

# Computational Neuroscience

## Assignment 3

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29 May 2025

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### Problem 1

I implemented a integrate and fire (IF) model with excitatory synapse by using the following equation:

$$c_m \frac{dV}{dt} = -\bar{g}_L(V - E_L) - g_{ex}(V - E_{ex}) \quad (1)$$

The code of the model implementation can be found in the Python script *excitatory\_LIF\_2.ipynb*. The integrate and fire model implements a plasticity rule allowing long-term potentiation (LTP) and long-term depression (LTD). As we observe from Figure 1, when we present the unconditioned stimulus after the conditioned stimulus, we see that the presentation of the conditioned stimulus elicits an action potential, even in the absence of the unconditioned stimulus. The neuron implements LTP rule. The neuron learned to associate the conditioned stimulus with the response and can thus be representative of Pavlovian conditioning. In figure 2 the conditioned stimulus follows the unconditioned stimulus, thus the neuron will implement an LTD rule, and the neuron will stop responding to the conditioned stimulus when presented alone.

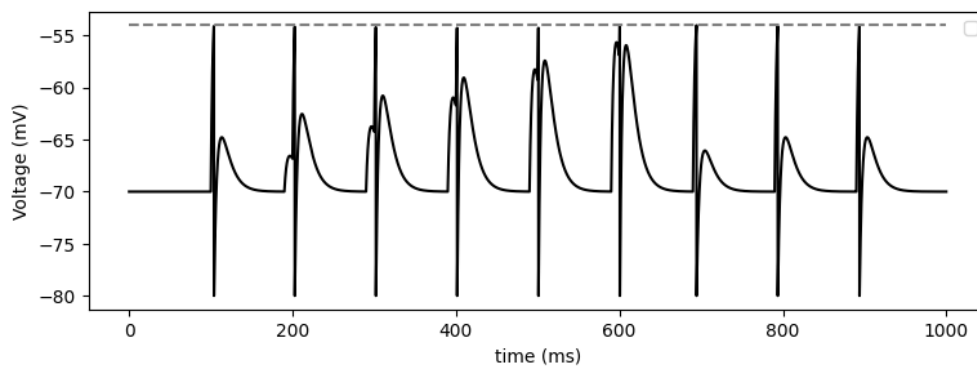


Figure 1: Voltage changes in a IF neuron with plasticity rule in case of conditioned stimulus preceding unconditioned stimulus

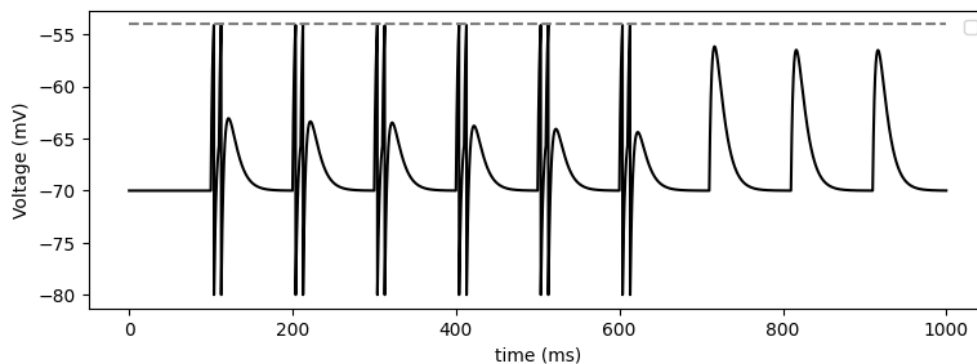


Figure 2: Voltage changes in a IF neuron with plasticity rule in case of conditioned stimulus following unconditioned stimulus

## Problem 2

In the second problem I simulated two types of synapses (depressing and facilitating) in response to a presynaptic spike train. The code can be found in *rate\_synaptic\_model.ipynb*. The plots of the exercise can be found in figure from 3 to 7. We can observe from the results that:

- At 10 Hz, the facilitating synapse increases firing rate with time, while the depressing synapse has several drops in response (fig 3).
- This is more evident at 50 and 100 Hz, where the facilitating synapse becomes even more responsive. (fig 4 and 5).
- In case of the burst, we can see the depressing synapse to initially respond and then stop firing, while the facilitating one responds at the end mostly (Fig. 6).
- Finally, we can observe that the transmission rate vs firing rate has a flat increasing curve for the depressing synapse. While it strongly increases for the facilitating synapse (fig 7).

