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Introduction

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Teuvo Kohonen

Self-organized formation of topologically correct feature maps
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The brain is organized in many places so that aspects of the sensory environment are represented in the form of two-dimensional maps. For example, in the visual system, there are several topographic mappings of visual space onto the surface of the visual cortex. There are organized mappings of the body surface onto the cortex in both motor (the motor homunculus) and somatosensory areas, and tonotopic mappings of frequency in the auditory cortex. The use of topographic representations, where some important aspect of a sensory modality is related to the physical locations of the cells on a surface, is so common that it obviously serves an important information processing function. (For a review, see Knudsen, du Lac, and Esterly, 1987.)

Kohonen is attempting to construct an artificial system that can show the same behavior. This is not quite the same as developing selective cells in response to particular input patterns. It is a related question: developing topographically organized systems. Clearly, there is development of cell selectivity in such a system as well, since cells develop maximum responsiveness to particular values of a parameter. But the emphasis here is on the global organization.

The fundamental fact that must hold true for a topographically organized system is that nearby units respond similarly. The essential mechanism of the Kohonen scheme is to cause the system to modify itself so this occurs. The way it is done is straightforward. Units start off by responding randomly to the parameter of interest—frequency, spatial location, whatever. An input signal, with some value of the parameter, is provided. One unit responds *best* to that input. This unit is located. The neighbors of this unit, defined to be some region around it, and the unit itself have their synaptic weights changed, so they also now respond more like the best unit than they did before. The synapses are subject to normalization of some form, so that the sum of the weights is roughly constant; increasing one strength diminishes the others on that unit. These simple assumptions seem adequate to do the topographic ordering: neighborhoods become similar in their response properties, and global order follows from the smooth gradation of one neighborhood into the next. Computer simulations show that the organization is fast and reliable. It is possible to prove directly in a few simple cases that the systems will organize properly. Kohonen describes this model in more detail in a recent book (Kohonen, 1984).

Kohonen suggests several biological mechanisms that could give rise to such a system. He suggests that it is possible to form the clusters by assuming a system where nearby cells excite each other, with inhibition for longer distances—very similar to the kind of center-surround organization seen in a number of brain regions. Excitatory interactions among nearby cells tend to form compact regions that are highly excited.

Such regions, coupled with a simple modification of the Hebb learning rule, could implement the system.

Kohonen describes a number of simulations of various forms of the model. The conclusion is that the self-organizing effects seem to be relatively insensitive to parameters. Often the size of the excitatory region is changed during learning, starting out quite large and shrinking as organization proceeds.

This paper is interesting for a number of reasons. It suggests that topographic self-organization can be done by several rather simple mechanisms. There is no doubt that this kind of organization is useful for representing information in a real nervous system, because it is so frequently found in the brain. Using Kohonen's technique, it is possible to have artificial systems topographically self-organize in useful and effective ways. Kohonen has used it to make a speech recognition device that can recognize a large vocabulary of isolated words. It works by forming an organized map of the acoustic cues of phonemes on a surface, and then recognizes words by using their trajectories across the phoneme space (Kohonen, 1987).

References

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