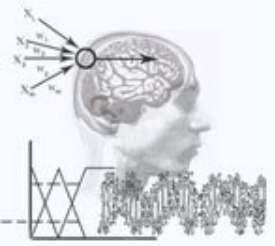
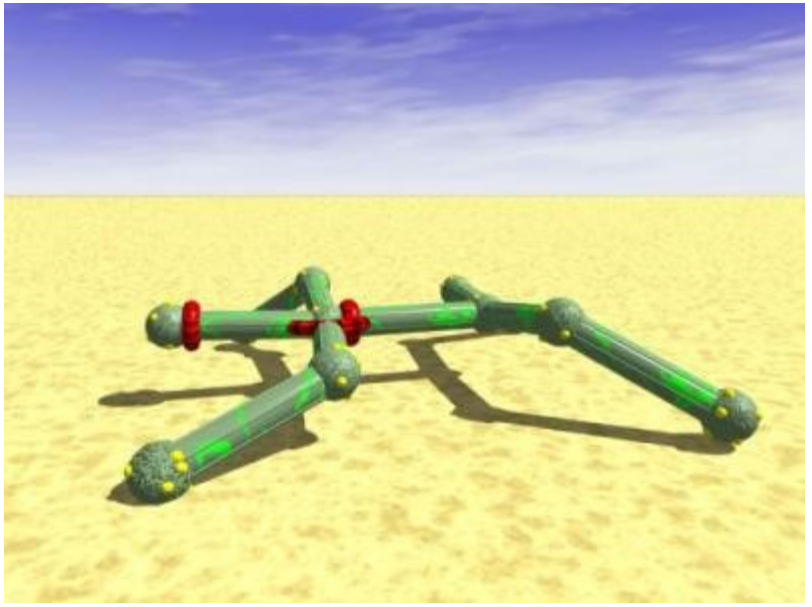


Framsticks: Biologically-inspired Visual-motor Coordination in a Navigation Problem

Jacek Jelonek and Maciej Komosinski. Biologically-inspired visual-motor coordination model in a navigation problem. In Knowledge-Based Intelligent Information and Engineering Systems, volume 4253 of Lecture Notes in Computer Science, pages 341-348. Springer, 2006. [view pdf]

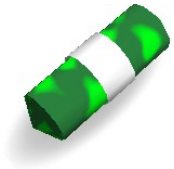
Framsticks

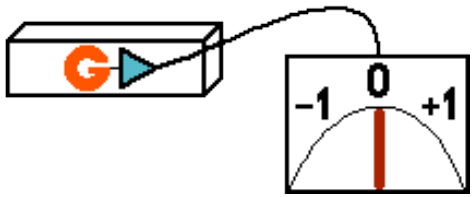
- three-dimensional life simulation environment
- physical structures (bodies) and control systems (brains) of creatures are modeled
- various kinds of experiments available, including simple optimization (by evolutionary algorithms), coevolution, open-ended and spontaneous evolution, distinct gene pools and populations, diverse genotype/phenotype mappings, and species/ecosystems modeling.



