Two-dimensional neural field simulator with parameter interface and 3D visualization

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Overview

A simulator[1] calculating two-dimensional dynamic neural fields with multiple order derivatives is presented in this work. The simulated neural fields are of the type

$$\left(\eta\frac{\delta^2}{\delta t^2}+\gamma\frac{\delta}{\delta t}+1\right)V(x,t)=I(x,t)+\int d^2y\,L(\|x-y\|)\,S\left[V\left(y,t-\frac{\|x-y\|}{c}\right)\right]$$

where I, L and S are respectively a field's input, spatial delay kernel with axonal transmission speed c and nonlinear firing rate function $S = S_0 / (1 + \exp(-\alpha(V-\Theta)))$. A Fast Fourier Transform in space is used to accelerate the integral calculation. The stochastic differential equation is useful for studying processes such as breathers, activity spread and Turing patterns shown below.

The underlying code is written in Python and is therefore cross-platform. It is also open-source, allowing researchers to modify the simulator in any manner.

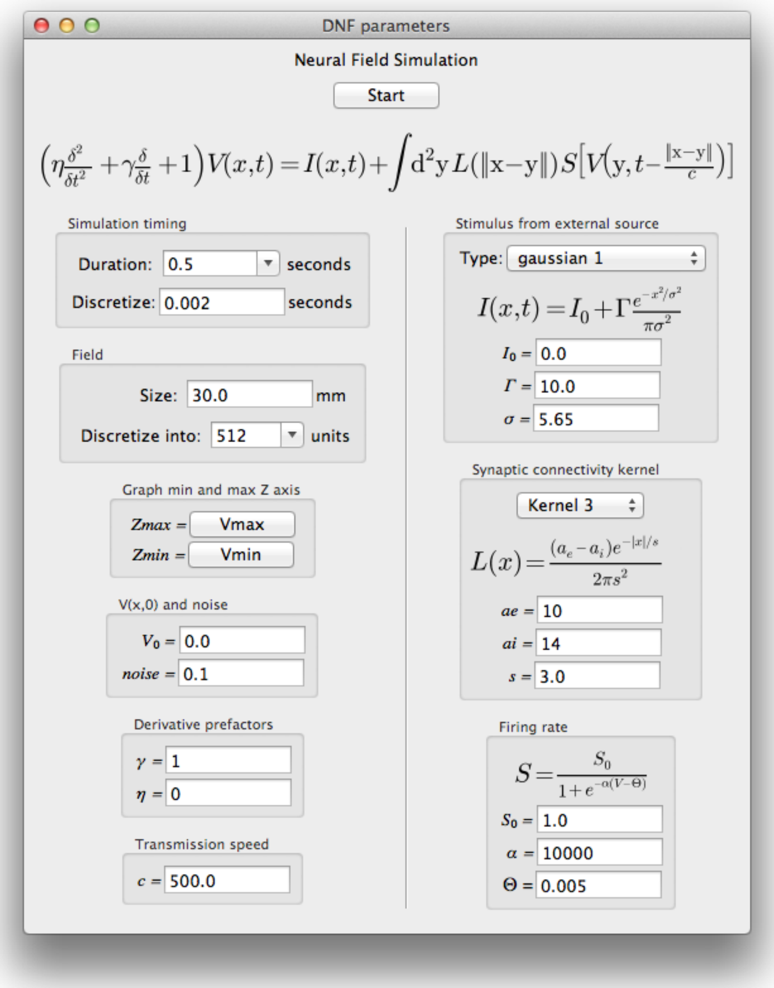
Interface

→ The simulator consists of a graphical interface (right) to facilitate modification of parameters before and during simulations that include:
- timing of simulation and discretization of the time *td*,
- field size and discretization of the field space,
- starting voltage *V* and noise,
- *V* values (minimum → maximum) displayed on the graph,
- derivative reducing prefactors,
- transmission speed,
- stimuli from external source,
- a selection of three spatial connectivity kernels and
- firing rate settings.

→ The interface is used to start, pause, continue and restart new simulations.

→ Moving the mouse over the stimulus from external source, kernel and firing rate areas of the interface pauses the simulation and displays the relative values in the visualization window, allowing adjustments of these equations' parameters to be viewed.

→ The selected values in this window are saved for quick subsequent parameter modification and simulation.

