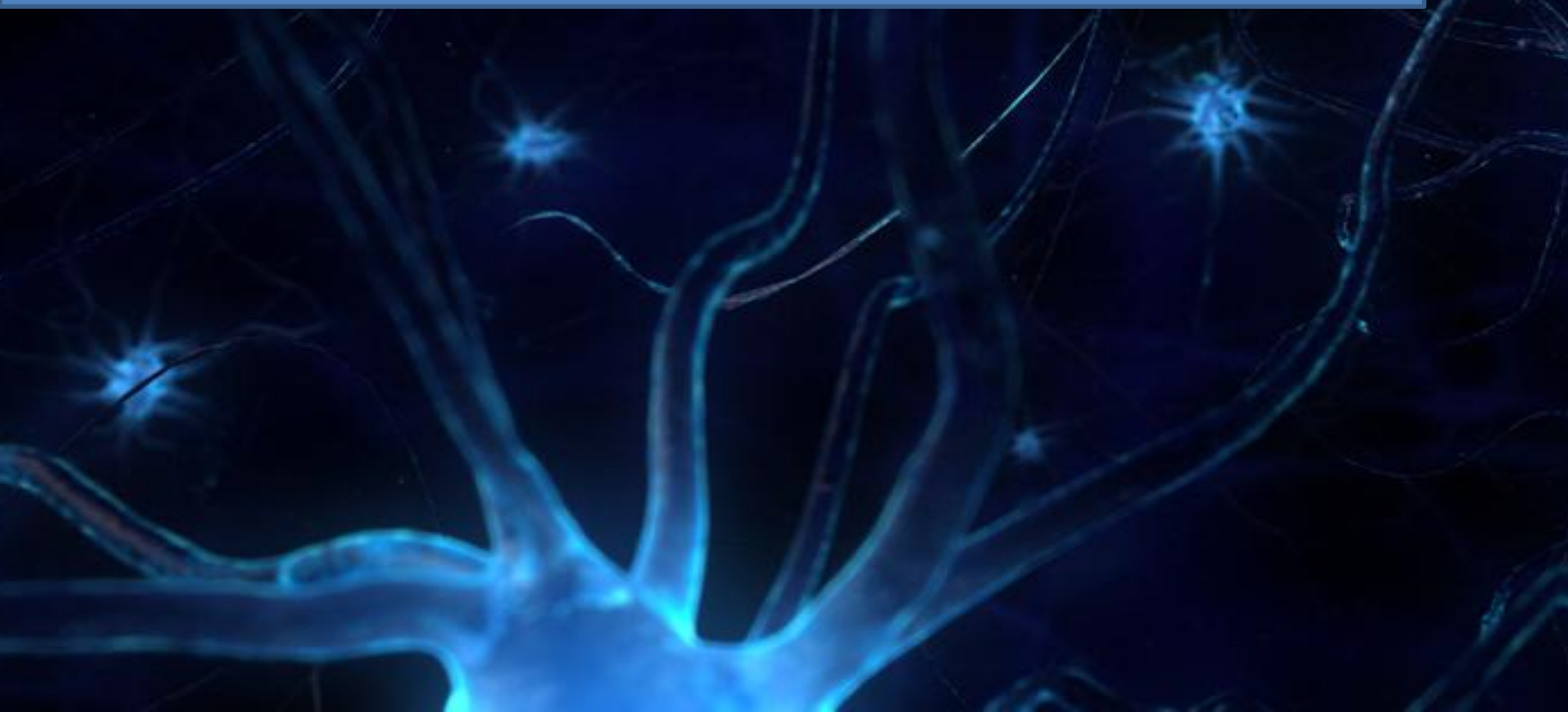
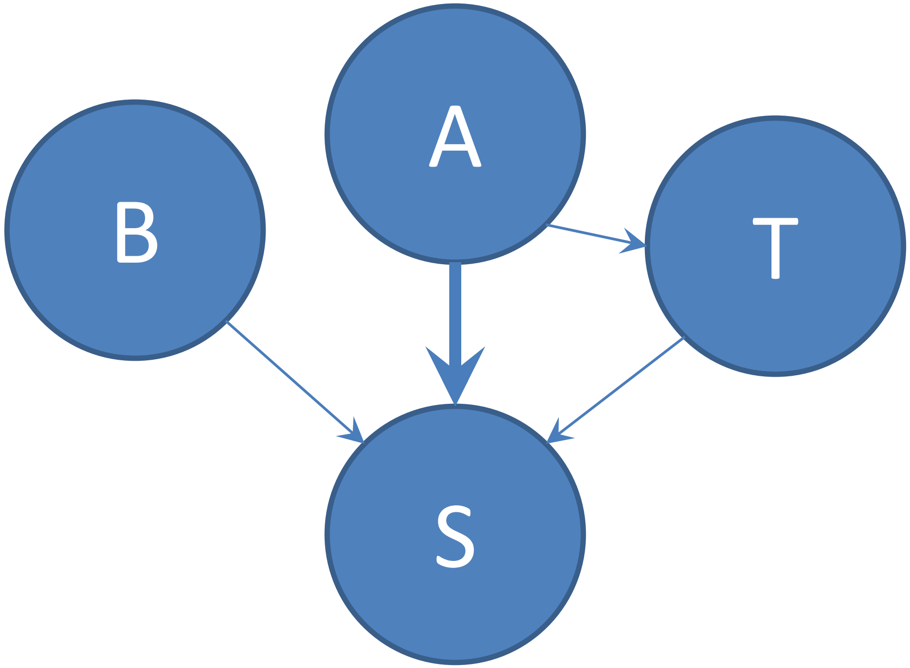
Spike-Time Dependent Plasticity