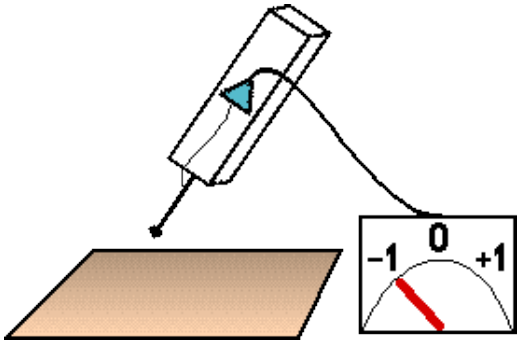
Framsticks' receptors

equilibrium

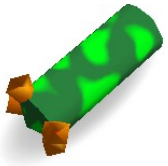


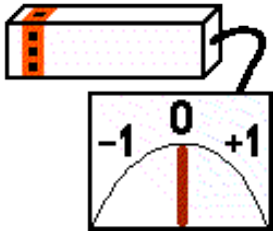


touch



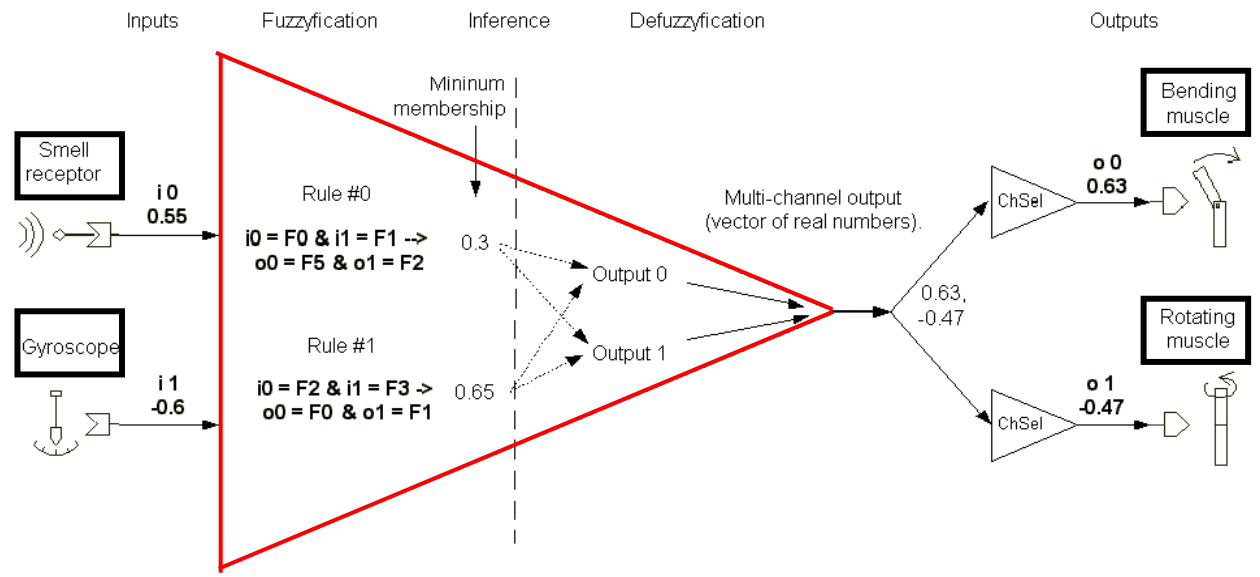
smell



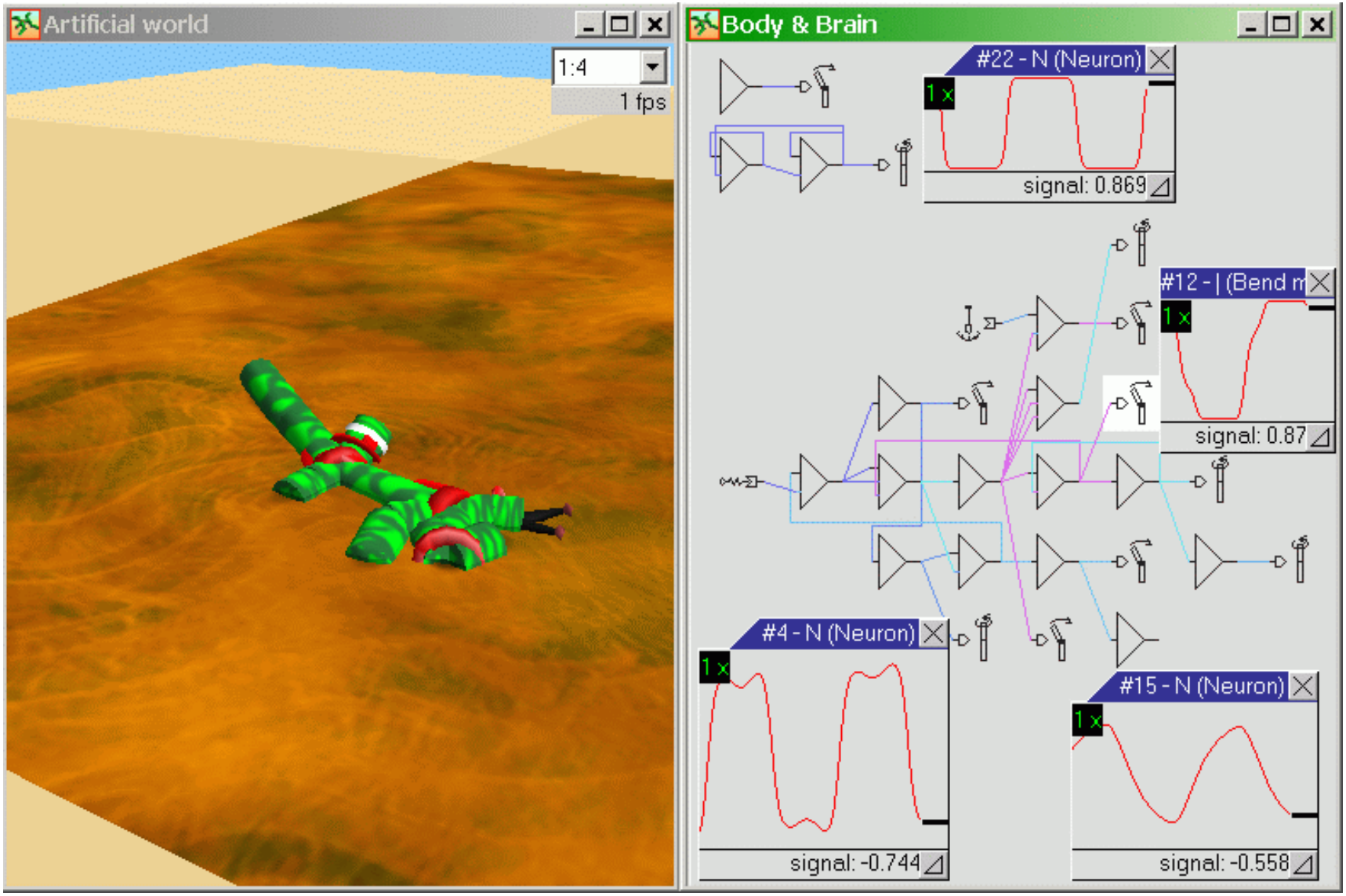


Framsticks ”brains”

…can be composed of many neurons and many neuron types, including non-linear units, complex processing units, delay units, memory units, and even a fuzzy rule-based control system (shown below)



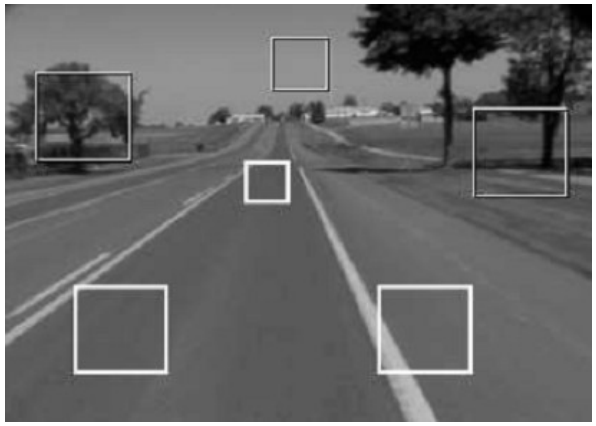
Studying agents' behavior



New Framsticks' sensor-effector module: visual-motor coordination module

The aim of the project:

