Title

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Author

Galitsky, Boris A.

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Boris A. Galitsky
Marketron, Inc., 2929 Campus Dr #400 San Mateo CA 94403
borgal@aol.com

The model

The knowledge on cell physiology of the distal retina gives an ability to represent the functioning of cone - horizontal cell - bipolar neural network as a whole. Six signal operations are combined in the model:

1) phototransduction operation (i.e. signal transformation from light into electrical response in the photoreceptor);
2) chemical synaptic transmission from photoreceptors to second order neurons;
3) electrical coupling between horizontal cells;
4) nonlinear (amplifying) properties of horizontal cell non-synaptic membrane;
5) the feedback from horizontal cells to photoreceptors in triad synapses;
6) dynamics of the bipolar neuron.

The current study develops the distal retina model (*Byzov, Shura-Bura 1986*), allowing the calculation of responses for arbitrary spatial stimuli. Time courses of horizontal cells (achromatic type) membrane potential, obtained experimentally for various temporal and **simple spatial stimuli** for fish and turtle retinas, were reproduced by the diffusion-type equations with the additional temporal constraint (electrical feedback in triad synapse). Experimental work with **complicated** spatial stimuli is hard, so the computational study with a verified model is required to analyze the network responses to movement.

The coding of velocity

The study is mainly focused on the spatial distributions of bipolar potential, which is the base of edge and motion detection. The fact of **weak** linear **dependence of bipolar responses** on stimulus **velocity** is obtained as a basis for the relative velocity representation constancy in respect to stimuli luminosity: ***d**Potential(Vel)*/**d***Vel = const*, though horizontal cells responses have exponential-like dependence.

The system functioning combines the **temporal smoothing** with the **spatial amplification** of area edges with illumination difference. The network estimation of edge intensity increases under the movement along the edge and drops under the transverse movement. For example, front and rear edges of a moving rectangle are smoothed, though the side edges are amplified proportionally to the velocity. The velocity value itself, which is represented by the amplitude, is smoothed under the sharp change.

In general, the optimal velocity for the moving objects detection is low in respect to the system time constant but high enough to be taken into consideration for better perception.

Consistency to noise

The network was analyzed in respect to external noise and deviation of internal parameters under spatial filtering. The network is capable to calculate the spatial derivative and to extract the **illumination difference** much **weaker** than the **variation** of membrane **parameters** from one photoreceptor to another. This feature is provided by the specifics of potential spread through the horizontal cells network and electrical feedback mechanism of the triad synapse.

Relations to psychophysics

Some human visual perception phenomenon can be explained in the bounds of the distal retina, for example, the failure of motion imitation by means of changes in the illumination conditions, while "empty field" specifics (imitation of the absence of relative movement) does not match the system behavior.

Hypothesis

Given the spatial-temporal distribution, it is possible to reconstruct the network functioning of specialized **detectors** (movement of the area edge, stripe, etc.). Hypothetical detectors can correspond to some classes of amacrine and ganglion retinal cells.

There exists the fastest and shortest dynamic link, which provides the high level layers with the information about the object acceleration. It is, probably, necessary, for the instantaneous following of the moving object by means of the pupil motion.

References

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