Vikas Aragam, Eli Pollock, and Stefan Torborg



Overview

•We want to implement a model of spike-time dependent plasticity to teach a “student” neuron to learn to fire in response to A, but not in response to B. A “teacher” will help accomplish this.



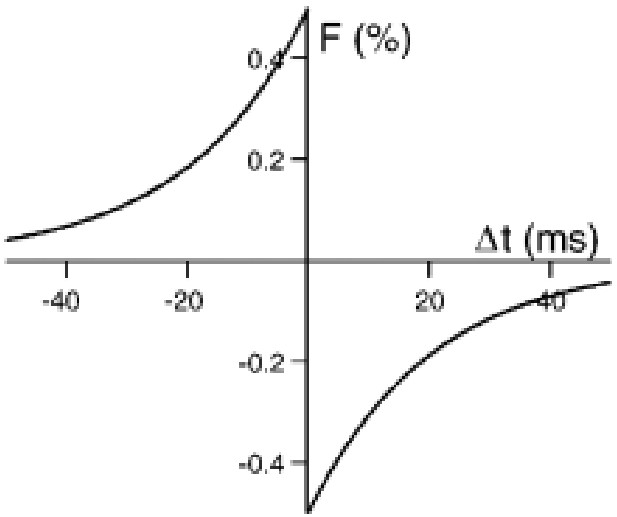
Background

"Neurons that fire together, wire together."

•Signals are modulated by the weight of synaptic strength

•The weights are changed by the STDP function

•If the student fires soon after A or B, synaptic strength increases. If it fires before, the opposite occurs.



$$F(\Delta t) = \begin{cases} A_+ \exp(\Delta t/\tau_+) & \text{if } \Delta t < 0 \\ -A_- \exp(-\Delta t/\tau_-) & \text{if } \Delta t \geq 0 \end{cases}$$

Source: Song et al. 2000

Significance

- Demonstrates ability of neurons to become tuned to respond to certain signals

- Useful for understanding how young animals learn (i.e. birdsong)

- Can help replicate biological plasticity in machine learning

Methodology

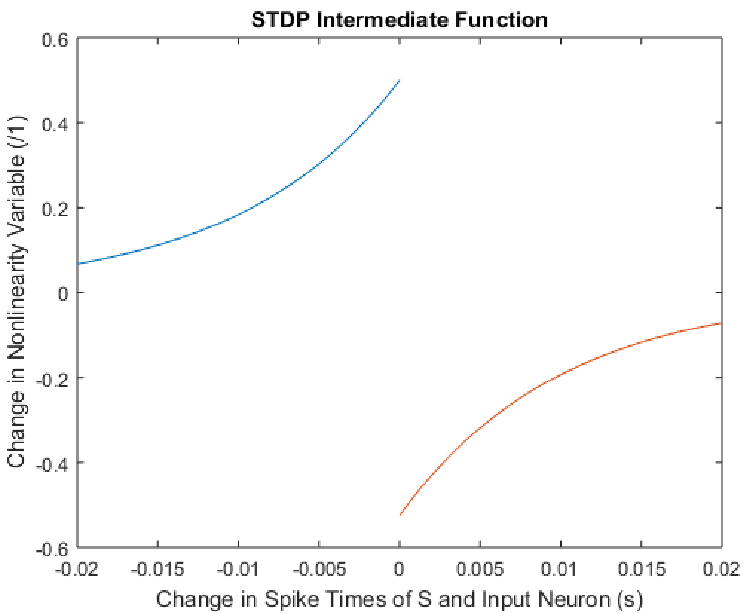
1. Simulated A and B as Poisson process neurons

