know at all where it is when it wakes up

Place Cells

- Place Cells in rodent brains (O'Keefe &Dostrovsky, 1971): neurons found in part of the brain called hippocampus
  - Neuron activity correlated with the rat's position in an environment
  - Activity depends largely on visual cues
  - Sensitive to animals motion (still active in the dark)

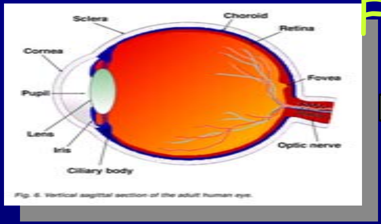




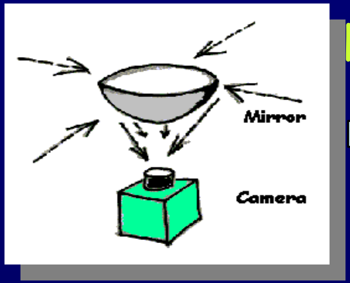
Hippocampal neurons firing patterns [Kazu Nakazawa et.al, 2004]

Physiologically Inspired Global Localization

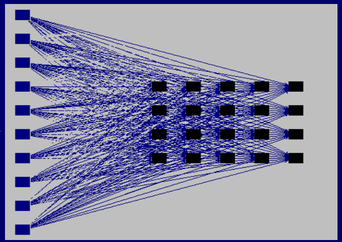
Sensory pathways in the brain are organized in such a way that its arrangement reflects some physical characteristic of the external stimulus being sensed, Kohonen (1982) proposed an unsupervised neural network architecture called self organizing map (SOM) to mimic two-dimensional arrangements of neurons in the brain.



