A method for the estimation of distal dendro-dendritic gap-junctional parameters

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Background

Neurons are specialised cells which form the fundamental computing unit of the brain and the central nervous system. Each neuron consist of a cell body, dendrites and an axon, where the dendrites receive pulses of voltage from other neurons axons, which act like an output.

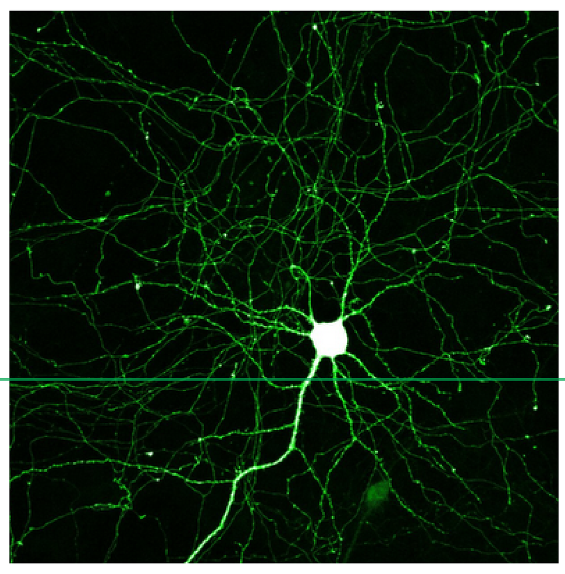


Figure 1: A neuron with an action potential going down the axon

Through voltage, the neurons may communicate to each other and this is what gives rise to the cognitive processes in any animal. When enough voltage enter a neuron, it spikes and send signals at a constant rate to all neurons connected to it, a so called action potential.

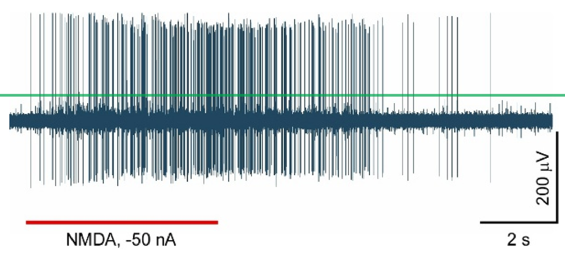


Figure 2: Recording of membrane potential of a neuron

On the level of a small scale network, or a single neuron, knowing the input/output relation when the cell membrane is subjected to an electrical current or spike lets us know a lot about the dynamics. The research of this poster investigates this question.

Basic Concepts

In our work the dynamic network is a series of graphs, that is, $DN = G_t(V_t, E_t)$, where $E_t \subseteq V_t \times V_t$ $(\forall t \geq 0)$. The initial network, G_0, is considered as a parameter of the process. The **node set fixed** and we worked with an about **constant number of edges**. We assume that the evolution of the network can be described as the result of an edge creation and an edge deletion process. We define G_t as the **snapshot network** and

$$G_T = (\bigcup_{t=0}^{T} V_t, \bigcup_{t=0}^{T} E_t) \text{ for } T \geq 0.$$

as the **cumulative network**.

Models

ER1 G_0 is a random graph. Add each non-existing edge with p_A, delete each existing edge with p_D probability.
ER2 G_0 is a random graph. Add k_A uniformly selected random new edges and delete k_D existing edges.
ER3 G_0 is a random graph. Rewire k_{RW} edges.
SPA (*Snapshot preferential*) G_0 is a scale free network. Add k_A edges from a random node with preferential attachment based on the snapshot network. Delete k_D existing edges.
CPA (*Cumulative preferential*) G_0 is a scale free network. Add k_A edges from a random node

Method

We use a model based on the cable equation modelling the voltage dynamics on the cell membranes of neurons. As the model is linear, we can specify the dynamics of the membrane-voltage completely by the so called Green's function $G_{ij}(x, y, t)$ which specifies how the voltage at length x of branch i develops in time with regards to a delta spike at length y of branch j at start. Throughout my project I only focused on the Green's function on the twin-cell network.

