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Fast visual responses: Is counting spikes enough?

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In visual processing, the cortex very quickly arrives at a hypothesis about the stimulus [1]. Thorpe et al. suggested, that this hypothesis is generated in a feed-forward network, where each feature-selective cell evaluates the order (rank) of incoming spikes [2]. However, to evaluate a rank code, every feature-selective neuron needs a local readout circuit. This is both biologically implausible and expensive to implement.

We propose, that post-synaptic neurons simply count the number of incoming spikes, and fire if the number of incoming spikes exceeds a threshold. This simple scheme for feature-selectivity uses spike-times only implicitly and does not require additional circuitry. We evaluate the quality of responses gained from a cascade of these labeled-line-encoders, given the tuning characteristics of primary receptors, and unreliable processing in the succeeding neurons.

To allow a quantitative analysis, we use a fully controlled visual environment, with parametric visual stimuli (colored blobs), and well-defined tuning of primary receptors. For the feature detectors, we apply a simple spike-counting neuron model with a binary output state (spike, no spike). The neuron signals an output spike with probability p_1, if the number of input spikes exceeds a threshold, and with probability p_0, otherwise. In cascades of labeled-line-encoders with N steps and L incoming lines per neuron, we evaluate the probability of correct responses to stimuli in the final step of the cascade, as a function of (p_0, p_1, N, L). We present results from computer simulations and mathematical analysis.

This architecture is part of a functional model of the sensory cortex [3,4]. To incorporate high-level knowledge into processing at lower levels, it applies a form of cognitive bootstrapping, where an initial top-level hypothesis about the stimulus is used to steer processing in the lower areas. Unlike other approaches using similar architecture, spatial invariance and low error rates are not in the focus for hypothesis generation. Instead, top-level responses must be fast and reasonably correct, to be suited for cognitive bootstrapping in our cortex model.

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