Neuronal model of decision making

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Overview

We have built a neuronal model of decision making based on sensory evidence, in area LIP of the brain. Our model performs a decision based on an imperfect discrimination between highly mixed stimuli, and expresses it with a saccadic eye movement. We use populations of Integrate-and-Fire neurons. Our model can be divided into three different parts. First we have the Global Direction Detectors. They are a very simple generalisation of the model we studied in earlier publications (Gaillard et al. Neurocomputing, 2005). The second part is a visual column in area LIP that uses the output of the Direction Detectors and receives global inputs from the brain and command an eye movement that expresses the decision. The generation of this eye movement is the third part of the model.

We use moving dots kinematograms as stimuli, and the model has to decide in which direction to move its eye, signifying if it thinks that the dots generally move downwards or upwards. This experimental set up has been extensively studied on living beings by Newsome and colleagues.

Direction Detectors

We restrict ourselves to the case of simple and well studied sensory evidence. Our moving dots kinematograms are composed of 100 dots. A percentage of them, called coherence, move coherently in one direction. The rest of them move randomly in any direction. We suppose that the early parts of the visual system evaluate the direction of each dot during successive short time steps and that each dot moving in a given direction triggers the activity of specific motion detectors. So the first detailed neurons of our model receive synaptic inputs that correspond to the directions of the dots. These neurons are detectors of the global direction of the dots in the kinematogram: They react strongly to a given general direction and weakly to its opposite direction.

Decision Making in the LIP Column

In order to take a decision that depends on imperfectly separated stimuli, we use a model that implements the principle of accumulation of evidence. More precisely, this accumulation of evidence is performed by a competition between groups of neurons that model a visual column in the Lateral IntraParietal area (area LIP) of the brain. In this column, we have groups of neurons that inhibit each other and recursively excite themselves, which generates the competition. In fact, this competition is not solely stimulus driven, but depends on the global neuronal activity of the brain. It is well known that neurons in the brain are highly influenced by this activity, called low-level background activity. So, besides the stimuli and the recurrent interactions, all the neurons of our model receive a low level excitation from the rest of the brain.

This structure has several stable states: one of them occurs when all activities are weak, and other ones when one local group of neurons has a higher activity and dominates the others through lateral inhibition.

The convergence to one of these stable states models decision making, guided by sensory evidence: The group of neurons sensitive to the specific stimulus has a comparative advantage on the others during the competition.

We propose a model in which the background activity does not only control if a decision is taken, but also controls the trade off between speed and accuracy: In urgent situations, we tend to take less accurate decisions. We use this structure to test our hypothesis that the statistical signature of the low level activity of the brain modifies the stability of the attractors of our model, and thus changes the dynamics of the competition that models decision making.

Decision Criterion: The Saccadic Eye Movement

The criterion by which we judge that a decision is taken is more realistic than just looking at the decisive neurons' activities. We model a saccadic eye movement directed by the activities of our LIP neurons, and we read the decision from the position of the eye. This experimental set up is comparable to biophysical experiments in which living beings express their decisions by saccadic eye movements.

Predictions

We study how the dynamics of the decision making change as a function of the first order statistics (mean) and second-order statistics (variance) of this global low-level background activity or noise. By studying its influence on Reaction Time and Error Rate, we show that this background activity may be used to control the dynamics of decision making. We provide a performance measure of such a model (Error Rate as a function of Reaction Time) that can be compared to the performance of living beings during psychophysical experiments.