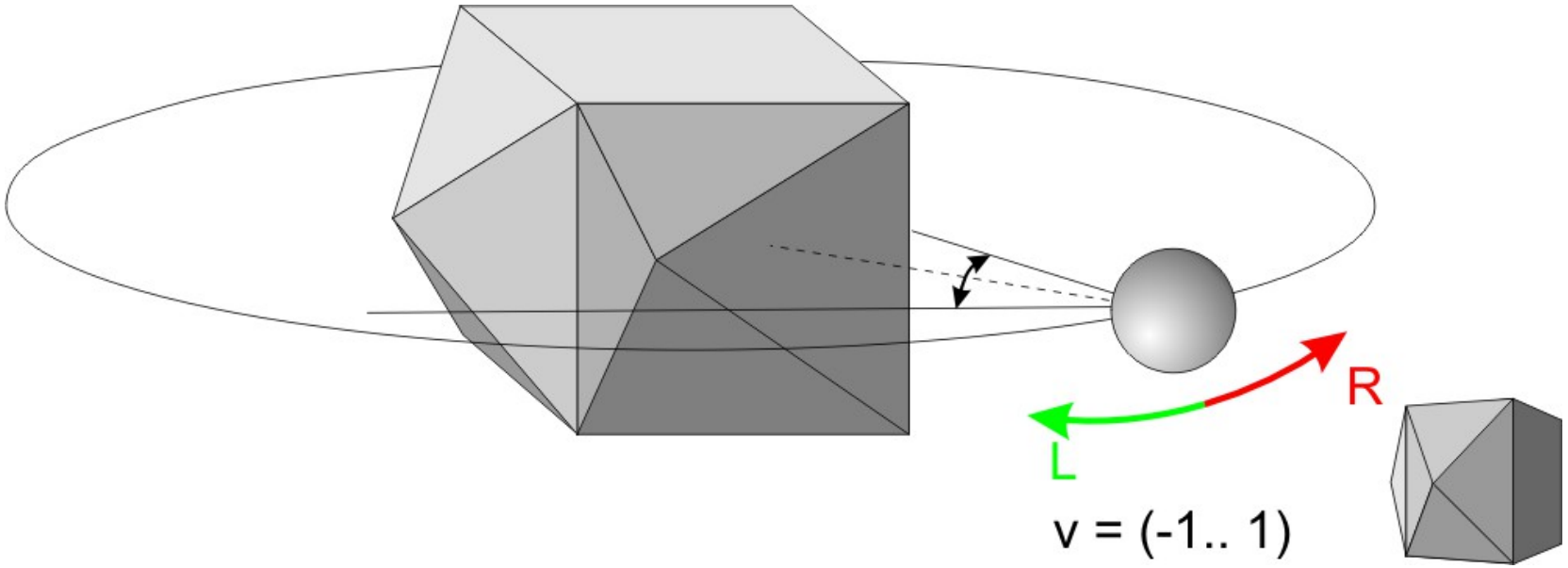
Design and implementation of the *visual-motor coordination module* in which motor actions, depending only on visual stimuli, solve some navigation tasks.



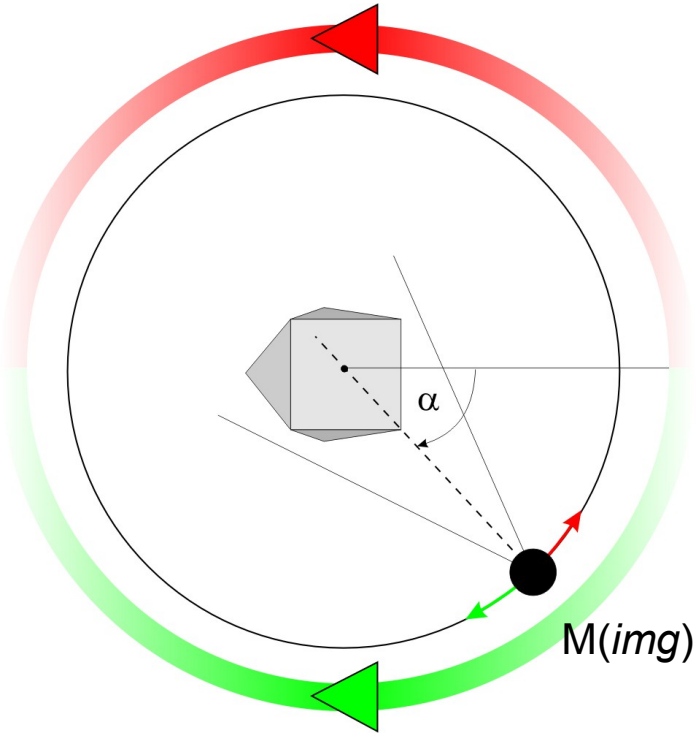
To do list:

1. Definition of a navigation experiment with success criterion,
2. Design and implementation of the visual-motor coordination model,
3. Tests – verification of the model.

Navigation experiment



„Life and death zones” navigation problem



M(*img*) – movement speed (-1..1) based on visual stimulus *img*

possible navigation solution of „life and death zones” problem:
M(*img*) = sin(α)

Formal problem definition

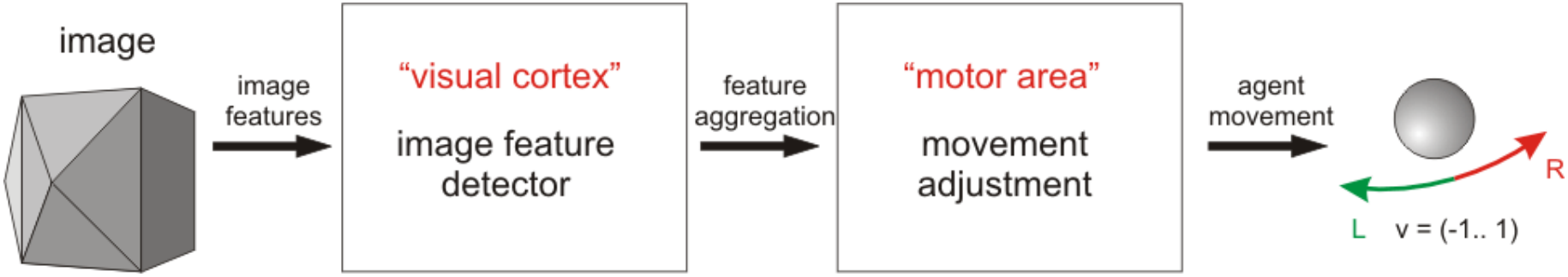
img_i – *i-th* image (its features) in a trip around the 3D object,
M(img_i) – expected value of movement velocity for img_i (e.g. sin(α)),
M'(img_i) – velocity output signal of the visual-motor coordination module.

