Behavioral and Brain Sciences 20(4):702–703, 1997

Context dependent feature groups, a proposal for object representation

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Abstract The usefulness of contextually guided processors is investigated a little further. A more general use for binding V1 cell responses than the one in the target article is proposed, which takes into account that strong responses of these cells can mean more than the presence of lines and edges. The possibility for different grouping depending on the activities of neighboring cells is essential for the approach.

The target article is good news for a computational modeler for several reasons. Firstly, it is rare luck to have a computational concept which is approved by a psychologist and a neurobiologist. Secondly, this concept is presented at a level of abstraction and simplicity which is not usually adopted by biologists while being a crucial prerequisite for reasonable computational models. Such a paradigm can spare (for the moment being) the complicated (and computationally expensive) simulation of the nitty gritty of synchronization. Instead, the proposed processors can be used to show that relatively simple networks can do something useful.

Now, why should new cortical processors be necessary at all? After all, it is clear that the brain consists of neurons, and computational models of neurons abound on all levels. Still, from an esthetic point of view, the system properties observed in the brain should arise "naturally" from the properties of the simple processing elements used. Most prominent among these system properties is invariant recognition in the various sensory modalities. Although much research has been done, there seems to be no convincing way to get this property from conventional neural networks.

Multiplicative synapses (see the exponent of the transfer function, first paragraph in section 3.1), have been popular in computational neuroscience for a long time. What is interesting in this paper is that multiplication occurs only between the CF and RF inputs. The proposed processors are ideal for invariant recognition by dynamic routing (Olshausen et al., 1993; Olshausen et al., 1995). In these articles, contextual guidance is used to test hypotheses on translation and scale of simple objects, with special cells being responsible for the mapping between input and stored model. A drawback of these models is that they operate only on very simple images with good contrast and few ambiguities. The RF properties of V1 cells are not part of these models.

Let me propose a model that creates robust object descriptions from the responses of simple and orientation-selective complex cells. An important property is that these responses must mean different things depending on the response distribution of neighboring cells. Concretely, they can stand for the presence of line elements, texture elements, or local pieces of structure.

In the first case, cells sharing the same RF center and orientation but of different RF size must be grouped. These groups code for the presence of a line/edge element and, as the authors mention, they in turn must group with neighboring groups of the same or slightly different orientation.

In the other cases, all cells sharing the same center must be grouped to code for a local texture or structure element (Lades et al., 1993; Würtz, 1995; Würtz, 1997). If those groups mean a texture element, they should group with neighboring ones that have the same activity distribution to yield areas of constant texture. For structure elements, top down information about the local structure of known objects must be used in order to bind the right elements together to an object description. Such a description usually also contains boundary lines, i.e. groups of the first type in a suitable spatial arrangement.

Such an approach at object description can be more robust, because constraints like the need for a *closed* boundary can be relaxed. An object can be also be described by an imperfectly closed boundary together with constant texture or known structure.

Now, what is required for this? Firstly, a possibility to group V1 cells without destroying their filtering properties, which is clearly provided by the authors of the target article. Secondly, the process must be cascadable, i.e. groups of groups must be possible. This is a bit more problematic, because the number of *different* synchronized groups at a time is very limited. For the system proposed here, this is not a serious problem, because the processors keep their RF properties intact, so the relevant cells for a whole object may be synchronized into one group without confusion. For implementing, e.g., a graph structure like the one used in (Lades et al., 1993) this problem would constitute a serious limitation.

If such object descriptions develop in a self-organized way on the input image it should be relatively easy to match them with stored models of objects, although the integration of flexible matching and associative memory remains an open problem. Anyway, the target article opens a couple of interesting new routes of investigation.

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