These results illustrate the differences between depressing and facilitating synapses. Depressed synapses are good for detecting transient inputs. Facilitating synapses, on the other hand, are good at detecting and amplifying repeated or burst-like patterns of activity.

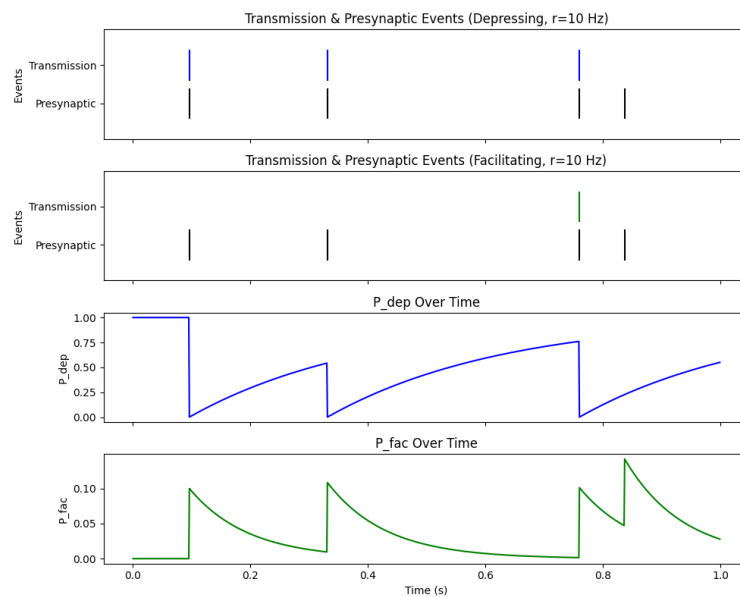


Figure 3: Transmission of the facilitating and depressing synapse, and probability in response to a presynaptic stim of 10 Hz

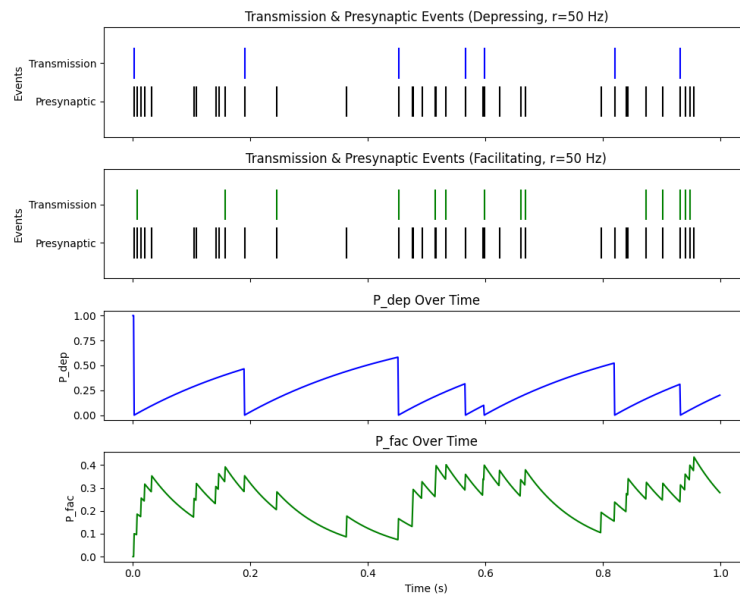


Figure 4: Transmission of the facilitating and depressing synapse, and probability in response to a presynaptic stim of 50 Hz