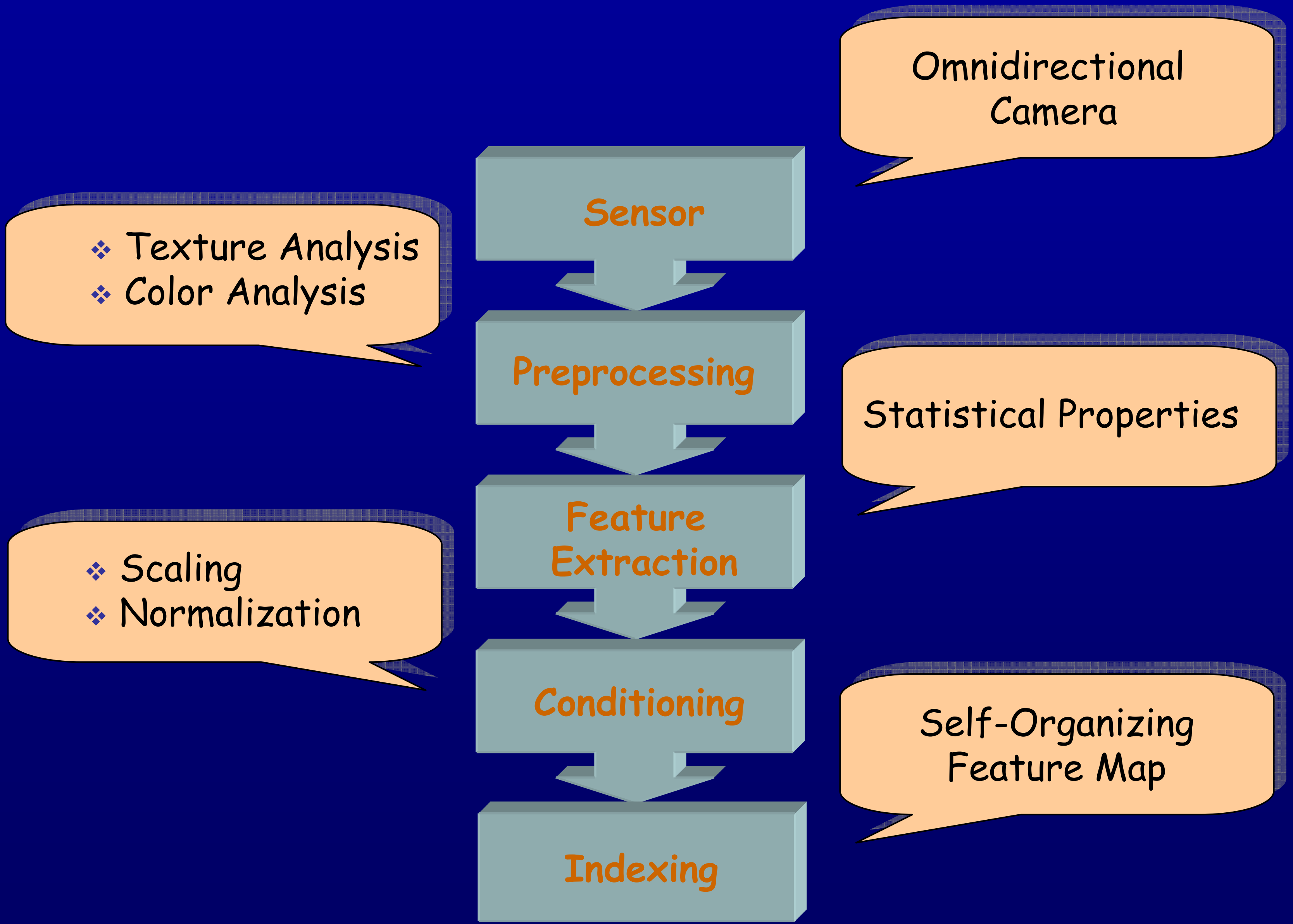
Feature Extraction & Compression



Feature Extraction & Compression



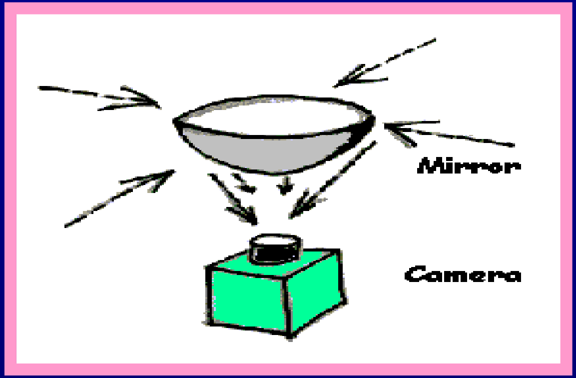
Project Framework



Omnidirectional Vision

The main advantages of an omnidirectional vision system are

- large field of view
- Provide the richest source of information
- Orientation independency
- Images of the entire environment can be acquired without rotating the camera



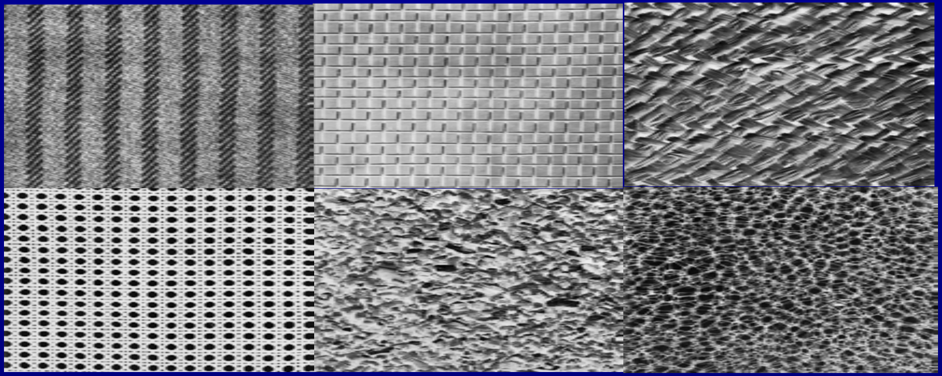
Other type of sensors as ultrasonic or infrared sensors have a short range and imply interference and wraparound, thus precise sensing of the environment requires high degree of directionality

Considerable evidence indicates that honeybees memorizes visual snapshots and correlates them with the currently perceived image to aim goal reaching

Feature Extraction

Texture Analysis

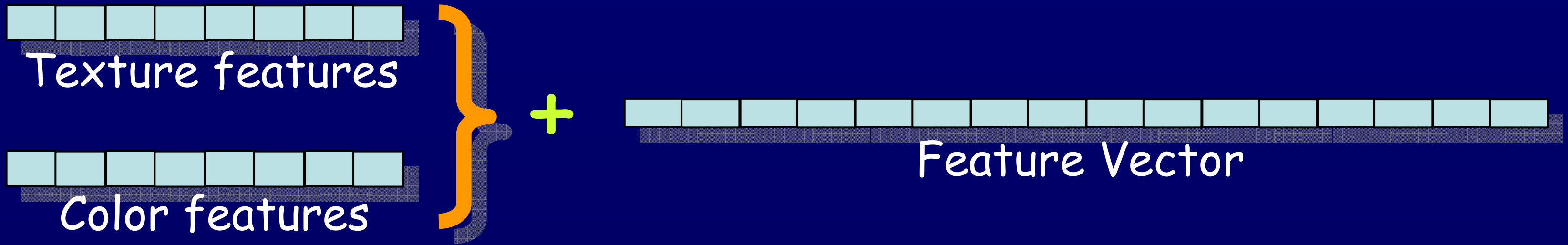
- Images can be concidered as combinations of different texture regions
- Texture regions associated features can be used for image retrieval action
- Need to address issues such as:
  - Feature extraction
  - Efficient indexing