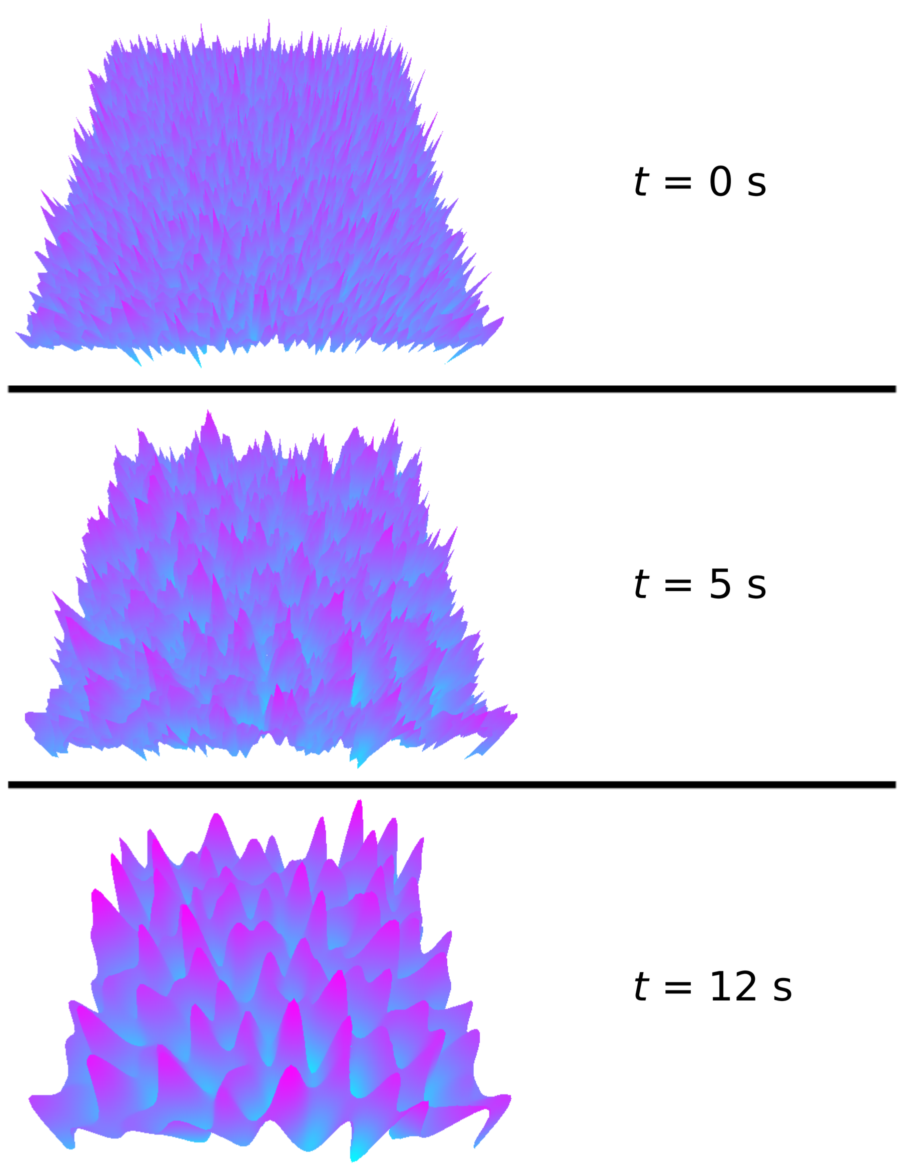


Output Visualization

→ The show3d library was created for the neural field simulator to visualize the output of simulations in three dimensions. It is built upon the Python binding to OpenGL for speed. The library is embedded within the simulator and can also be downloaded separately[1] along with documentation to view any 2D matrices in three dimensions using the Python language.

