Laminar Neural Field Model of Spatially Structured Patterns of Orientation Selectivity

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In this study we propose a laminar neural field model to study the spatiotemporal dynamics of orientation selective populations of neurons in V1. Previous neural field models have considered a single network that describes the dynamics of orientation selective cells in superficial layers 2/3 of V1 and have had great success in describing a range of phenomenon such as geometric visual hallucination patterns, [1]. Recent experimental findings have suggested that the superficial layer and deep layer 5/6 work in tandem to determine the patterns of cortical activity observed in vivo. In particular when the deep layer's activity is suppressed, then propagation of activity does not occur in the superficial layer, however propagation of activity in the deep layer persists when suppressing the superficial layer, [2]. This suggests that the feedforward connections from the deep to superficial layer play a major role in the spatially structured activity of orientation selective cells.

In light of these findings, we have constructed a bilayer model consisting of the deep and superficial layers. The deep layer is taken to be independent of orientation and is described by the classical Wilson-Cowan model. The superficial layer is given a continuum hyper column structure representative of the Hubel-Wiesel view of orientation selective cells, and receives feedforward input from the deep layer. We decompose the recurrent connections into local connections within a hyper column and weak long range horizontal connections between hypercolumns linking only cells with similar orientation preferences.

We first study 2D stationary solutions and use perturbative methods to derive an equation describing the phase of orientation bumps. We find that our phase equation is identical in form to those describing the dynamics for the phase of a continuum of coupled neural oscillators. More importantly, the phase equation allows us to explore a wider range of stationary solutions that would be very difficult to find in the original neural field equations. We then describe how our model supports traveling wave solutions that link an orientation bump state to an orientation independent state.

References

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