Samples from the Brodatz Album

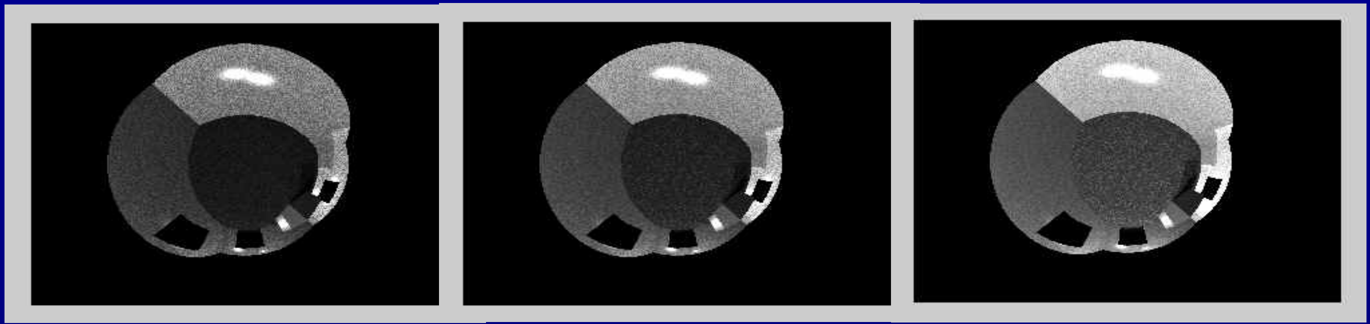
Color Analysis

- Color Map Conversion
- Color distribution
- Dominant color values

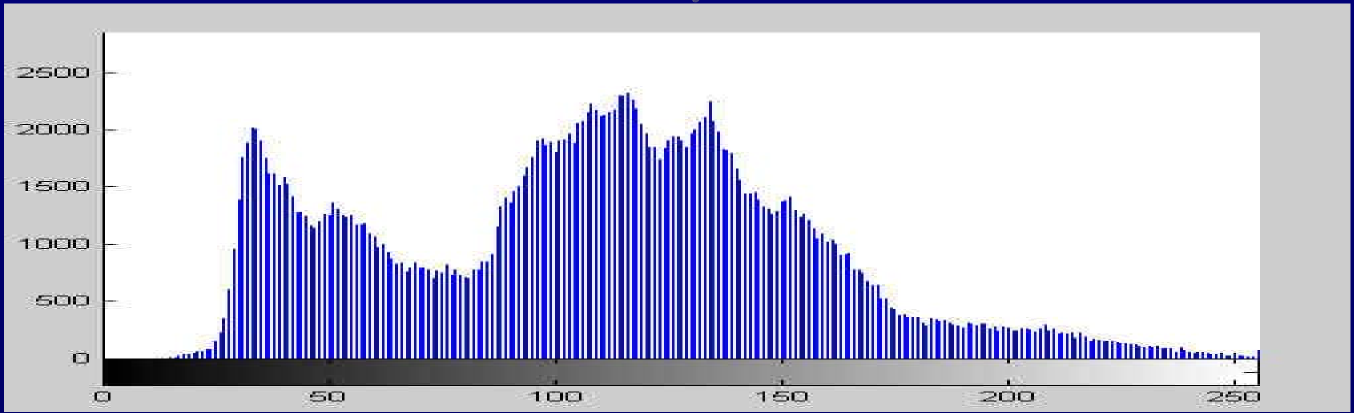


Color Analysis

- Image breakdown to color components
- Concatenation of image histograms
- Color histograms due to their statistical nature, provide a complete rotationally invariant representation when employed with panoramic cameras



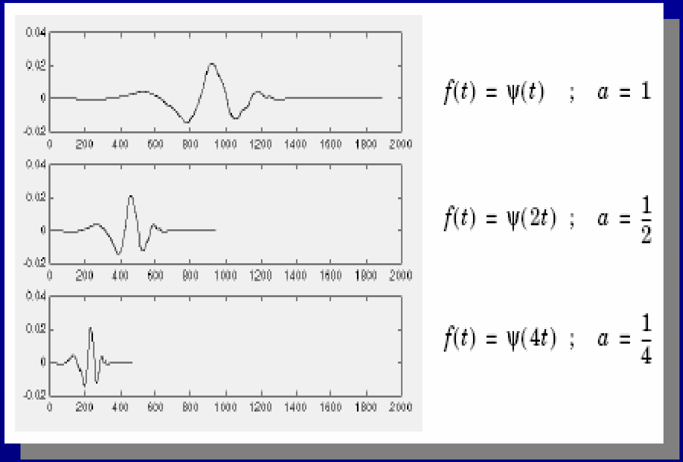
Red Component Green Component Blue Component

