**Simulation of Layout and Connection Pattern Development of Horizontal Cells**

**Midterm Report**

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**Project Description**

Lateral inhibition in which a group of cells suppresses the activities of their surround cells has been found in various systems of multicellular organisms. Primary visual processing of visual animals, from insects to mammals, involves lateral inhibition to enhance sharpness and modify color discrepancy of visual scenes. In mammals, horizontal cell, an interneuron playing a critical role in primary retinal lateral inhibition, facilitates the formation of center-surrounding receptive fields, whose sizes and densities vary among species to accomplish optimal performances.

However, how this elaborate structure evolves and whether there are any alternatively effective structures remain unclear. This project hypothesizes that there are other considerable structures that lead to local maxima of fitness. To explore those alternatives, genetic algorithm, a random-based searching algorithm optimal for identifying multiple local extreme values, is used and analysis of these structures will be performed.

**Method**

Representation of Retina

Retinal lateral inhibition is commonly modeled as either neural network, where horizontal cells are in hidden layers, or image filtering, where horizontal cells are filters convolved with visual input. The former is used since it enables flexible alteration of horizontal cell properties and dynamics. Receptors are hard-coded to process raw visual input, and their states are then modified by interneurons.

Parameters to be Optimized

Neurons and their connections are built from a set of descriptors to be optimized, including axon and dendrite descriptors, numbers of cells of each types, number of cell types, and distance-dependent decadence factor. Each type of horizontal cell has an axon descriptor vector and a dendrite descriptor vector, that abstractly represent their axon and dendrite properties, respectively. The affinity coefficient between one neuron and another is the dot product of the former’s axon vector and the latter’s dendrite vector. Since the size of the retina is predefined and horizontal cells distribute uniformly in the space, it is able to determine the distance between two neurons, and therefore calculate the exponential decay. The weight from one neuron to another is the product of the exponential decay and the affinity coefficient.

Selection and Crossover Strategy

In order to suppress premature convergence of genetic algorithm, each individual is granted a probability to crossover that depends on its fitness value. The crossover is allele-wise, i.e. the crossover unit is a scalar or a vector, for crossing over merely a part of vectors could create drastic change in terms of dynamics.

Visual Input

The visual input in consideration is one-dimensional, which is simpler yet effective to promote the evolutionary process. If possible, two-dimensional scheme will be developed in the future. The visual input is a discretization of brightness changing in the world. The brightness curves of prays are artificially defined to be narrow and unimodal, while those of predators are wide and multimodal.The input will be perturbed and blurred so as to test the performance of retinas.

Fitness Evaluation

The project, like many other models, assumes there is no information loss due to signal transduction. Therefore, the modified visual information is considered as the input to the further visual processing, which is abstractly modeled as a perceptron that classifies predator and prey patterns. The fitness of an individual will be assessed according to the performance of a perceptron.

**Progress Summary**

Many experiments and discussions were done before the mid-October in order to determine the fitness assessment and parameters. A modified reconstruction of a retina model[[1]](#footnote-0)[[2]](#footnote-1)[[3]](#footnote-2)[[4]](#footnote-3)[[5]](#footnote-4) is done in Jupyter-Notebook so as to investigate the properties and functions of horizontal cells. Several designs of fitness assessment and parameter set were made, but were then aborted, because of 1) too many limitations and assumptions, 2) less representative fitness assessment, and 3) unnecessarily computation-heavy.

Implementation of the work above began in the late October, after making a relatively robust design of the simulation. All the work is updated on my [Github repository](https://github.com/gongziyida/Simulation-of-Layout-and-Connection-Pattern-Development-of-Horizontal-Cells) weekly. I plan to start with one-dimensional retina, which is still effective, with only rods, i.e. brightness photoreceptor, and add complexity based on the model, if necessary.

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3. Matthews T, Osorio D, Cavallaro A and Chittka L (2018). The Importance of Spatial Visual Scene Parameters in Predicting Optimal Cone Sensitivities in Routinely Trichromatic Frugivorous Old-World Primates. Front. Comput. Neurosci. 12:15. doi: 10.3389/fncom.2018.00015 [↑](#footnote-ref-2)
4. Sumner P And Mollon J (2000). Catarrhine Photopigments are Optimized for Detecting Targets Against a Foliage Background. J. Experimental Bio. 203, 1963–1986. [↑](#footnote-ref-3)
5. Xu J, Pokorny J, and Smith V (1997). Optical density of the human lens. J. Opt. Soc. Am. A. 14(5), 953-960. [↑](#footnote-ref-4)