Decoding Spikes without Stimulus Information: Its Implications on Receptive-Field Learning

Yoonsuck Choe and Huei-Fang Yang

Department of Computer Science, Texas A&M University, College Station, TX

It is well established in the literature that visual cortical receptive fields have an oriented Gabor shape. However, why the visual cortex adopted such a representation is a matter of debate. For example, there are theories based on sparse representations, independent component analysis, information maximization, efficient encoding, etc. that show the kind of computational principles that may underlie the formation of the visual receptive fields.

One question that is not often asked is, how can the output from the visual cortical neurons be interpreted in subsequent stages in the brain? This question is nontrivial because the subsequent stages only receive the signal in the form of action potentials, with no direct information from the external visual environment: The subsequent stages are only looking at an encoded version of the visual signal (i.e., reverse correlation is not possible). In certain cases, such as in the hippocampus, topological properties in the stimulus space can be recovered by considering the spikes alone [1], however, for the visual cortex, such an approach may not be applicable since geometric properties (e.g., orientation) need to be recovered. In previous work, we showed that this problem can be overcome if we allow the subsequent stages to (1) generate motor outputs that can cause changes in the incoming (encoded) information and to (2) observe their lawful relationship [2][3]. In this view, the particular motor primitives (stereotypical motor patterns) available to an animal become important, since the understanding (or decoding) of the encoded sensory message depends on these motor primitives. If this is the case, it becomes necessary to reevaluate the theories of receptive field formation mentioned above, to incorporate considerations for the decoding aspect, especially the motor aspect (cf. [4]).

Here, we present a computational model based on a simple Hebbian learning rule, combined with standard reinforcement learning. The combined learning rule enables the discovery of the linkage between sensory receptive fields (encoding) and the motor primitives that have similar properties (decoding), while the receptive fields are forming, concurrently. The results show that principles of receptive field formation should account for the role of motor primitives in decoding.

References


