Reliable recall of spontaneous activity patterns in chaotic cortical networks
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Introduction

Biological neuronal networks spontaneously generate irregular activity patterns whose structure and significance are still a matter of debate. In attempting to mimic such dynamical behaviour, recent models of spiking neurons have been able to produce an asynchronous, irregular, self-sustained activity without any stochastic input [Vogels and Abbott, 2005].

However, the propagation of external stimulation within those networks is still a challenge since stimulus-evoked activity is corrupted by the chaotic background, triggering a response that is neither reliable nor predictable. Here we hypothesize that reproducible dynamics and responses in a generic recurrent cortical-like network can be obtained if the imposed external drive reproduces the self-sustained activity.

The Frozen Paradigm

Illustration of the Frozen Paradigm. A variable fraction of a neuronal network (the "clamped" neurons) is forced to replay a part of the spontaneous activity, and we measure the extent to which this frozen population drives the rest of the network ("free-running" neurons) to the "target" activity, i.e. the completion of the spontaneous pattern.

Example in a real network

We can observe a reliable convergence to the target activity which is insensitive to initial conditions, for half of the network frozen.

The reliability is enhanced by the activity of the recurrent connections.

Material & Methods

• Integrate and Fire model

  - Neuron model: Neurons are composed of 10000 leaky integrate-and-fire neurons with membrane time constant $\tau_m = 20ms$, and resting membrane potential $V_{rest} = -70mV$. When the membrane potential $V$ reaches the spiking threshold $V_{th} = -50mV$, a spike is generated and the membrane potential is clamped to the resting potential during a refractory period of duration $\tau_{ref} = 5ms$.

  - Synaptic connections: The synaptic connections between neurons are modelled as an absence of conductance, resulting in a model similar to the CUBA and COBRA models of [Vogels 2005].

  - Equation of activity:

    \[ \frac{dv}{dt} = -\frac{v}{\tau_m} + g_{syn}(v(t)) + g_{ext}(v(t)) \]

  - For a Poissonian input:

    \[ g_{ext}(v(t)) = \sum_{i=1}^{10000} g_{syn}(v(t)) \]

• Experimental results

  - Intracellular responses (spikes and $V_m$) of a simple V1 cell of an anesthetized and paralyzed cat to two movies, repeated 10 times: a natural image animated with simulated eye movements, and an optimal drifting grating [Baudot et al, SfN abstract, 2005].

  - The reliability of the cortical responses seems to be stimulus dependent.

Conclusions and further works

• Considering neuronal network dynamics as a high-dimensional attractor, here the stimulation makes the system converge to a particular predefined orbit, instead of switching into another low-dimensional attractor.

  - Reliability in a recurrent network with irregular activity is stimulus dependent, increasing for inputs with ongoing activity statistics.

  - Implement this paradigm on more structured networks, including topological structures, to stretch differences between spontaneous activity, structured, and surrogate inputs.