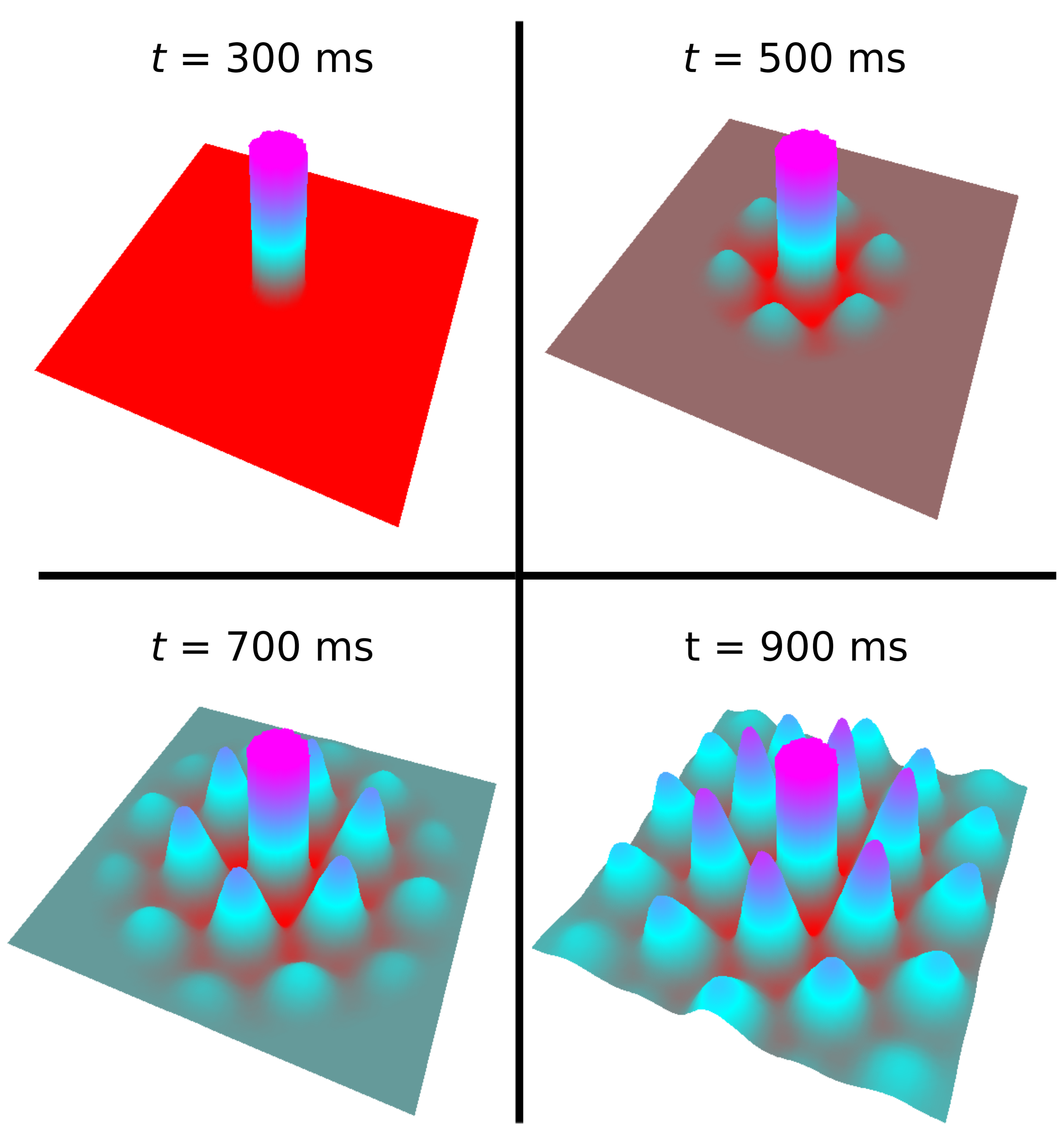
→ The simulator output allows the researcher to...
- move the field in every direction,
- spin the field in every direction,
- zoom the field in and out,
- change the background colors,
- change the graph colors to interpolate between 2 or 3 colors with selections of 8 colors,
- adjust the color ranges to higher or lower values to highlight different depths,
- save an image or make a video of the animated field for later review and
- modify the interval of axis values.