Success measure = optimization function:

$$\min \sum_{i=o}^{n} | M(img_i) - M'(img_i) |$$

?

Architecture - data flow



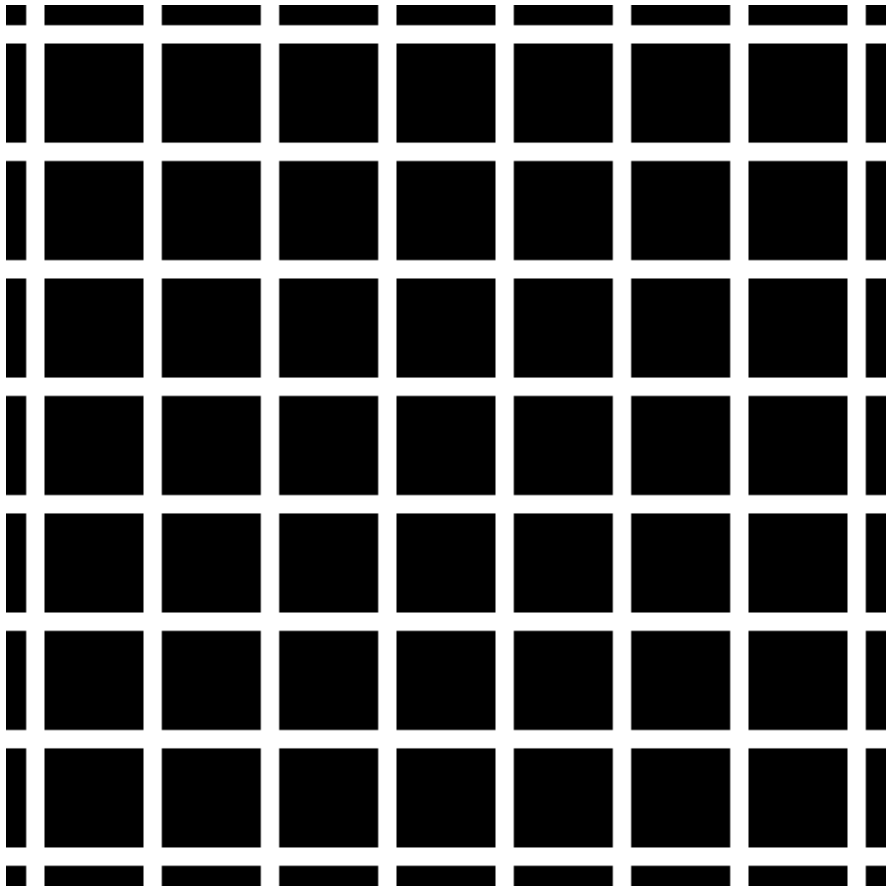
visual-motor coordination module

Feature design - biological inspiration

Mach bands

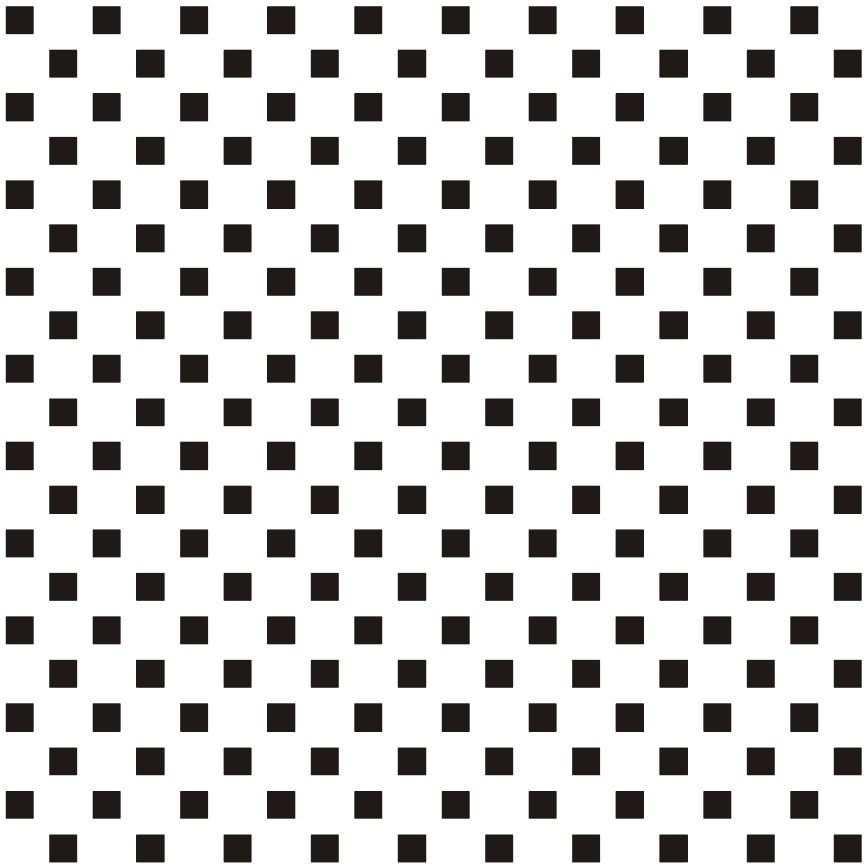
All bars are uniformly colored but each of them appear darker on the right side than on the left.

