A model of rapid surface detection in primate visual cortex

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Modeling surface detection with spiking neurons

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Introduction

Primates can perform image segmentation and object classification in a purely feed-forward manner, using only 10-15 ms per processing stage[1].

Each neuron in the processing chain has only time to fire 1-2 spikes.

No time for lateral or top-down interactions to enhance edge-detection and edge-based segmentation!

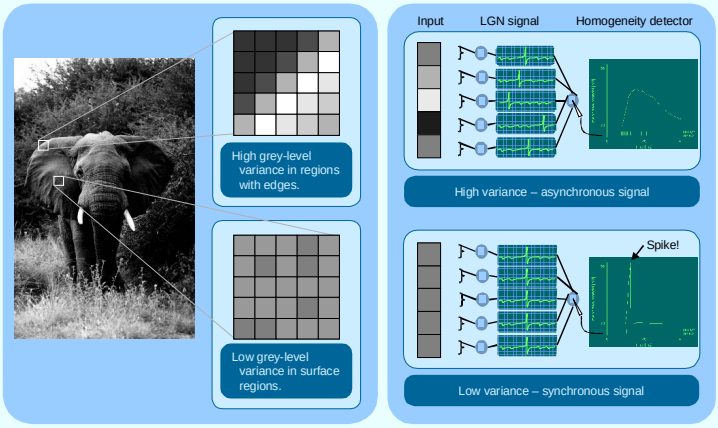
About one third of the neurons in the perifoveal area of V1 respond to homogeneous surfaces[2].

How might the cortex implement homogeneity detection?

What can homogeneity information be used for?

We present a network of spiking neurons performing surface detection. We show how homogeneous image areas can be used to enhance fast feed-forward image segmentation. Moreover, we provide an hypothesis where in the visual system homogeneity detection may be implemented.

Working principle



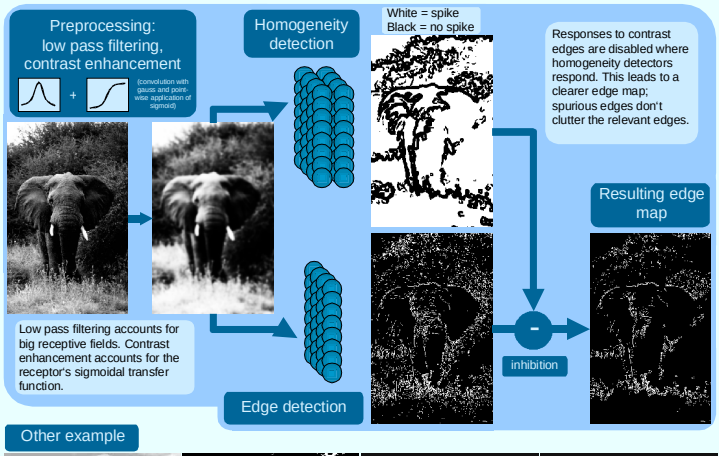
Simulation environment

All simulations were carried out using the NEST-simulator[3]. Simulation time was 50 ms with a resolution of 0.1 ms. Largest simulation had 1.8 million neurons and took about 14 minutes on a SunFire V880 (8 x 900 MHz Sparc).

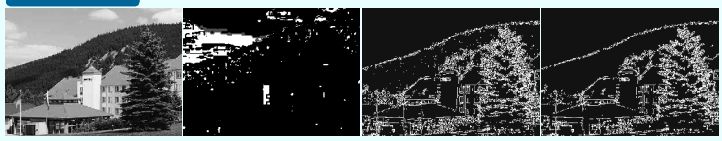
References

[1] S. Thorpe et al. Speed of processing in the human visual system. *Nature*, 381:520-522, 1996
[2] H. Komatsu et al. Surface respresentation in the visual system. *Cogn. Brain Res.* 5:97-104, 1996
[3] M. Diesmann, M.-O. Gewaltig. NEST: An environment for neural systems simulations. In V. Macho (editor): *Forschung und wissenschaftliches Rechnen, GWDG-Bericht*. Ges. für Wiss. Datenverarbeitung, Göttingen 2002.

Network layout & Results



Other example



Biological representation

Possible visual pathways where homogeneity detection is performed:

M-Path: fast, relatively large receptive fields, however very contrast sensitive

K-Path: large receptive fields without antagonistic center-surround structure

K-axons terminate in Layer II/III in V1, sparing one synapse on the way to higher brain areas.

But not many details are yet known about the function of the K-Path.

Hypothesis: K-Path homogeneity detection may disable responses to spurious edges in Layer II/III, before they are relayed to higher areas. It could be switched off by top-down inhibition when more details are needed.