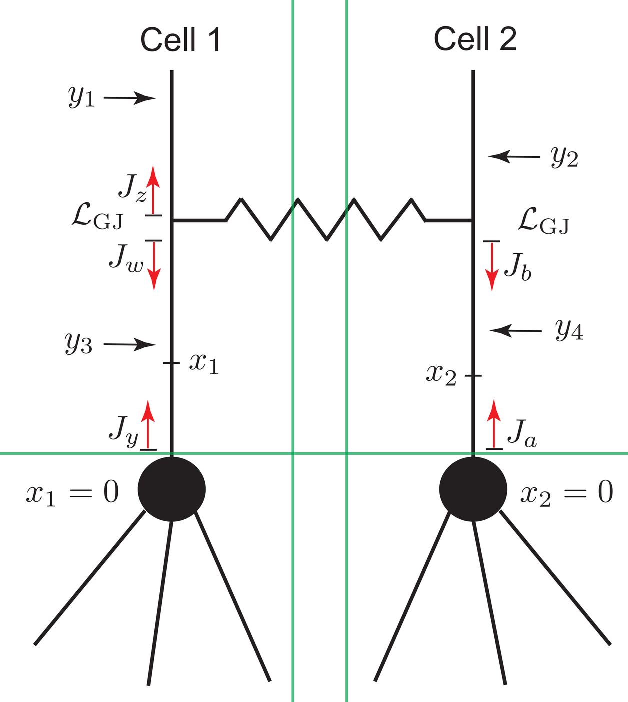
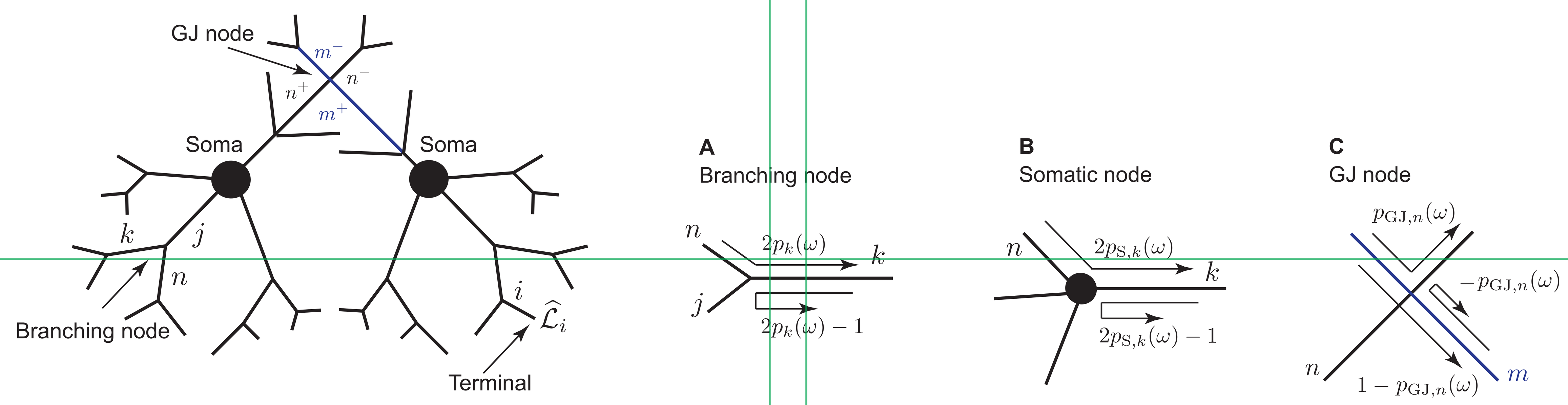


Figure 3: Schema of twin-cell network

To calculate the Green's function in the frequency domain we use the method of local point matching which depends on trips over the network from x to y.



The above figures show the type of nodes in the network and how the trips are modified by multiplication of constants depending on how they traverse the network going from x to y. I looked at the dynamics of the network by plotting and analysing how the strength and distance of the gap-junction change the dynamics.

Results

I calculated the response function for cell 1 and 2 in the symmetrical twin-cell network, giving me the response function
input at the cell bodies and output at the cell body of cell 1 and different distances up until the gap junction for cell 2, the graphs show how the output (frequency domain) depends on distance and strength of gap junction.

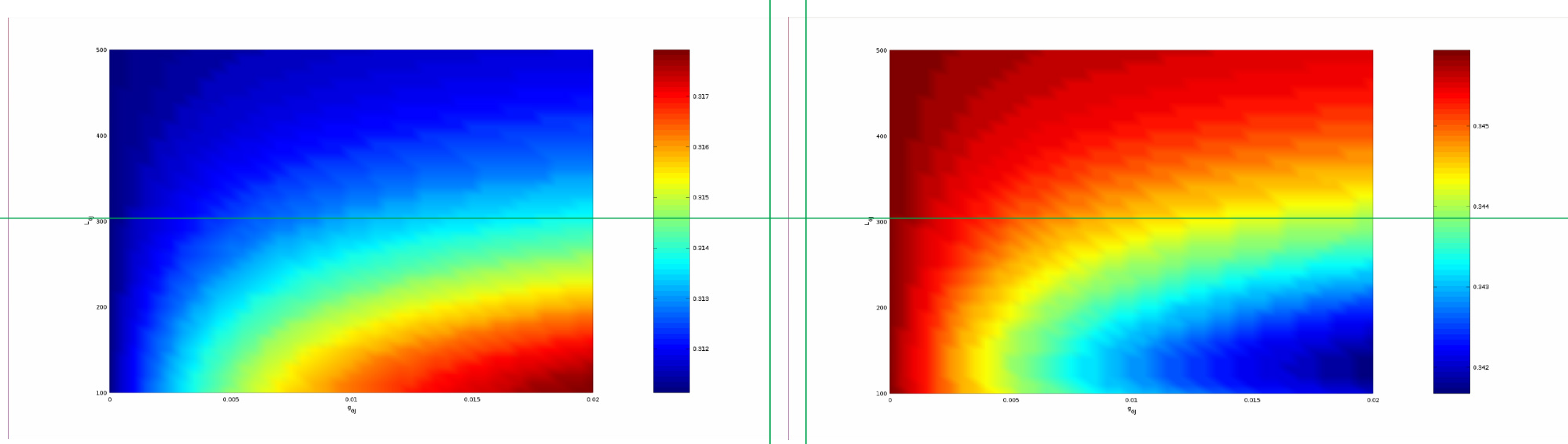


Figure 4: Graphs of cell 1 and cell 2, L_{gj} is the distance and g_{gj} the strength of the gap junction