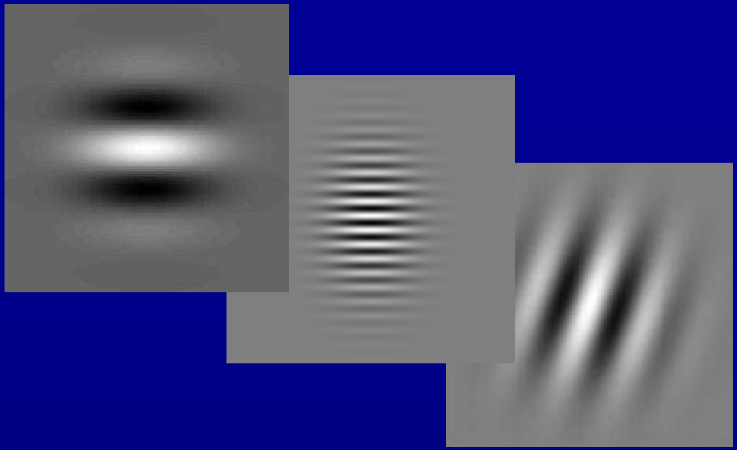


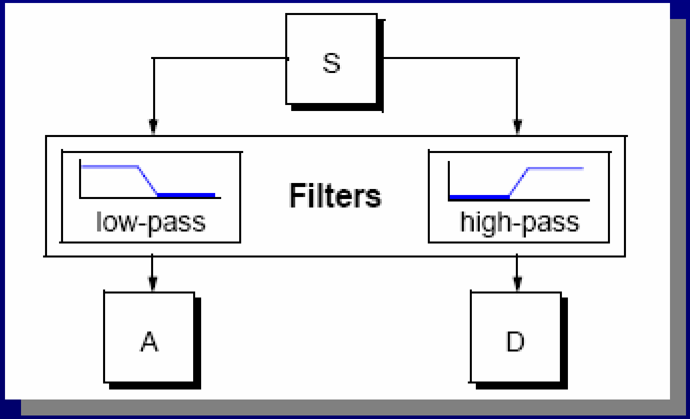
RGB Image Histogram

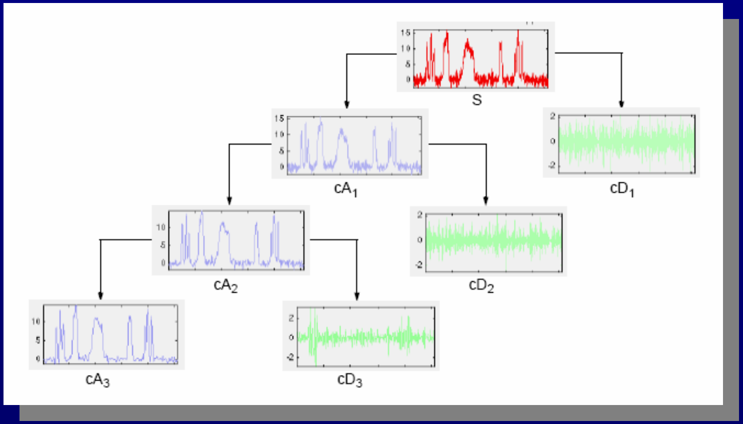
Wavelet Decomposition

- The Discrete Wavelet Transform involves filtering and subsampling



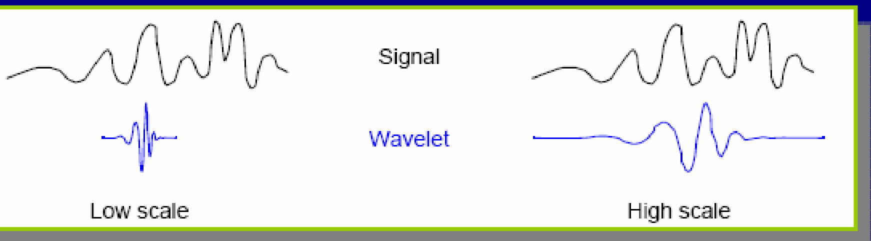




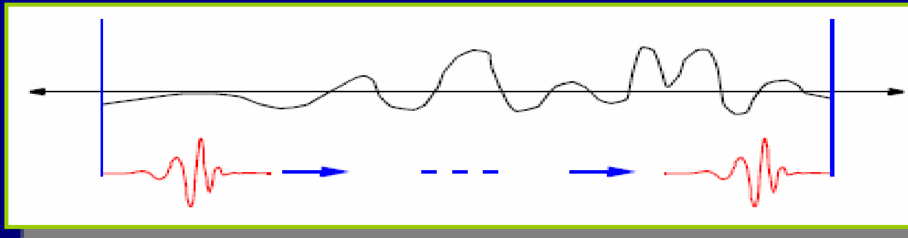


Wavelet Coefficients and Self-Similarity

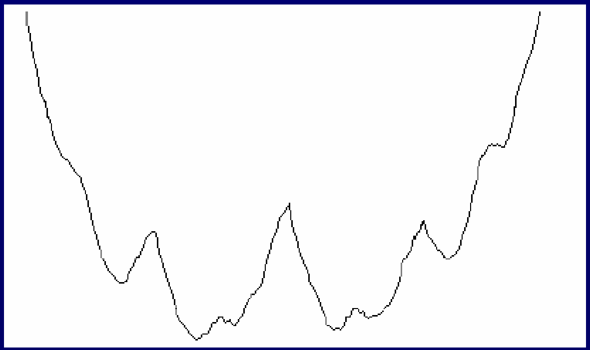
- The wavelet decomposition consists of "resemblance indices" (Coeficients) between the signal and the wavelet.
- If the index is large, the resemblance is strong, otherwise it is slight.
- Coefficients reveals patterns among scales and shows the signal's possibly fractal nature



Scaling

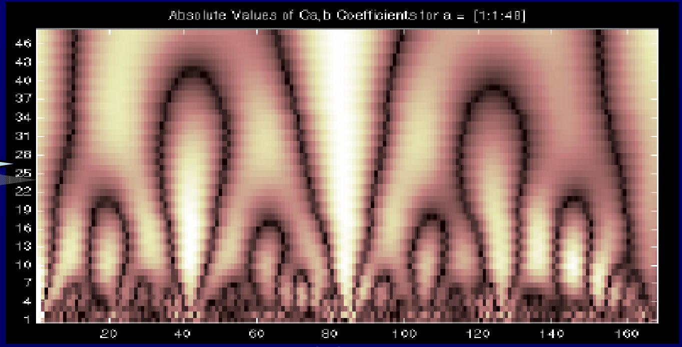


Translation



Original Image

Wavelet Transform

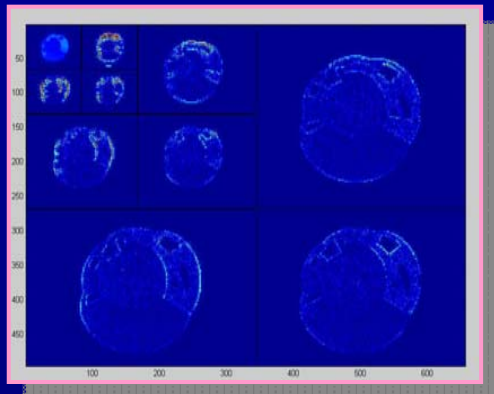


Coefficients

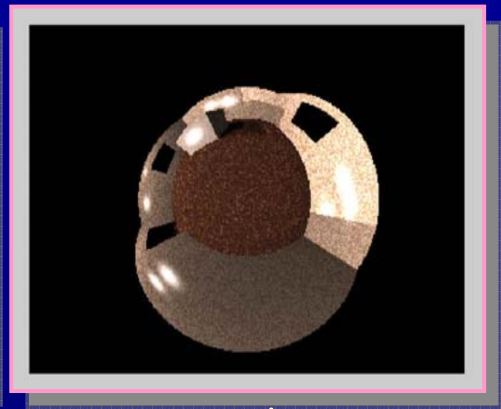
Texture Analysis

Calculation of statistical propoerties of the wavelet coefficients for three level decomposition, for every scale and orientation

