Emergence of a Cortical Perceptual Code by Combination of Recurrently Interacting Gaussian Subunits

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Cortical receptive fields (RFs) can be considered the means by which the brain comes up with a perceptual code to be used for an efficient description of visual information. From an architectural point of view, cortical RFs are the resultant of a collective behavior of neighboring cells, and reflect the overall coupling effect and not only the direct neuroanatomical connectivity. Thus, functionally, at each level along the visual pathway, we can single out components (i.e., perceptual primitives) due only to feed-forward connections; the properties not found in the components of a given level can emerge, by their organization and their interaction, in the components of the subsequent one. According to these principles, we have developed a continuous space-time model of primary visual cortex. This model relies upon the superposition of functional projections from LGN, modeled by convolution operators with Gaussian functions, and intracortical interactions, modeled by linear integro-differential equations. Intracortical interactions are characterized by specifying their spatial organization (e.g., anisotropic clusters localized in space), and the different latencies of synaptic transmission of excitatory and inhibitory contributions. The resultant RFs, interpreted as the retinotopic mapping of the spatial distributions of the activity on the cortical plane, account for a variety of properties, both stationary (e.g., the refining of the orientation and the spatial frequency tuning) and spatio-temporal. Specifically, lagged inhibitory and non-lagged excitatory combinations of the outputs of clustered intracortical inhibition on Gaussian subunits are responsible for direction selectivity, and the emergence of velocity-tuned Gabor-like receptive field profiles.

Key words: Neural modeling, cortical receptive fields, Gabor filters, motion detection.