A NEURAL NETWORK MODEL FOR FEATURE INTEGRATION AND ILLUSORY CONJUNCTIONS

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Abstract

An artificial neural network model for explaining the feature integration and the illusory conjunction was proposed. This model was implemented by the coupled oscillating neurons according to the synchronization hypothesis. Compared with other models proposed previously, the prominent features in this model are: (1) Visual cortex neurons have retinotopical maps which represent the visual input corresponding to its location. (2) It is through attention that the pulvinar neurons which are reciprocally connected with visual cortices facilitate and modulate feature integration. (3) Attentional shift emerges from these pulvinar neurons. Our numerical simulation demonstrated that the number of objects that were displayed simultaneously and the spacing among them determined the formation of illusory conjunction. Two properties of this network can explain this behavior. One is that the neurons in each feature map have coarse location information, and the other is that there are indirect connections (via pulvinar neurons) between the two corresponding locations in these feature maps. It is suggested that this model is compatible with the psychological theory of feature integration (Treisman[1988]).

Pulvinar is one of the areas which have strong retrospective and prospective connections from several visual areas. In pulvinar, there exist some parts which reflect rough retinotopical map. This parts emerged the modulations by the shift of visual attention (Petersen, Robinson, & Keys, 1985; Petersen, Robinson, & Morris,1987; Bender,1982). Therefore, pulvinar can be considered as a kind of the 'convergence zone' which was proposed by Damasio(1989). In this presentation, I propose the hypothesis that pulvinar neurons are considered as the 'master map' which was proposed by Treisman(1988), and are given a substantial role for the visual feature bindings.

Horn, Sagi, & Usher(1991) have already proposed a neural network model which explain the illusory conjunctions according to the synchronization hypothesis. In their model, each visual object was represented by adding time–correlated noises which originated externally. In their model, thus, there is no

ability in order to represent location information manifestly. In psychology, location information of objects would play an important role (eg., Nissen(1985); Bundesen, Shibuya, & Larsen(1985) partial report experiments). And physiological study shows that there are several subareas in V1 in order to process the differnt apsects of visual stimuli such as color, orientation, and so on.

The feature of this model are:

1. There are maps which correspond to each visual feature. In this area, there are retinotopical maps which represent the visual input corresponding to its location(Treisman,1988).

2. External signals preserve retinotopical locations of stimuli. This means that neurons are excited in some degree when the adjacent neurons receive external inputs.

3. Through the interactions among neurons, feature integrations are accomplished when non–linear oscillating units show phase lock oscillations (synchronization hypothesis). This is the same as the previous studies that the integrations among visual features were regarded as the phase lock oscillations.

4. 'Master map' in Treisman, 'convergence zone' in Damasio(1989), or pulvinar meditate the information in order to realize phase–locking oscillation. I assume that there is no direct connection among primal visual areas. This assumption corresponds to the basic framework of the feature integration theory (Treisman, 1988).

5. Competitive interactions (that is inhibitory connections) within this area cause a kind of shift of attention. By means of this attentional shift, it is expected that selection of input signals and information integration.

This neural network model can be regarded as another formulation of feature integration theory (Treisman & Gelade, 1980;Treisman, 1988) on the basis of synchronization hypothesis. From mathematical point of view, this is another expression of the feature integration in terms that the outputs of multiple non–linear dynamics system are retracted into limit cycles irrespective of arbitrary initial values.