Hermann-grid illusion



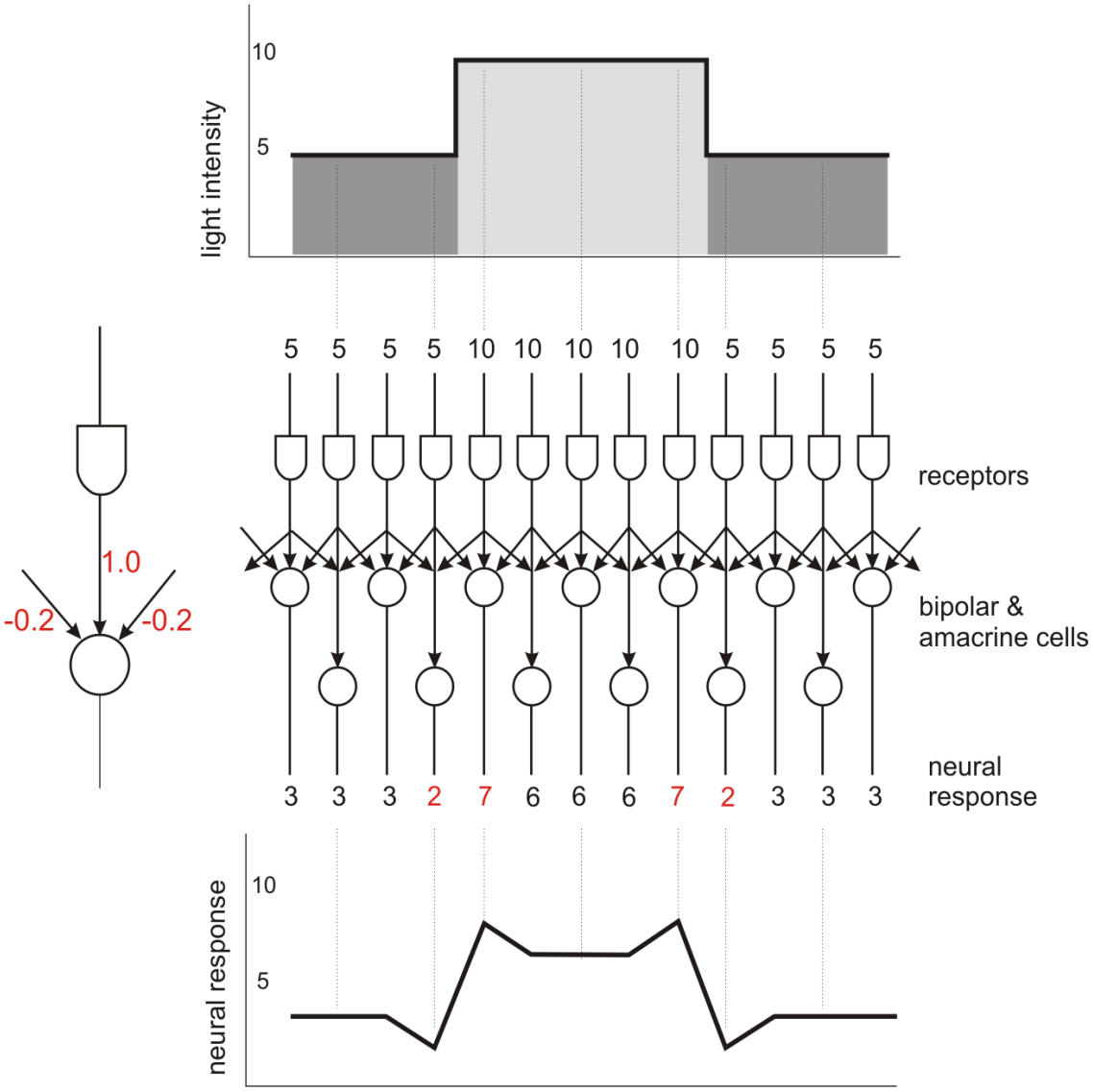
Dark patches appear in the street crossings, except the ones which you are directly looking at.

Springer illusion



Dot pattern can produce perception of faint diagonal lines.