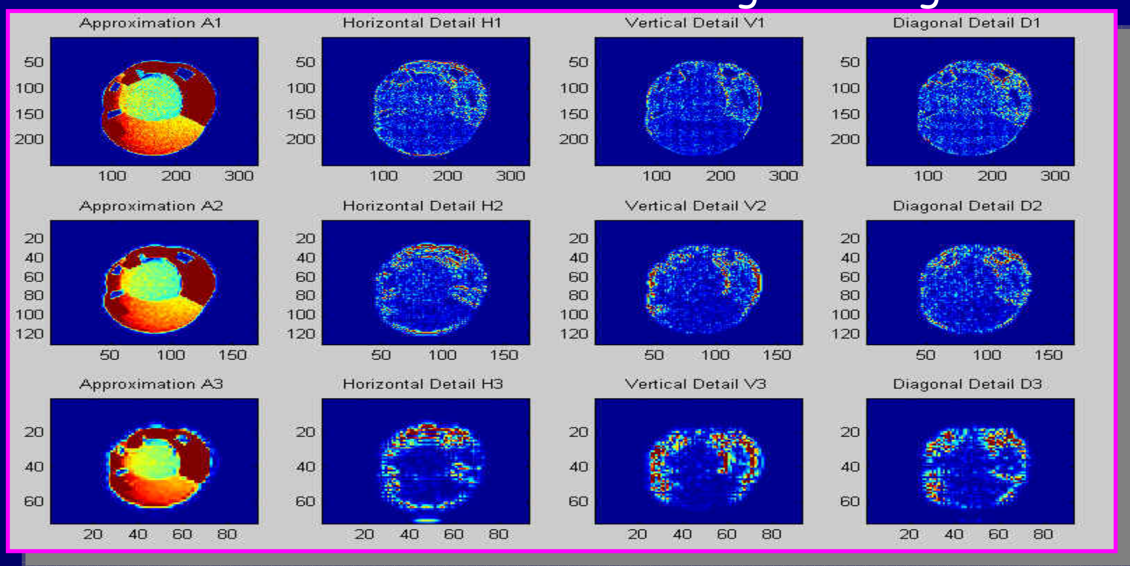
- Mean Value
- Standard Deviation



Detail Coefficients



Original Image



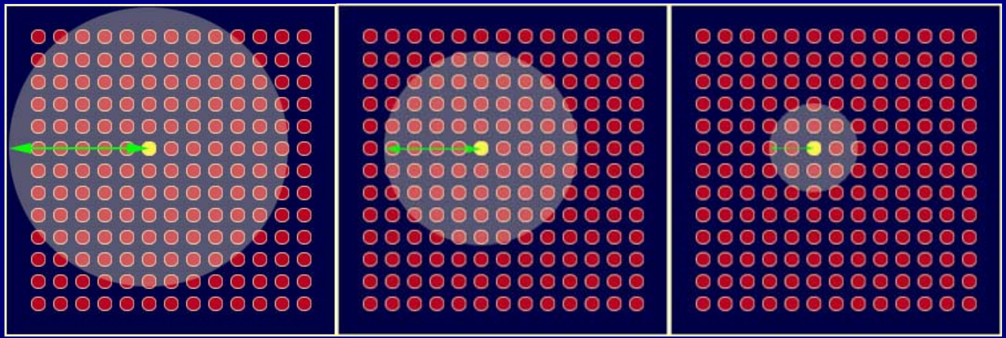
SOM Learning Algorithm

- Weights initialization (typically to small random values)
- Calculate the Best Matching Unit

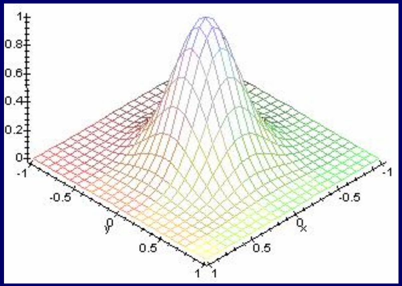
$$Dist = \sqrt{\sum_{i=0}^{i=n} (V_i - W_i)^2}$$

V is the current input vector and *W* is the node's weight vector

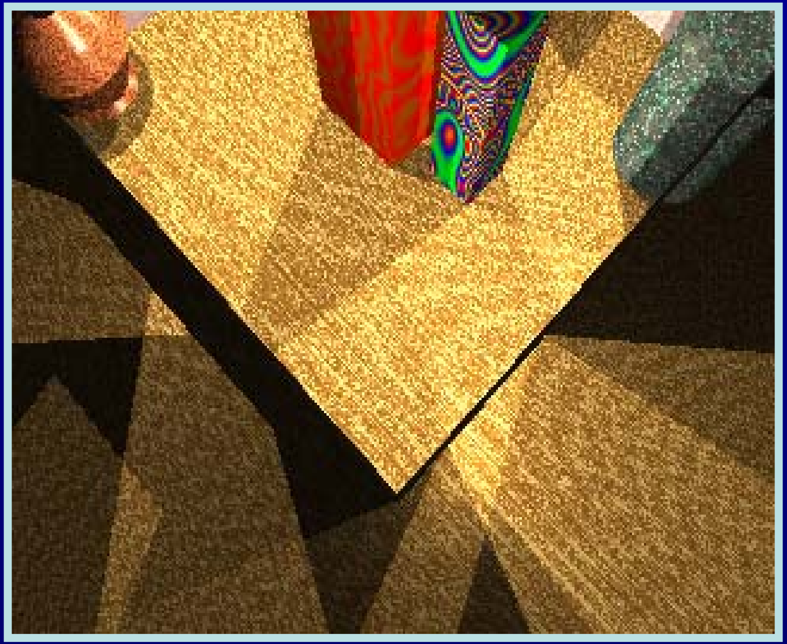
- Determining the Best Matching Unit's Local Neighbourhood