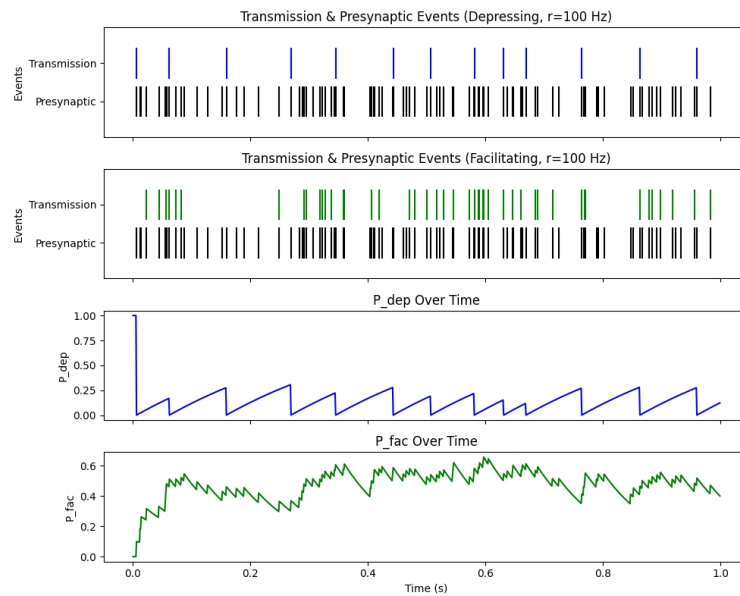


Figure 5: Transmission of the facilitating and depressing synapse, and probability in response to a presynaptic stim of 100 Hz

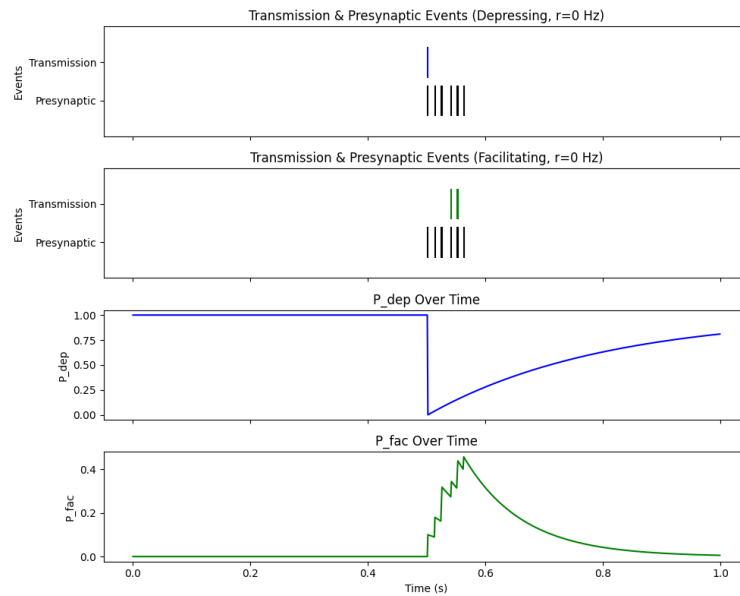


Figure 6: Transmission of the facilitating and depressing synapse, and probability in response to a presynaptic stim of a burst of 100 Hz

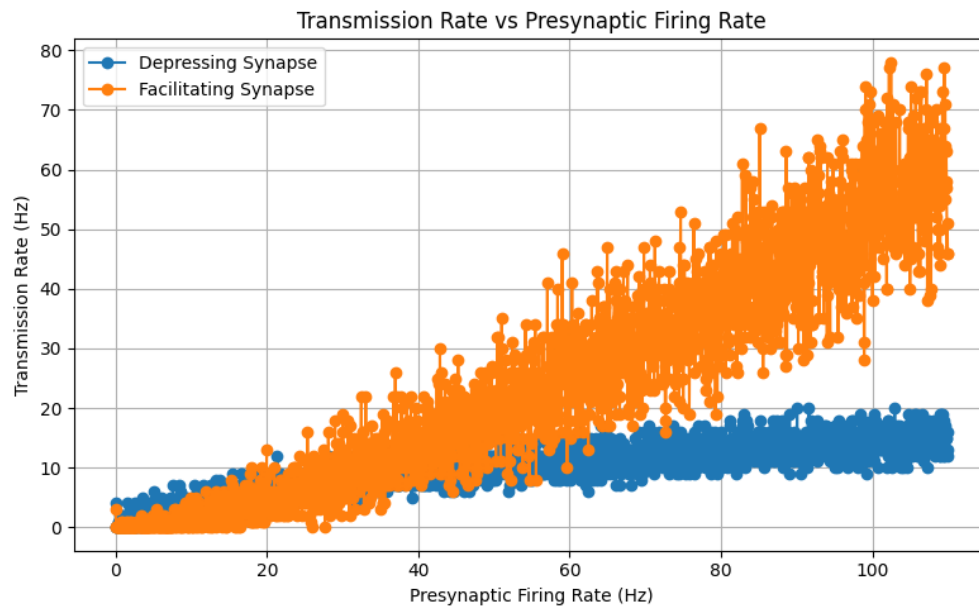


Figure 7: Transmission rate for depressing and facilitating synapse in function of increasing presynaptic firing rate