2. T fires whenever A fires.

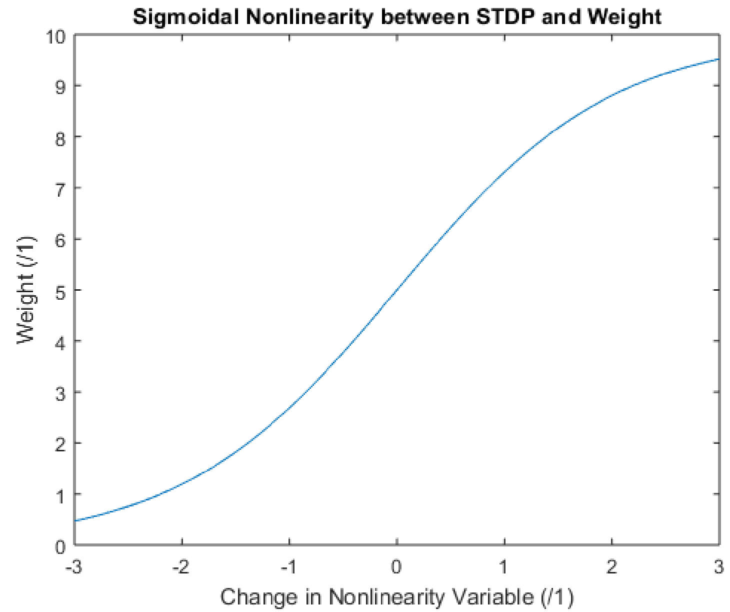
3. S is modeled as an integrate-and-fire neuron with a constant external current as well as spikes in current due to spikes from B and A+T.

4. Timing of spikes determines position on STDP plot.

Methodology (cont.)



Our STDP function. The negative part is stronger so that without the teacher's help, the synaptic weights are more likely to decay.

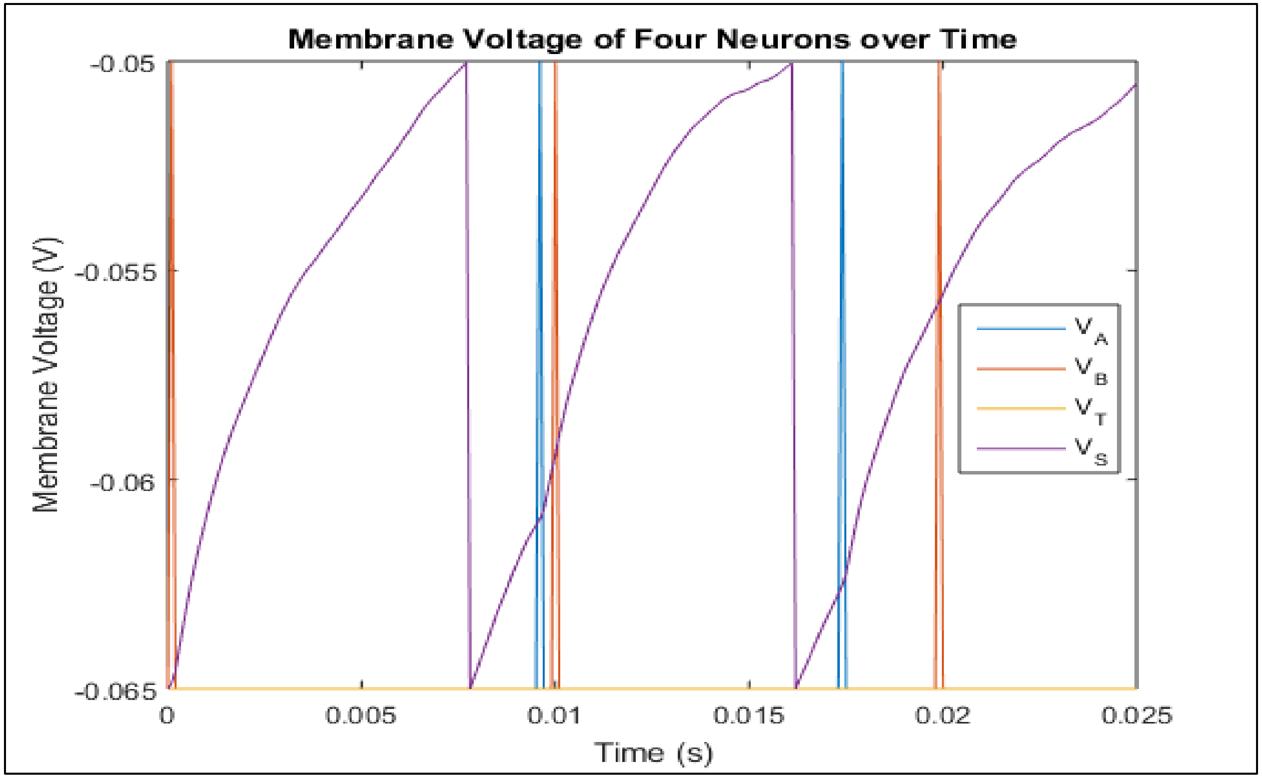


The STDP plot creates changes in the x-axis on this plot, and the resulting weights are on the y-axis.