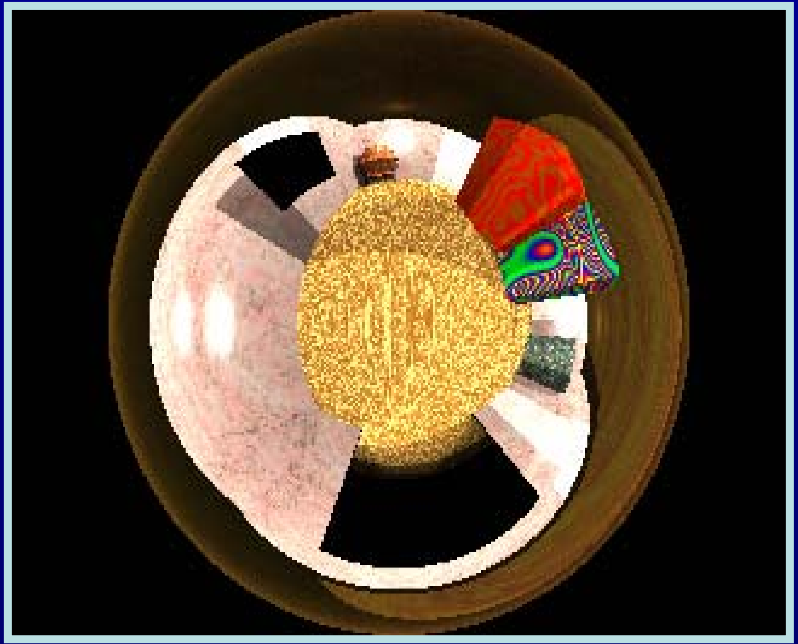
- Adjusting neighbor Weights (e.g. Gaussian function)



