Activate IAF Neuron

CNT Labs

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Kick the Baby

If you've ever watched *South Park*, then you probably remember one scene in which Kyle punts his little brother Ike like a football after saying,

"Kick the baby!"

,to which Ike responds,

"Don't kick the goddamn baby!"

Activating IAF Neuron

In this lab, we're also gonna *Kick the Baby*! More specifically, *Baby* stands for the **integrate-and-firing(IAF) neuron** and *Kick* stands for **activating with spikes**.

IAF

$$I(t) = C_m \frac{dV_m(t)}{dt}$$

As we've learnt, a naive IAF neuron simply stores ions(**integrate**) and blows off(**firing**) when reaching a boundary.

First Kick

Our first try would be activating an IAF neuron with constant **current injection**. Now, let's give it a Kick!

Rethinking

So the neuron spikes and resets periodically with constant current injection which we already know. Well, not so interesting. What about we try something else? Something that **makes more sense**?
One thing that you should keep in mind is that when neuroscientists talk about making sense, they probably have the idea of **biological plausibility** in mind. Let's just stick to this meaning as start and take a glimpse of what could happen in real brain.

A Two-Layer Network

Topology

Now, here's a two-layer network. As shown, there are two ensembles of neurons distributed in 3D space. We'll call those two ensembles the *input layer* and the *output layer*.

Neurons in the output layer are **inter-connected IAF neurons** receiving stimulus from the input layer. Each neuron is connected to its neighbours with certain probability. As shown below, a neuron in the center(large red dot) connects to several neighbouring neurons(small red dots).

Each neuron in the input layer generates a **poisson spike train**. A poisson spike train simply means at any arbitrary time there is a constant probability that a spike would emerge. Neurons in the input layer connect to close neighbours in the output layer if we overlap the space of these two layers. As shown below, a neuron in the center(large red dot) connects to several neighbouring neurons(small red dots) in overlapped space.

Correlation Via Connection

Kick it again!

Cool, let's kick it now!
Intuitively, it could be seen that output spikes have a clearer pattern. To see it, let's count the **coincidence of spikes** between different output neurons. As plotted in the figure, some pairs of neurons have strong correlations.

What does correlation mean?

Now, we see that correlation arises in networks.
What is the underlying mechanism?
In this case, the correlation of output activities arise from the connection pattern as a natural phenomenon. Next, let's look even closer at a single neuron and ask this question:
If we consider a neuron as an input-output device,
how is input correlation projected to output correlation?

Input Correlation

Probabilistic Copy

We are gonna generate spike trains with arbitrary correlations by simply using probabilistic copy. It means, just as the words, to copy spikes from a common spike train with certain probability.

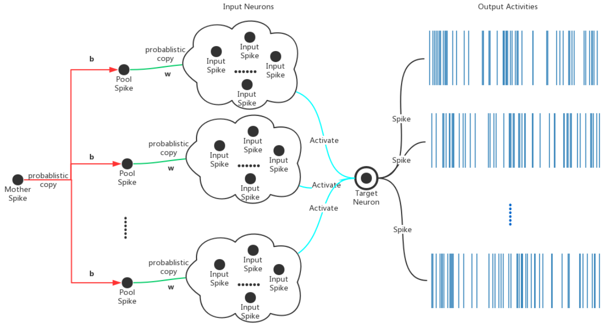

Figure: Kick Setting

Correlation Via Single Neuron

Kick Setting

As shown in the figure above, a mother spike train is copied to several pool spike trains with probability **b**. Then each pool spike train is copied to a pool of input neurons with probability **w**. With input prepared as such, each pair of pools has certain group correlation and each pair of neurons has certain individual correlation.
Now, we activate the same target neuron with each pool of neurons and record the activities of the target neuron shown as the spiking events on the right of above figure. Let's Kick the Neuron!

Observation

- Absolute Coincidence: the **absolute coincidence** of the output activities has peak value at certain $\{b, w\}$ region. The reason is quite simple: when input correlation is too low, there are not enough spikes arrived at the same time thus cannot activate the neuron; when the input correlation is too high, there are abundant spikes arrived at the same time thus the number of possible activation is reduced. In one word, the inputs are well **exploited** with certain input correlation.
- Normalized Coincidence: the coincidence can be normalized with the **energy** $c_{norm}(i,j) = \frac{c(s_i,s_j)}{c(s_i,s_i)}$, where the function s calculates the coincidence of two sequences s_i, s_j. As shown in the figure, the normalized coincidence keep increasing as the input correlation or $\{b, w\}$ increases.

Beyond Point Neuron

Time Delay

The neuron we've been dealing with is a point neuron meaning we consider all the magic happens in the **soma** of the neuron. However, the real situation is much more interesting. One additional factor requires consideration is **time delay**. Time delay means the spike trains from different input neurons reach the target neuron with different time delays due to transportation time. So when dealing with more realistic models, correlation is analyzed in time-variant context.