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

Isak Falk, Yulia Timofeeva

i.falk@warwick.ac.uk, y.timofeeva@warwick.ac.uk

Complexity Science, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL

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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.

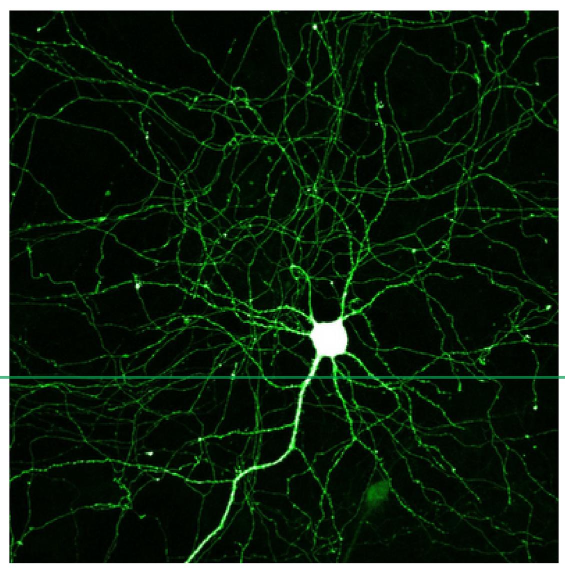

Figure 1: A neuron with an action potential going down the axon [?]

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.

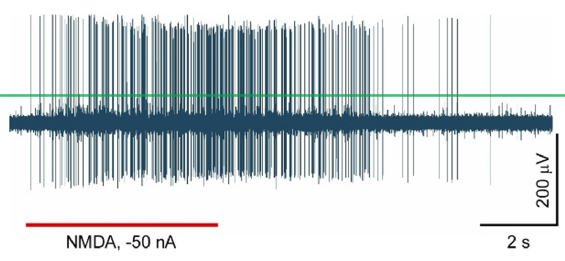

Figure 2: Recording of membrane potential of a neuron [?]

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.

By finding a map between something easily measured, like voltage, and the strength and distance of a gap junction, it would be possible for experimentalists to recover the parameters of the gap junction, something that is hard to do directly. It is this question that I have considered in my research project.

References

[1]
[2]

Acknowledgement

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URSS The Undergraduate Research Scholarship Scheme

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.

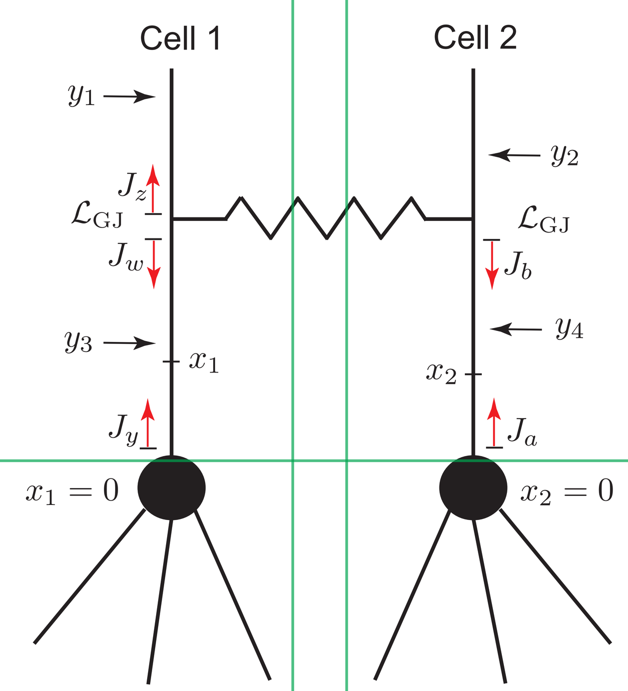
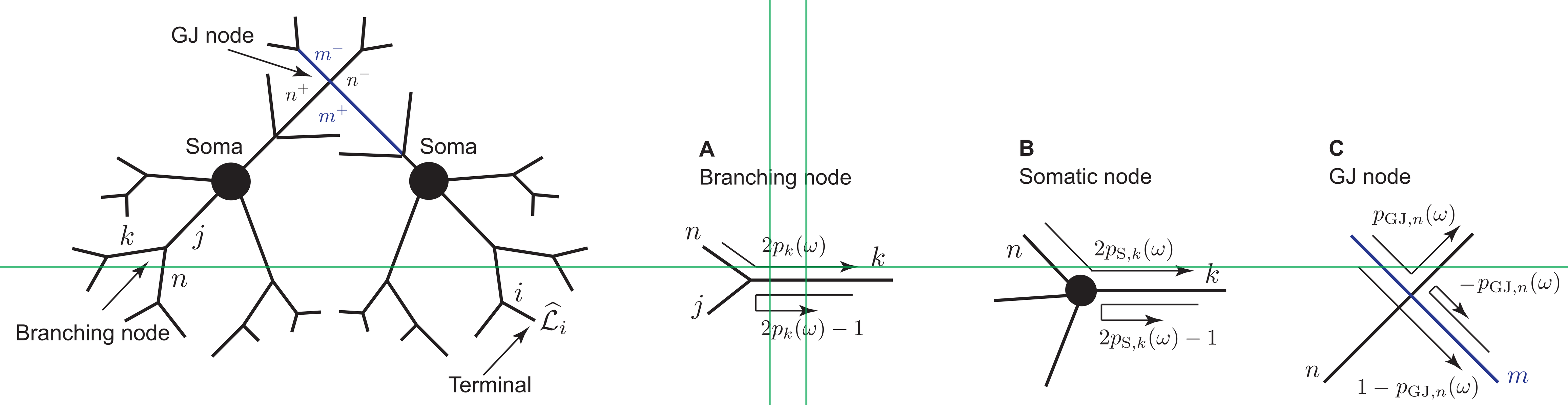