Turing Pattern



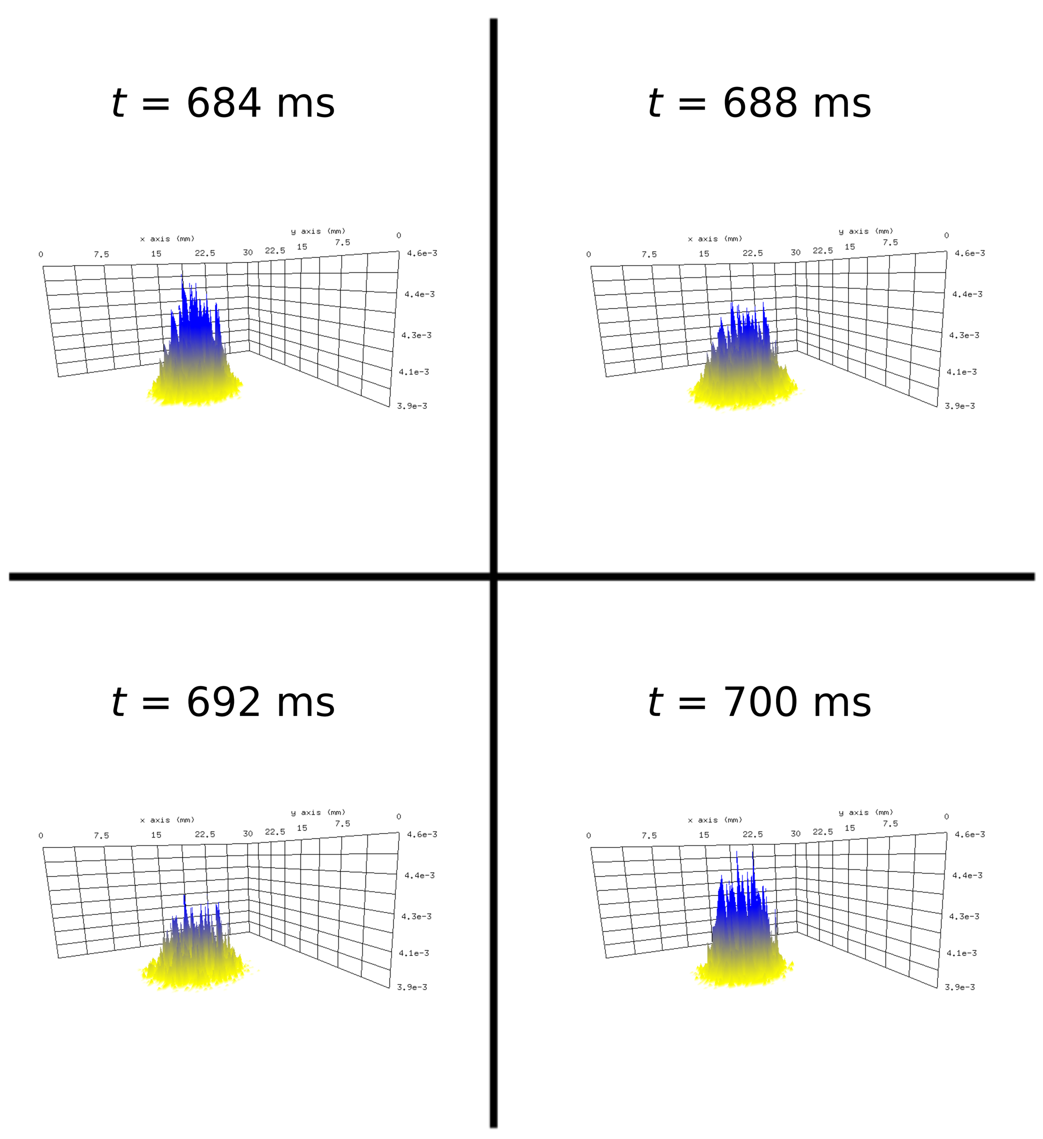
A Turing pattern appears in a noisy 90mm^2 field discretized into 512 units with V_0=5.4, *noise*=0.1, *td*=0.01, γ=1, η=0, *c*=1000, *I*=0, S0=2, α=1.24, Θ=3, $L=((20.7 - 18(0.7^2))\exp(-|x|/0.7))/2\pi$. The graph's parameters are Zmax=*Vmax* and Zmin=*Vmin*. The pattern begins to emerge from the noise at 5 seconds (s) and *V* is stable at 12 seconds.

Activity Spread



Spatio-temporal activity spread. The graph's parameters are Zmin=*Vmin* and Zmax=2.03, cutting off *Vmax*≈6.05. The field is 10mm^2, discretized into 256 units, V_0=2, *noise*=0, *td*=0.004, γ=1, η=0.35, *c*=10, S0=2, α=5.5, Θ=3, $I=2+(\exp(-x^2/0.2^2)/\pi 0.2^2)$ and $L=0.1\Sigma_{i=0}^{2}\cos(k_i, x)\exp(-|x|/10)$).

Breather



A Breather is shown in a 30mm^2 field discretized into 512 units with V_0=0, *noise*=0.1, *td*=0.002, γ=1, η=0, *c*=500, $L=(10 - 14)\exp(-|x|/3)/2\pi 3^2$, $I=10(\exp(-x^2/5.657^2)/\pi 5.657^2)$, S_0=1, α=10000 and Θ=0.005. The graph's parameters are Zmax=0.0046 and Zmin=0.0039.

Acknowledgments

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References

[1] https://gforge.inria.fr/projects/nfsimulator/