Simulating anticipatory activity in a 1D Spiking Neural Network Model

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Network model

The network model is a 1D segment of 1000 neurons representing 21 mm of cortical space. Each neuron is modelled as a leaky integrate-and-fire point neuron with fixed threshold and exponentially-decaying post-synaptic conductance. Neurons are connected on the ring by lateral projections which follow a Gaussian spatial probability of connection $p_{ij} \propto \exp -\frac{1}{2} \cdot l_{ij}^2 \sigma^2$, having excitatory spatial spreads equal to 5 mm and inhibitory equal to 2.5 mm. While using a ratio E/I set to 4, parameter optimization found a functional balance with excitatory synaptic weights set to 0.9 nS and inhibitory synapses weights set to 55 nS (with std = 10).
In contrast to previous models, we also tuned the synaptic delay between pairs of excitatory and inhibitory neurons. Assuming a constant conduction velocity of lateral connections, the synaptic delay is proportional to distance $d_{ij} = \frac{l_{ij}}{v_c}$, where $v_c = 0.021\ \mathrm{m\,s^{-1}}$.

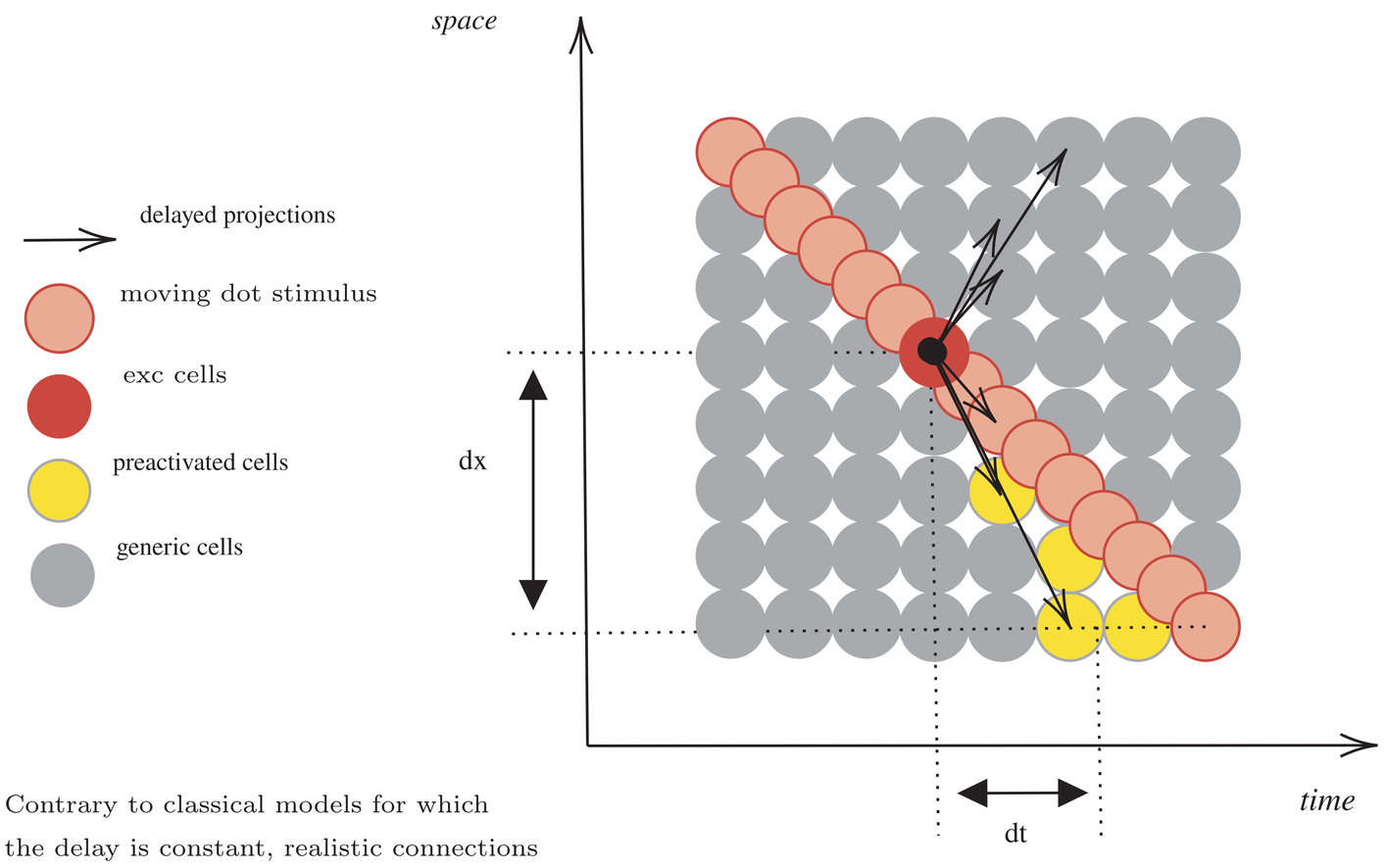
Inputs and simulation info

The thalamic inputs are spike sources which simulate the response to a moving dot stimulus. This stimulus is presented according to three different trajectories (short: 250 ms, medium: 500ms, long: 750ms) or a flash at 500 ms. A 5 Hz Poisson noise is finally added to the stimulus. The dot is of size 0.1% relative to the line. We tested also a second input, called pulse, that tested the network with a central dot stimulus presented at 500 ms. All simulations have been performed using NEST simulator [3] and PyNN modelling language [2] with a 1 ms time-step.