Figure 3: Schema of twin-cell network

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, 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 for a specific distance of input from cell body.

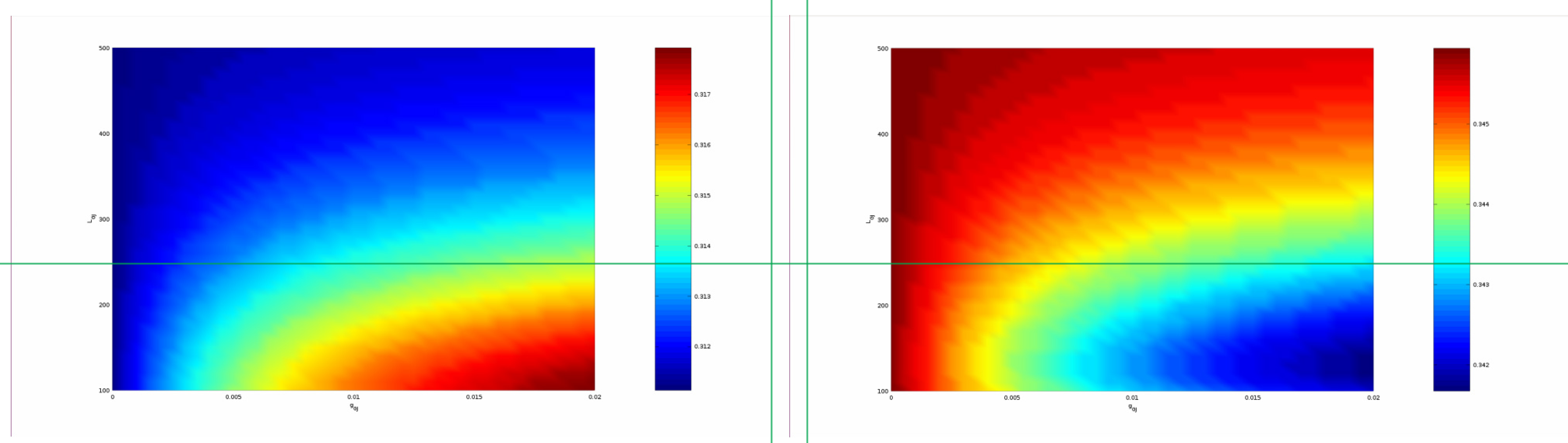


Figure 4: Graphs of cell 1 and cell 2, L_{gj} is the distance and g_{gj} the strength of the gap junction

Conclusions