Explanation - lateral inhibition



I-order visual cortex

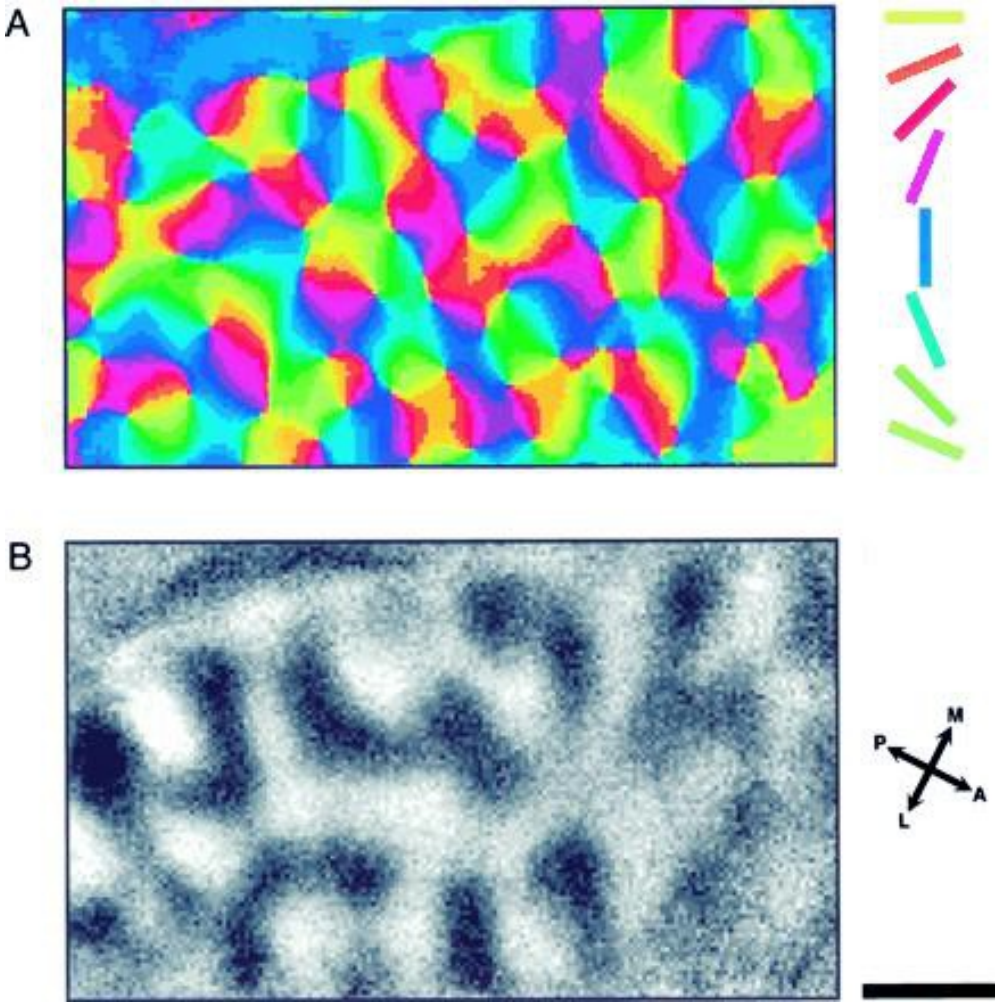
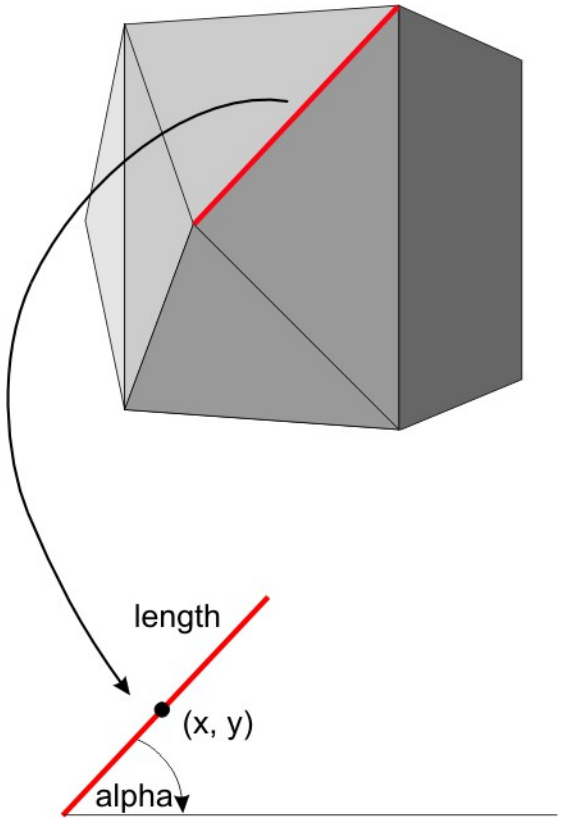
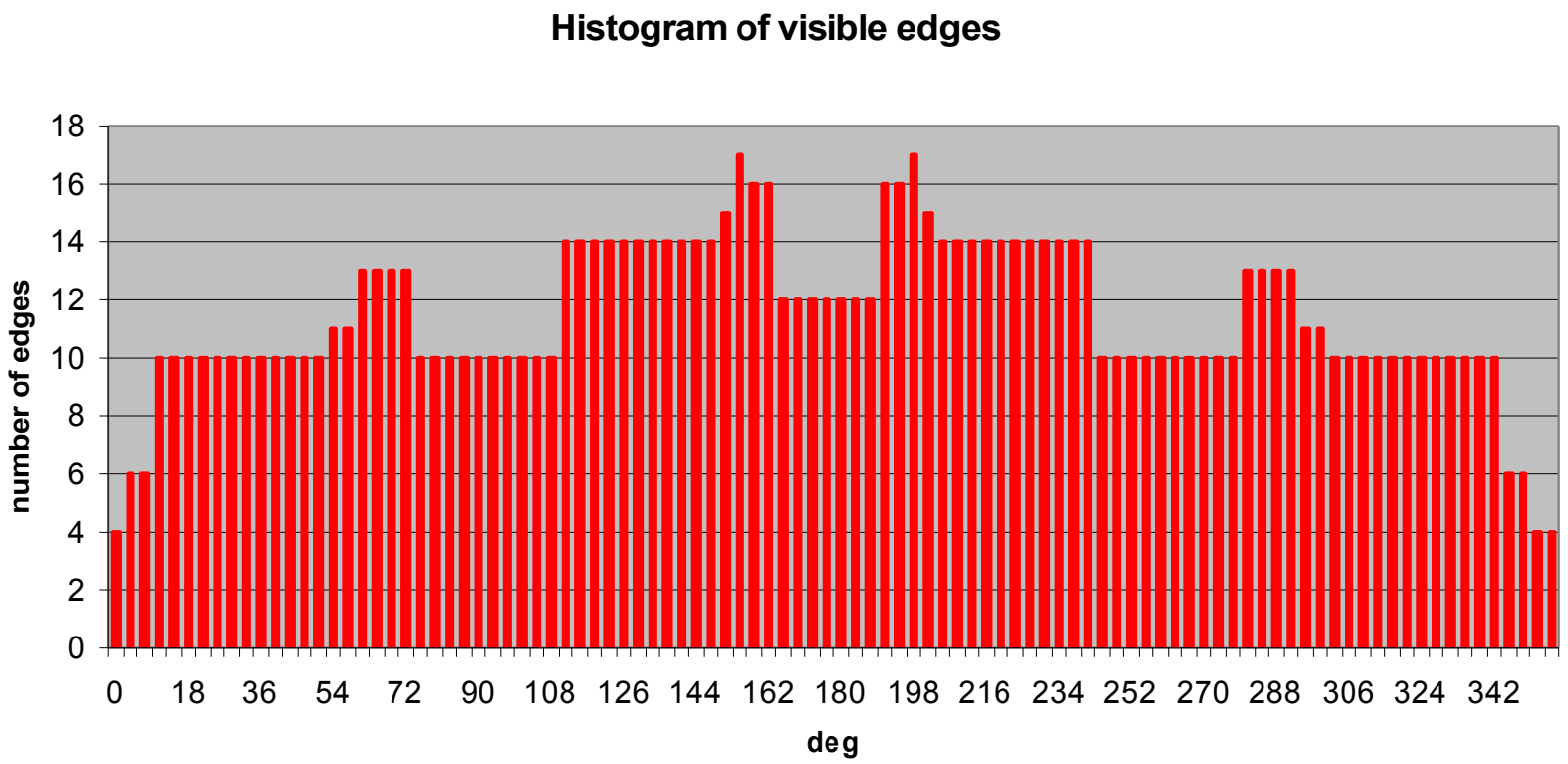


