Spiking Neural Fields and Applications to Image Processing

Li Yang, NeuroMathComp Team at Inria, li.yang@inria.fr

Why could we perceive a river or a road from a GPS satellite map? How is the identification achieved between a subgroup of stimuli and the perceived objects? These classic questions can be addressed from various perspectives of views, physiological, biological and mathematical.

Many physiological studies [5, 7] suggest the evidence of grouping in visual cortex and the visual grouping has been studied in various mathematical frameworks including graph-based methods [6], probabilistic approaches [4] and variational formulations [8]. Biologists have proven that in the brain, at a finer level of functional detail, the distributed synchronisation occurs at different scales [10, 3]. Inspired by this biology theory Wang and Terman [11] performed very innovative work using neural oscillators for image segmentation and extended their work to auditory segregation [12]. Recently, adopting the similar ideas, Slotine and Yu [15] proposed a simple network of neural oscillators coupled with diffusive connections to solve visual grouping problems.

Similarly inspired by the neural synchronisation mechanisms we consider the visual grouping problems with the aid of spiking neural fields. Neural fields proposed in [1, 13, 14] model the large-scale dynamics of spatially structured biological neural networks in terms of nonlinear integro-differential equations whose associated integral kernels represent the spatial distribution of neuronal synaptic connections. Among the neural fields models spiking neural fields [2] is a continuum neural field equation starting from a voltage-based model of a network of synaptically coupled spiking neurons.

Recently spiking neural fields theory is a growing and very active area of research with important applications in engineering and technology. This paper is to consider a general spiking neural fields model whose connections between neurons depends on the neurogeometry of the cortex and the external input. In order to implement this model for visual grouping problems the main idea is to build a one-to-one mapping between the neurogeometry and the geometry of the image pixels as well as one between the external input and the quantities of pixels (i.e., intensity and angle). In this paper we apply such idea for the image processing applications, i.e., image segmentation and contour integration and achieve successful simulation results. Furthermore, based on the mathematical theory of $p-$cluster synchronisation [9] a sufficient condition on a parameter of spiking neural fields is proposed for the successful visual grouping implementations. We also compare our results with Slotine [15] and Wang [11] for image segmentation and find that our achieved results are similar to the ones by Slotine [15] and better than Wang [11]. However, both methods by Slotine and Wang do not provide a specific and clear condition for the successful implementations.

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