Simulation Environment



1. Artificial room

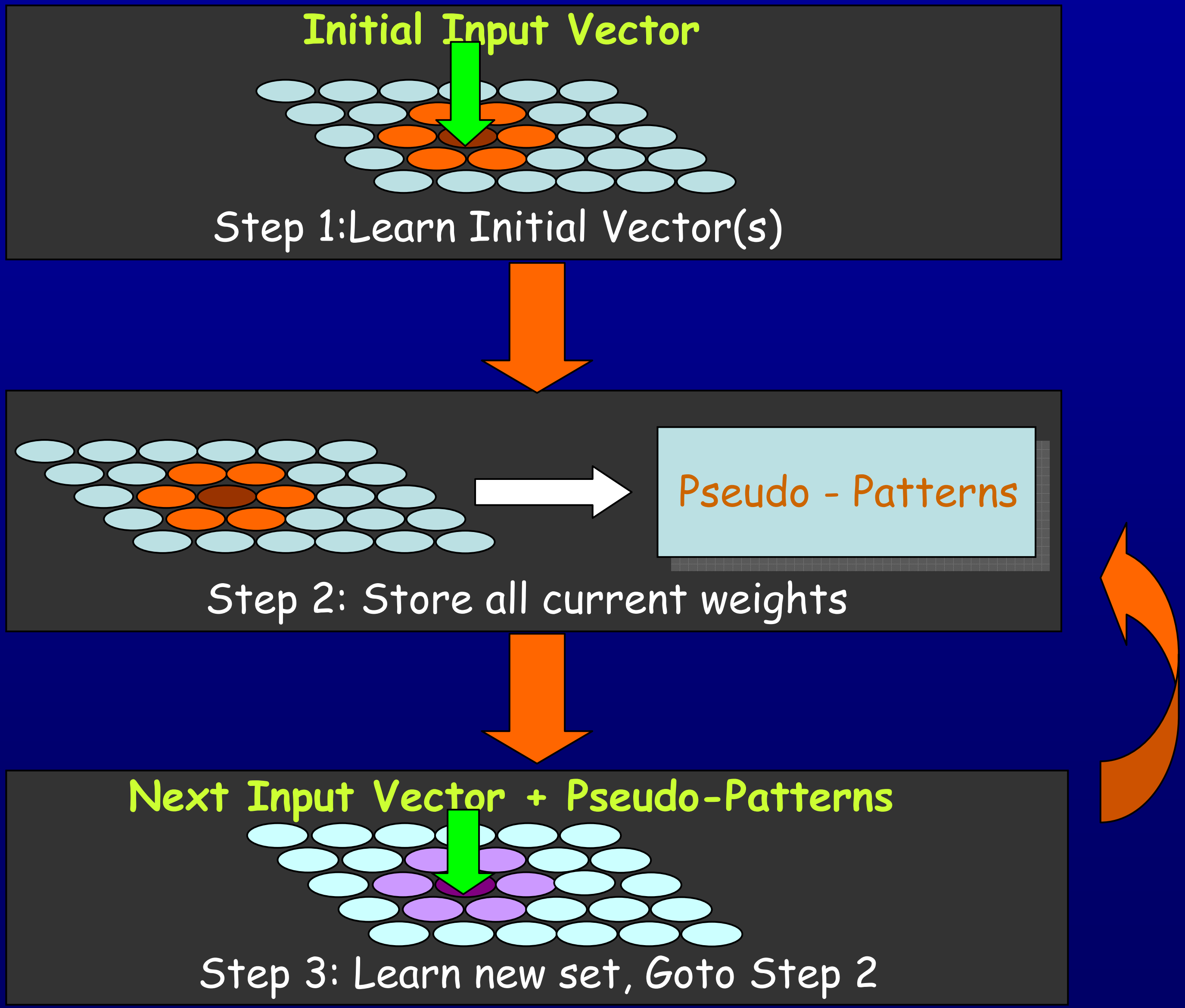


2. Omnidirectional camera view

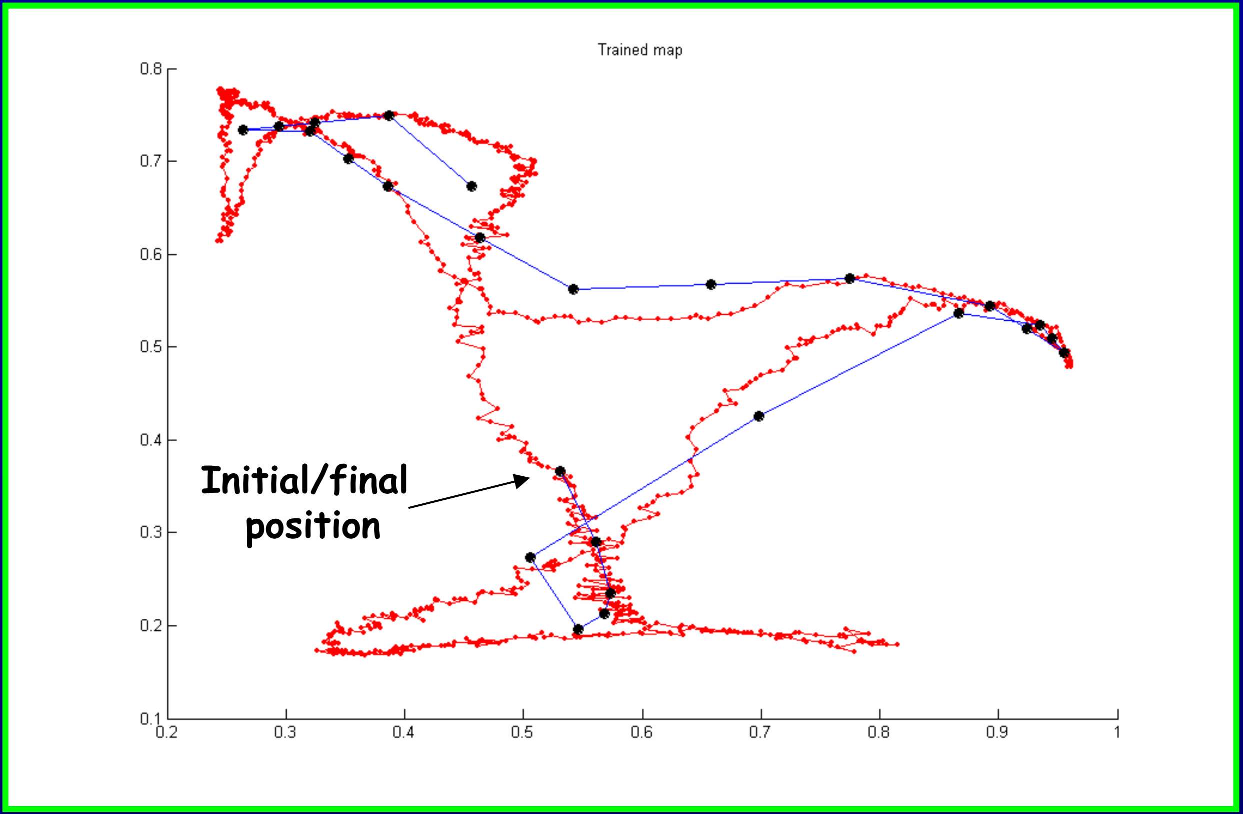
The Plasticity Elasticity dilema
(or Catastrophic forgetting)

- Catastrophic forgetting is a phenomenon which occurs when learning of new information completely erases previously learned information
- Building a robot that excibits real cognition requires the ability to learn sequences of events
- Pseudorehearsal and Rehearsal consolidation process proposed in psychological and cognitive literature
  - Interleaves internally stored information with newly arrived information

Rehearsal-SOM Algorithm Overview



Preliminary Results (2/3)