Image features – edge attributes



Problem – variable number of features



Formal problem definition - continuation

$$\min \sum_{i=o}^{n} | M(img_i) - M'(img_i) |$$

img_i – i-th image

$img_i \rightarrow V_i$, (feature extraction)

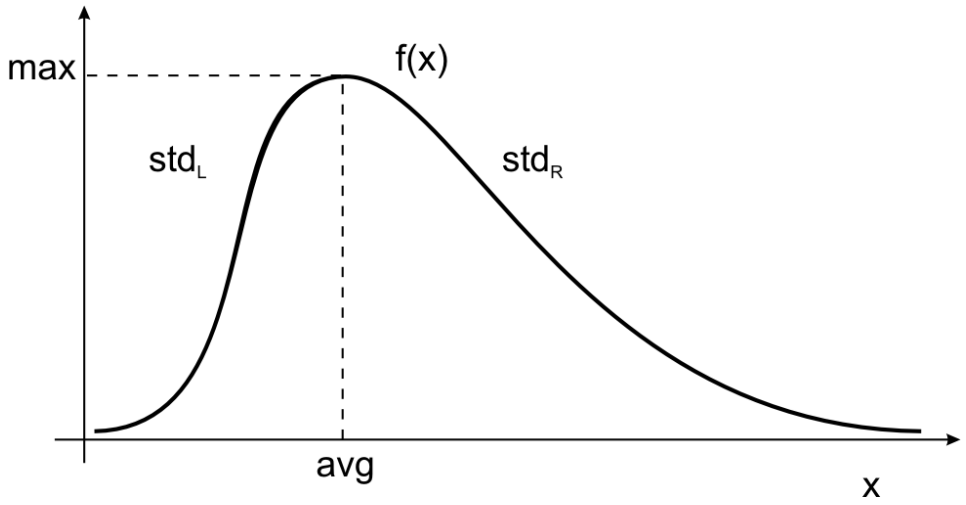
V_i, – set of edges of the i-th image, each edge is described by 4 attributes (x, y, length, alpha)

$$v_i = M'(V_i)$$

Problems:

1. Design of the parametric model *M'*, i.e. parametric function which computes visual-motor coordination output (y_i) for any set of features (edges) – V_i.
2. Aggregation of features.

