An explanation of complex cell development by information separation

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Complex cells in the primary visual cortex exhibit approximate invariance to position within a limited range. Hubel and Wiesel (1962) assume that complex cells receive their major inputs from simple cells or simple-cell-like subunits selective for the same orientation in different positions[1]. Nagano & Kurata (1981) and Földiák (1991) explain the shift invariance property of complex cells by using a modified Hebbian learning in which the modification of the synaptic strength is proportional not to the pre- and post-synaptic activity, but to the presynaptic activity and a temporal average of the postsynaptic activity [2, 3].

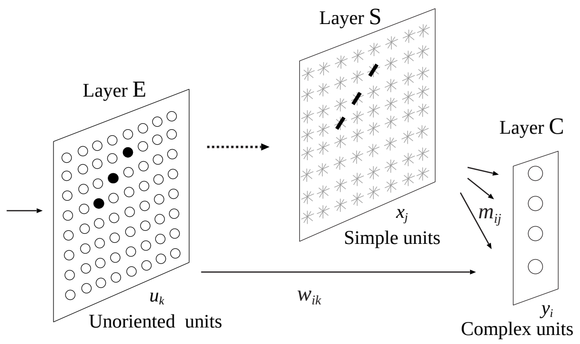

Figure 1. Architecture of our model. Units in the layer E have position selective. Our model is considered to be one in which layer E is added to the model of Földiák[3].

Although postsynaptic activity seems to be sustained for a period of time, there might be another mechanism by which the shift invariance property is obtained. Here, we propose a new computational model of complex cell development based on another possible mechanism. The model network(Fig.1) consists of three, E, S, and C, layers by which we model excitatory cells in LGN and/or V1, and simple cells, and complex cells in V1 respectively. Units in the layer E are assumed to be position-selective, and units in the layer S are line detectors for each specific location. During the learning phase, the network is exposed to randomly located short oriented bars, and units in the layer C develop its selectivity. The units in the layer C receive and learn inputs from the layer S through Hebbian or SOM (Self-organizing Map[4]) type connections, while anti-Hebbian connections from the layer E to C are assumed to force the layer C to represent aspect of the inputs uncorrelated to that represented on the layer E. We demonstrate that units in the layer C learns invariance to shift in input position.

Complex cell development might be explained in terms of information separation. The input signal to complex units carries essentially three-dimensional information, that is the location(two-dimensional) and the orientation(one-dimensional) of the bar. In our model, the “E” units are position-selective, and the “S” units are both position- and orientation-selective. When an “E” unit and a “C” unit are activated simultaneously, anti-Hebbian connections between them becomes more inhibitory to discourage the simultaneous activation of these two units in the future, and their correlation is decreased.

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References

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