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Neural field model of rat's cortex based on realistic connectivity from diffusion weighted MRI and neural morphology

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Generative models of neural circuits may help to create a link between neural mechanisms and observable data. We propose a model of rat's cortex using a neural field model containing biologically plausible anatomical connections from tractography based on dwMRI data and from the neural morphological database NeuroMorpho [1].

There are three principal types of anatomical connections in the cortex: Local, long-range and distal connections [2].

For specifying local connections we use neural morphologies from [1]. We consider each voxel in the model as a neural mass and distribute randomly drawn neurons from the database therein. After that we use bootstrap methods to determine the total number and variability of synaptic contacts. For the distal connectivity we estimated the degree of anatomical connectedness using white matter tractography on the basis of diffusion weighted MRI [3].

Our neural field consists of 5 layers. For each layer we assume three different neural masses: pyramidal cells, excitatory and inhibitory interneurons [4]. The mutual interactions between neural masses will be described by a system of integral differential equations: $\left(\frac{\partial}{\partial t}+\frac{1}{\tau}\right)^2 V(r,t)=HT\int W(r,\tilde{r})S\left(V\left(r,t-t^{(d)}(r,\tilde{r})\right)\right)d\tilde{r}+(r,t)$ where **V** is the state vector (mean membrane potentials), **T** the time delays in the dendritic arbors, **S** the sigmoidal output

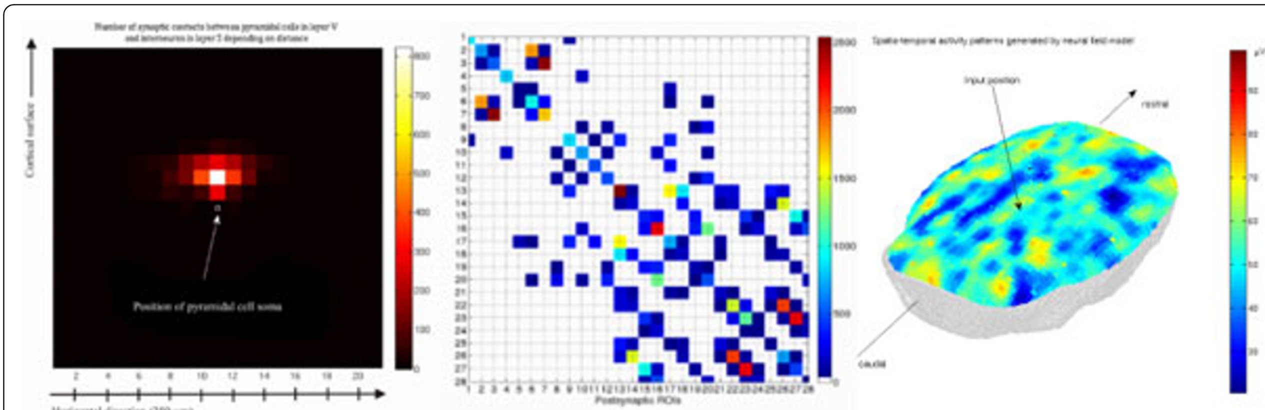

Figure 1 (A) Local connectivity profile between a pyramidal cell in layer V and an interneuron in layer III (grid size 250 µm). (B) Distal connectivity map estimated from dwMRI between 28 regions. (C) Spatio-temporal activity pattern 100 ms after the onset of a constant input to the pyramidal cells of layer 5 of the somatosensory cortex, as simulated by the neural field model.

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function, **W** the connection coefficients between the neural elements, **I** the input, and $t^{(d)}$ is the distance dependent time delays. Figure 1A shows the estimated spatial dependency of local connectivity, which is in accordance with anatomical observations [2]. The distal connectivity map of 28 regions is displayed in Fig. 1B. An example map of simulated activity on the cortex in response to a stimulus to somatosensory cortex is illustrated in Fig. 1C.

To summarize, we developed a method for estimating the local connectivity and constructed a neural field model of the entire cortex enriched by estimated local and distal connectivities. With this model we are able to simulate spatio-temporal activity patterns. This is a first step for a comprehensive dynamic brain model and thereby for understanding complex brain processes.

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