Main results

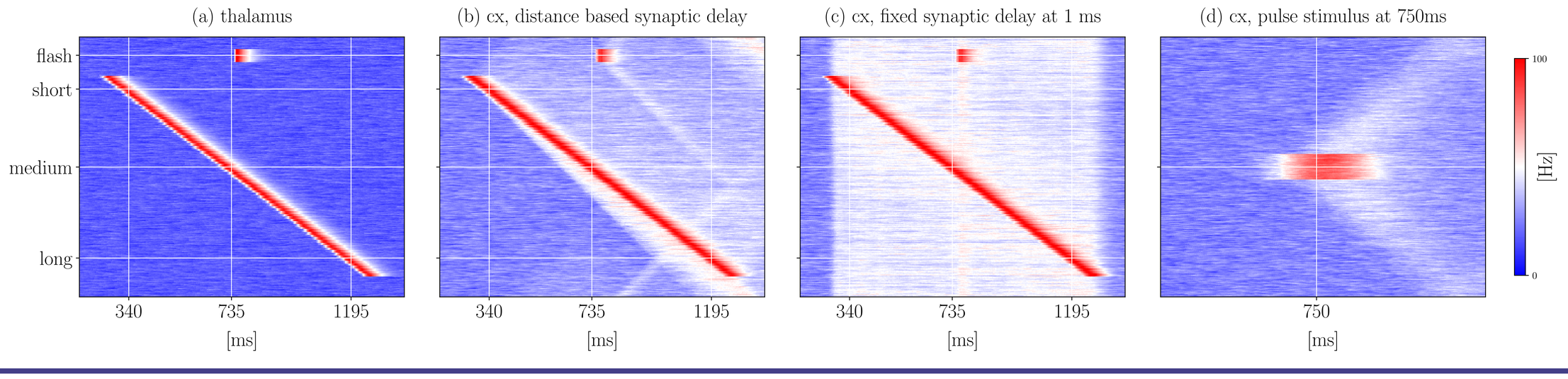
By tuning synaptic delay in a general model of V1 cortex, we found an incremental pre-activation of the topographic map arising in relation to medium and long moving dot trajectories, while cells fire without anticipation across the short trajectory and in relation to control conditions (fixed delay and flash). This results replicates the experimental evidences recently found in monkeys [1]. Moreover, the model reproduced the computational evidences about a propagating wave as population response from a pulse stimulation [4].

Effect of distance-dependant delay on synapses

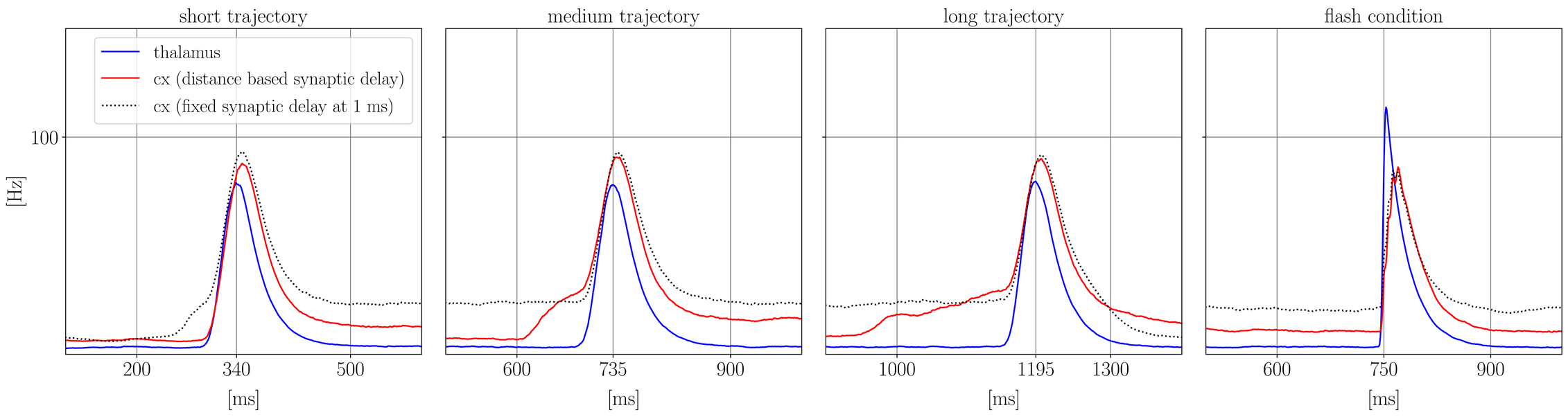


Contrary to classical models for which the delay is constant, realistic connections exhibit a distance-dependent delay.

Moving dot paradigm in thalamus (a) and cortex (b, c) and pulse stimulation (d)



Anticipation as incremental pre-activation across medium and long trajectories



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References

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