ABSTRACTS

Hybrid Models of Turtle Retinal Ganglion Cells

Models of retinal ganglion cells have proven to be an important tool for understanding the initial steps in visual processing. Here we present hybrid-models of direction selective and non-direction selective turtle ganglion cells that consist of a cascade of filters, representing cells of the outer retina, and compartmental models that represent ganglion cells. The models transform a light intensity function into a stochastic spike train. These models are shown to capture general features of the biophysics and response properties of turtle retinal ganglion cells and can be assembled into an array to study information coding in populations of ganglion cells. (100 words)

Hybrid Models of Turtle Retinal Ganglion Cells

Turtle retinas contain several morphologically and physiologically distinct populations of ganglion cells. We constructed a two-part model that represents the behavior of the direction selective and non-direction selective retinal ganglion cells of freshwater turtles. The first part is a cascade of linear and non-linear filters that transform a light intensity function into a time varying conductance response. This cascade of filters is implemented in ***Matlab***. The resulting conductance is used as an input to the second part of the model, which is a biophysically realistic, single compartment model of a ganglion cell that is implemented in ***Genesis***. The output of the model is a spike train that will be used as a front end for a large-scale model of the turtle visual pathway.

Both the direction selective and non-direction selective models have a linear cascade of filters. The first filter transforms light to voltage, the second is a difference of Gaussians, the third is a temporal impulse response function, and the fourth transforms the voltage transient to a time-varying conductance. The first filter is a Naka-Rushton function that converts light intensity in photons/mm^2 to mV, and represents the phototransduction events of photoreceptors. It is based on results obtained by Baylor and Hodgkin (1973) who recorded the voltage changes in turtle red cones produced by light flashes. The second filter is a difference of Gaussians weighting function that represents the spatial structure of the ganglion cell's receptive field. Since this particular version of the model is representing an on-center ganglion cell, the filter has an excitatory center and an inhibitory surround. The receptive field has a diameter of 12 degrees of visual space and is based on the results of Granda and Fulbrook (1989) who recorded the response properties of turtle retinal ganglion cells using extracellular recording methods. The third filter is a temporal impulse response function that represents the cellular processes that are upstream to the ganglion cell. It is based on the electrophysiological results of Borg-Graham (2001), who recorded the conductance responses of turtle retinal ganglion cells using whole-cell patch recording methods. This function is convolved with the input to the filter to produce a time varying output function. Finally, the output is multiplied by an adaptive gain factor that represents the feedback control exerted by horizontal cells on photoreceptors and bipolar cells. This step ensures that the magnitude of the output conductance is in the correct range. The direction selective

model additionally has a cascade of two filters that run parallel to the other series of filters. The first calculates the local direction and speed of the moving stimulus using the gradient of the intensity input function. This calculation represents processes carried out by cells in the outer retina (Borg-Graham, 2001). The direction of movement is feed into the second filter, a weighting function that represents the directional selectivity of the ganglion cells. Following Rosenberg and Ariel (1990), this is a limaçon function. The particular values of the function are based on the results of Ammermüller et al. (1995). The resulting direction selective factor is multiplied with the output of the non-direction selective cascade of filters to produce a direction selective conductance.

The time dependent output conductance serves as the input to a single compartmental model of the ganglion cell. The model consists of a resistance, capacitance, fast sodium conductance, a delayed rectifier potassium conductance, a high voltage calcium conductance, an after hyperpolarization potassium conductance, and a leak conductance. The first two conductances generate action potentials in the model implemented by Hodgkin-Huxley equations and a noise source. The second two conductances produce spike rate adaptation in the model, consistent with the finding of several authors (e.g. Marchiafava, 1979; Baylor and Fettiplace, 1979; Borg-Graham, 1991). Biophysical parameters were based on values obtained by Borg-Graham (1991) in his recordings from turtle ganglion cells with patch clamp methods.

Our model of turtle retinal ganglion cells appears to adequately capture general features of the biophysics and response properties of turtle retinal ganglion cells. Like real cells, it shows spike rate adaptation following intracellular current injections. It also responds accurately to simple visual stimuli such as light flashes and moving spots of light.

References:

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