5. Strengthening/weakening changes a variable in a sigmoidal distribution of weights, giving a maximum weight of 10 and minimum of 0.

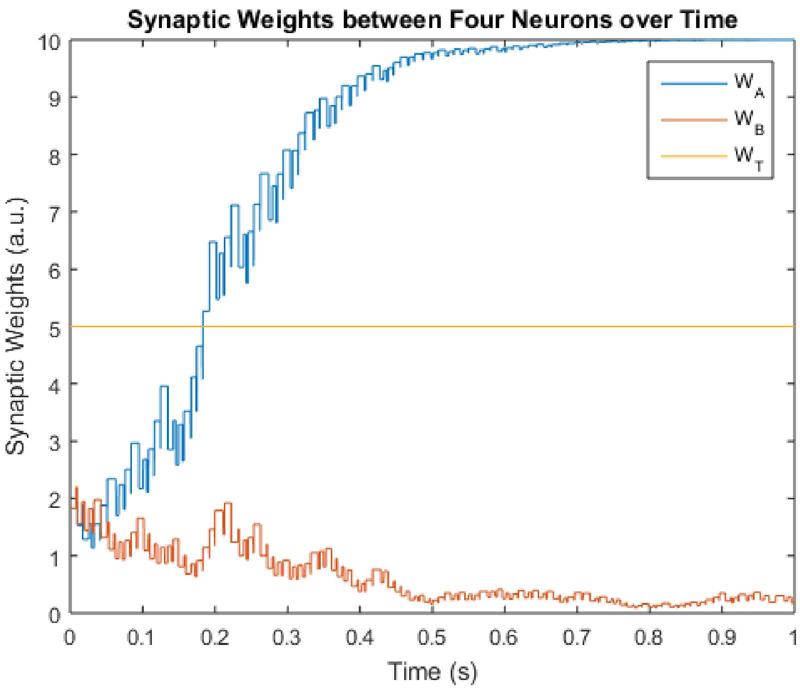
6. Find out how many times learning occurs for different weighting values of T.

Preliminary Results

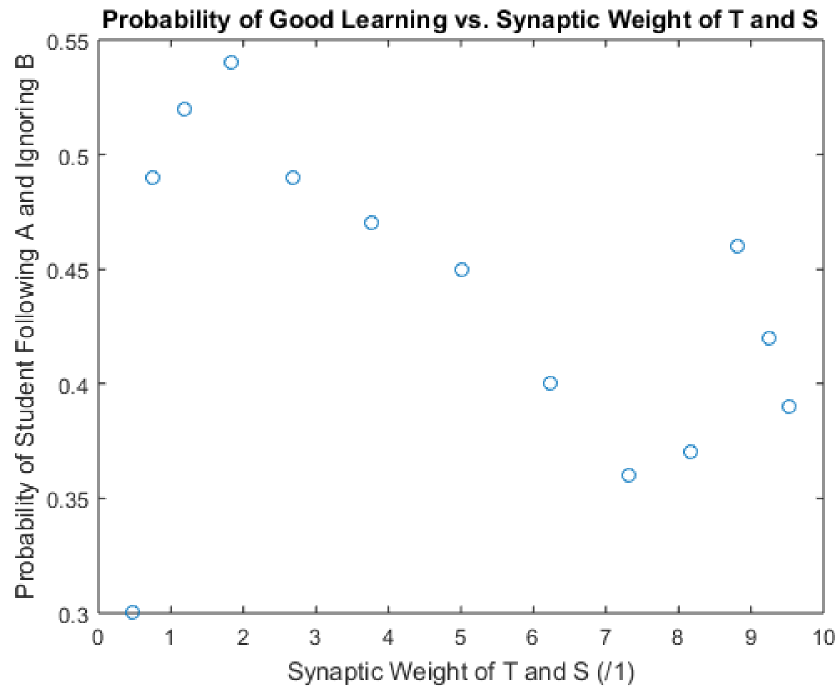


Voltage plots for all four neurons in the first 0.025 s of the trial. Notice the sudden increases in voltage of S after a spike from A or B.

Preliminary Results (cont.)



When learning occurs, the synaptic weight of A increases to the maximum of 10, while that of B goes to 0.



The teacher's synaptic strength does not show positive correlation with probability of learning.

Discussion

- Thus far, we have demonstrated that our student neuron can learn.

- Next steps:
  - Figure out why increasing the teacher’s synaptic strength does not correlate with learning.
  - Implement the birdsong learning mechanism.