Feature aggregation – ”fuzzy” sum of attributes

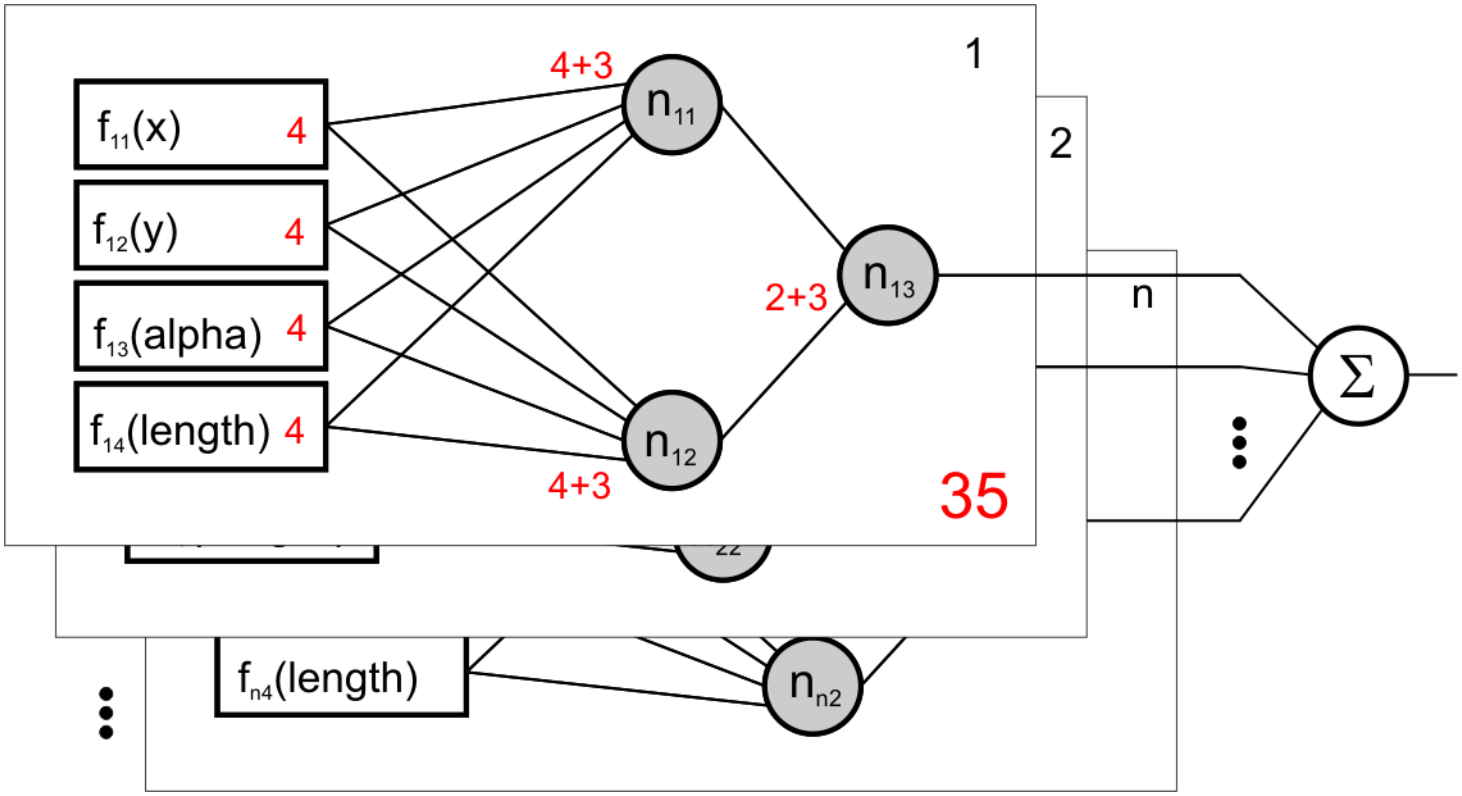


$$v_i = M'(V_i)$$

$$V_i = \left\{ A_j : A_j = \left\langle x_{i,j}, y_{i,j}, length_{i,j}, alpha_{i,j} \right\rangle \right\}$$

$$v_i = M'\left(\sum_j f_1(x_{i,j}), \sum_j f_2(y_{i,j}), \sum_j f_3(length_{i,j}), \sum_j f_4(alpha_{i,j}) \right)$$

The architecture of the motor area



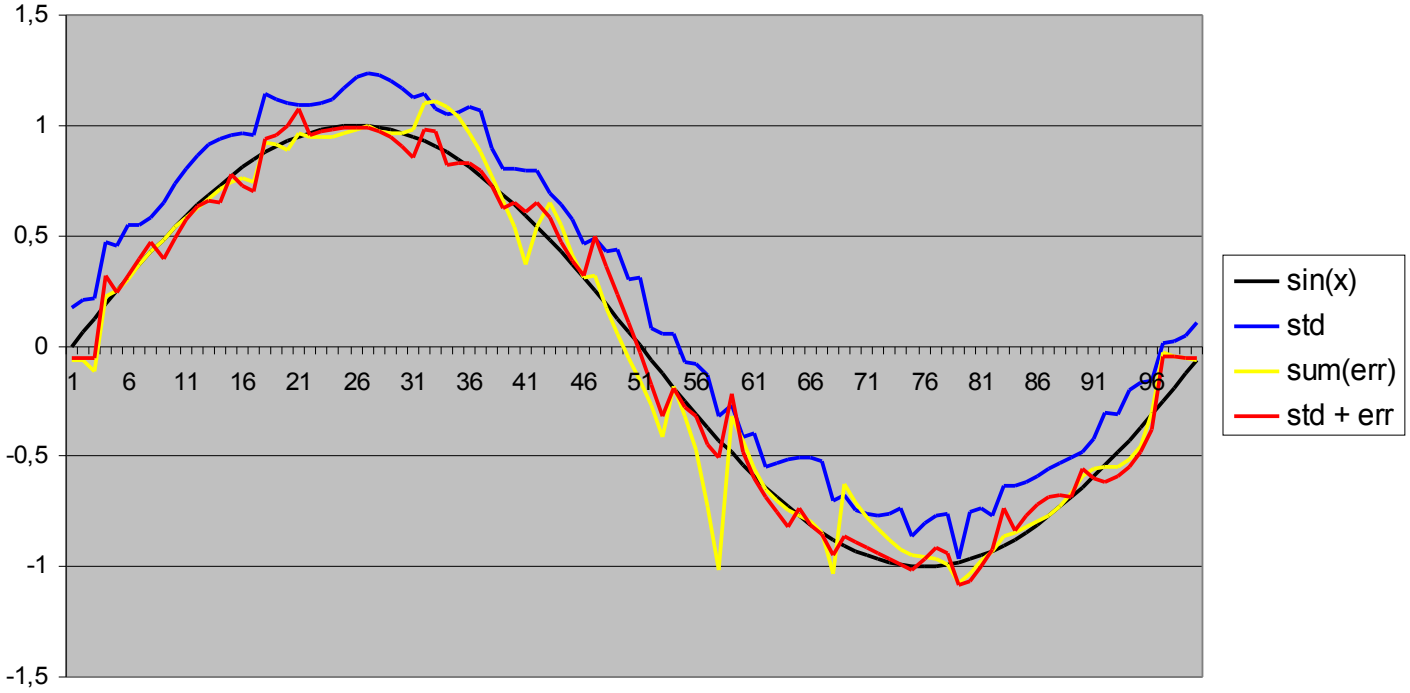
Optimization

- variable step gradient optimization,
- optimization functions:

  err = SUM(|M(o) – M'(o)|)

  std = STD(M(o) – M'(o))

  err + std



To do list:

✓ 1. Definition of a navigation experiment with success criterion,

✓ 2. Design and implementation of the visual-motor coordination model,

✓ 3. Tests – verification of the model.

Demo

Summary

- a new visual-motor coordination model has been proposed,
- biologically-inspired image features (edges) and a small set of their attributes (position – x, y; angle and length) allow to successfully map high-level image information into low-level, single motor value (effector speed),
- the model has been successfully verified in „life & death zones” navigation tasks,
- additional experiments have proved generalization capability of the model - changing the size of the object, and changing the distance of the agent from the object hardly increased error, so the system proved to be robust to minor changes in the environment,
- an interesting feature of the proposed model is that the system performance can be visualized and interpreted (explained) - it is possible to estimate the influence of each edge on the output value, and to visualize it.

Future works

- experiments with unsupervised learning approach,
- implementation of better optimization techniques – metaheuristics,
- new navigation tasks in 3D space,
- progression from simple S-R behavioral patterns toward more complex ones by design and implementation of new cognition modules, which would lead to successful behaviors in more advanced and demanding tasks.