

Open-source numerical simulation tool for two-dimensional neural fields involving finite axonal transmission speed

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The *Neural Field Simulator* integrates numerically integral-differential equations of the type

$$\left(\eta \frac{\partial^2}{\partial t^2} + \gamma \frac{\partial}{\partial t} + 1 \right) V(x, t) = I(x, t) + \int_{\Omega} d^2y K(\|x - y\|) S \left[V \left(y, t - \frac{\|x - y\|}{c} \right) \right] \quad (1)$$

with the mean neuron potential $V(x, t)$ at location $x \in \Omega$ in a two-dimensional quadratic spatial domain Ω with a periodic boundary condition. The term $I(x, t)$ denotes the external stimulus I , $K(x)$ is the synaptic connectivity kernel K and $S(V)$ is the firing rate. The finite axonal transmission speed c induces space-dependent delays.

Conventional implementations of two-dimensional integration with space-dependent delays are rather slow due to the missing convolution in the integral. It has been shown in a previous work [1], that this unfortunate property can be overcome by introducing a spatio-temporal kernel, rendering the integral into a spatial integral and an integral over delays.

Three major aspects accelerate the integration speed: (a) the underlying numerical method is expedited with a fast Fourier transform in space (b) the simulator writes and executes its own code based on interface selections to efficiently calculate and display only the user-defined features (c) the displayed matrix is put onto the running system’s graphics processing unit for hardware acceleration of the visualization.

The simulator gives the user full control of the variables by permitting free choice of all variables through a text-based interface. Two dimensional field matrices V , I and K can be displayed in rich detail in a three-dimensional plot as shown in Figure 1. The visualization of field data is easily modified by a keypress, performing functions such as moving, rotating, zooming and changing colors and axis limits. Images and videos can be saved and simulations can be paused and resumed using the keyboard. The software is open-source and written in Python [2].

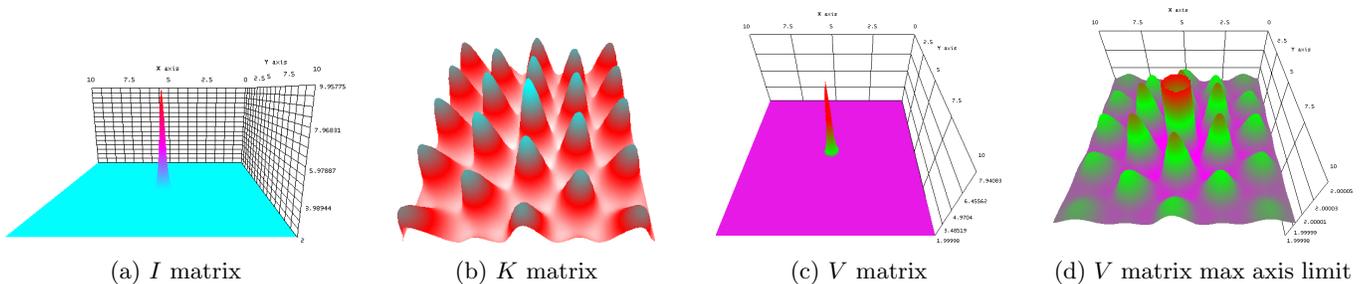


Figure 1: The simulator visualizing the input I (a), the synaptic connectivity kernel K (b) and the mean neuron potential V (c). In (d), the maximum axis value of V is set to an upper limit for visualization reasons.

References

[1] A. Hutt, N. Rougier. Activity spread and breathers induced by finite transmission speeds in two-dimensional neural fields, *Physical Review E* 82 (5):055701 (2010).
 [2] <https://gforge.inria.fr/projects/nfsimulator/>