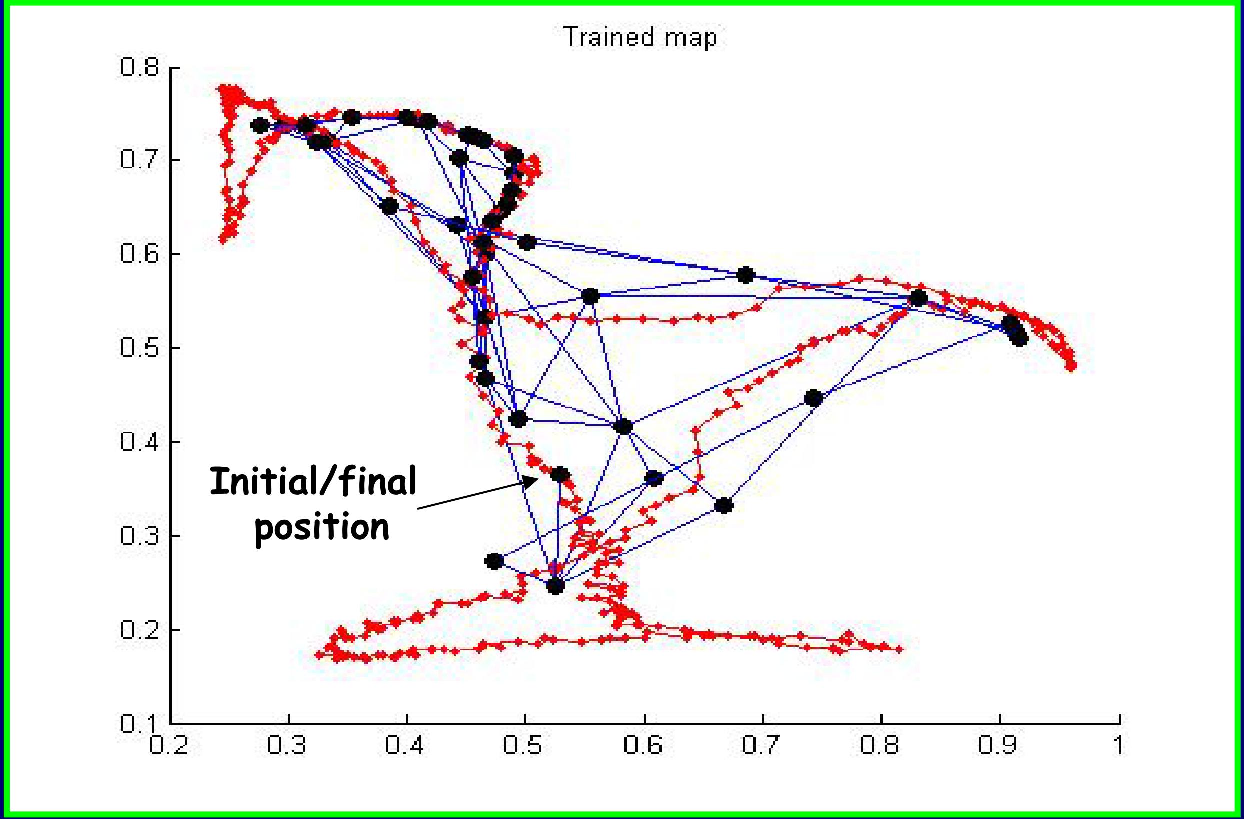


Som trained sequentially for 1000 snapshots. Grid size: 1x25

First two elements of each input vector:

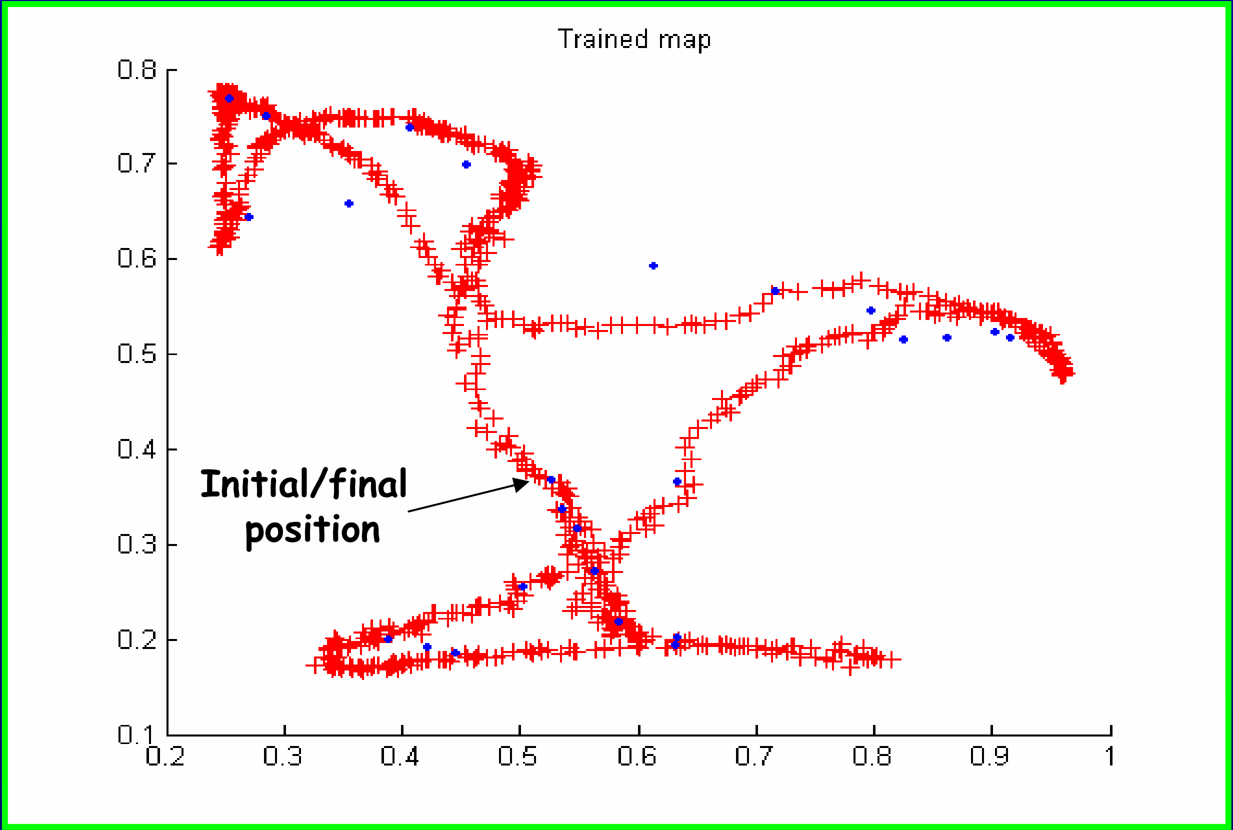
First two elements from every weight:

Preliminary Results (2/2)



Som trained sequentially for 500 snapshots with Rehearsal SOM. Grid size: 1x25
A second Net captured the outputs from Rehearsal SOM. Grid size:5x5
First two elements of each input vector:
First two elements from every weight:

Preliminary Data with Neural Gas



Neural Gas trained sequentially for 500 snapshots. Number of Neurons: 25

First two elements of each input vector

First two elements from every weight:

Conclusion

Capturing behaviors of biological systems can lead to improved performance

Rehearsal SOM gradually learns and forgets a sequence of input snapshots

SOM network can not approximate the input space accurately because of the predefined structure

Future Work

Use of networks than dynamically add or remove nodes and connections

Compare the performance of various Unsupervised Neural Networks

Evaluation on a real Robot

Integration of innate motor state information