

An Analytical Study Of Leaky Integrate–And-Fire Neuron Model Using MATLAB Simulation

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Abstract

There are so many biological neuron models available to analyzing the behaviour of neural networks. These model plays a key role for characterizing what nervous system do, determining how the function, and explains why they operate in particular ways. The Integrate-and-fire neuron model is a simple and powerful spiking neuron model and is the widely used and analysis of subthreshold operation and a potential threshold for spike generation. An action potential (spike) is generated when the membrane potential reaches a certain threshold voltage, but actually changes associated with the membrane voltage. This research article is concerned with the computational technique available to describe the integrate-and-fire neuron model although results from MATLAB simulation.

1. Introduction

The simplified mathematical models for spiking neurons cannot account for the entire range of computational functions of the biological neuron. Rather, they try to abstract a number of essential computational aspects of the real cell function. The essential features implemented can differ between models, as a function of what the designer of model considers to be relevant and crucial for its domain study. Thus, the integrate–and–fire neuron model focuses upon the temporal summation function of the neuron. The integrate-and-fire neuron model describe the membrane potential of neuron in terms of an equivalent an electric circuit consisting of a resistor and capacitor in parallel, representing the leakage and capacitance of the membrane. The integrate-and-fire neuron model is a point neuron means it is a single compartment model in which the basic structure of neuron is belong with the dendrites is neglected. The integrate-and-fire neuron model is introduced in Section2 giving details of inputs and the solution for injected current. In section 3 we will discuss leaky integrate-and-fire neuron model with equations and in

section 4 present MATLAB simulation and buildings blocks using in MATLAB program we also give the simple leaky integrate-and-fire model. The section 5 will discuss the result of MATLAB code and at last but not least in section 6 we conclude research work.

2. Integrate-and-Fire neuron model

The integrate-and-fire neuron model is wide application areas and simplest model that is used for analysis and behaviour of neuronal activity of neural circuit. A more widespread analysis of integrate-and-fire neuron proposed by Lapicque in 1907 with injected current was carried out by Hill. The major insights into neuronal behaviour that this approach captures is the separation in time scale of the relatively slow subthreshold integration ant the very rapid spike generation. Rather than being simple, this approach has been very useful because the rapid voltage change during spike generation is particularly conventional.

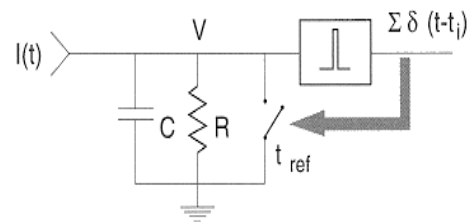


Figure 1: Integrate and Fire neuron model

3. Leaky Integrate-and-fire neuron model

The leaky integrate-and-fire (LIF) neuron is probably one of the simplest spiking neuron models, but it is still very popular due to the ease with which it can be analyzed and simulated. In its simplest form, a neuron is modeled as a “leaky integrator” of its input $I(t)$:

$$t_m \frac{dv}{dt} = -v(t) + R * I(t) \quad (1)$$

Where $v(t)$ represents the membrane potential at time t , t_m is the membrane time constant and R is the

membrane resistance. This equation describes a simple resistor-capacitor (RC) circuit where the leakage term is due to the resistor and the integration of $I(t)$ is due to the capacitor that is in parallel to the resistor. The spiking events are not explicitly modeled in the LIF model. Instead, when the membrane potential $v(t)$ reaches a certain threshold v_{th} (spiking threshold), it is instantaneously reset to a lower value v_r (reset potential) and the leaky integration process described by Equation 1 starts anew with the initial value v_r . To add just a little bit of realism to the dynamics of the LIF model, it is possible to add an absolute refractory period abs_ref immediately after $v(t)$ hits v_{th} . During the absolute refractory period, $v(t)$ might be clamped to v_r and the leaky integration process is re-initiated following a delay of abs_ref after the spike. The neuron is leaky since the summed contributions to the membrane potential decay with a characteristic time constant (the membrane time constant). If this decay of the membrane potential over time is neglected, the model is a perfect integrator. When the membrane potential reaches a (fixed) threshold, an output spike is generated– the integrate-and-fire mechanism.

3.1. Refractory Period

A refractory period is a period of time during which an organ or cell is incapable of repeating a particular action, or (more precisely) the amount of time it takes for an excitable membrane to be ready for a second stimulus once it returns to its resting state following an excitation. After initiation of an action potential, the refractory period is defined two ways: (1) The absolute refractory period (2) The relative refractory period

The absolute refractory period is the interval during which a second action potential absolutely cannot be initiated, no matter how large a stimulus is applied. The relative refractory period is the interval immediately following during which initiation of a second action potential is inhibited but not impossible.

4. MATLAB Simulation

In this section we explained how we construct our leaky integrate-and-fire simulation using MATLAB and which kind of parameter we use.

4.1. Building the simulation

A single neuron is already a complex biological object. But, basically, neurons are electrically excitable cells that are composed of a soma (cell body), a dendrite tree and an axon. Dendrites and axons connect to each other (through synapses) to create a neural network. Thus, to

make a model, we can, for example, choose geometry and some rules that produce the rule of connection between neurons. Our simulations are built as follows. First we define the constant current in nA membrane Capacitance C and resistance R , and the refractory period is defined two ways: (1) The absolute refractory period (2) The relative refractory period

4.2 MATLAB Code

```
% Implementation of Leaky integrate-and-fire neuron
% We Provide here Constant Input Current and absolute
% refractory period.
% The leaky integrate and fire neuron using equation
%  $V = V - (V/(R*C)) + (I/C)$  and plot it.
clear
% input current
I = 1 % nA
% capacitance and leak resistance
C = 1 % nF
R = 50 % M ohms
% I & F implementation  $dV/dt = - V/RC + I/C$ 
% Using h = 1 ms step size, Euler method
V = 0;
tstop = 50;
abs_ref = 5; % absolute refractory period
ref = 0; % absolute refractory period counter
V_trace = []; % voltage trace for plotting
V_th = 10; % spike threshold
for t = 1:tstop
    if ~ref
        V = V - (V/(R*C)) + (I/C)
    else
        ref = ref - 1;
        V = 0.2*V_th; % reset voltage
    end
    if (V > V_th)
        V = 50; % emit spike
        ref = abs_ref; % set refractory counter
    end
    V_trace = [V_trace V];
end
plot(V_trace)
xlabel('Time [s]');
ylabel('Membrane Potential[mV]');
```

5. Results

In this section we explain our results. We prove that our simulations have perfect model for biological neuron and we identify some properties of these model. An analysis of leaky integrate-and-fire neuron model.

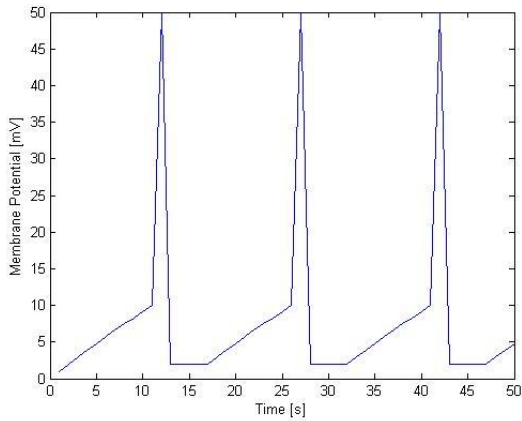


Figure 2: Leaky integrate-and-fire neuron model with synaptic current $I=1nA$.

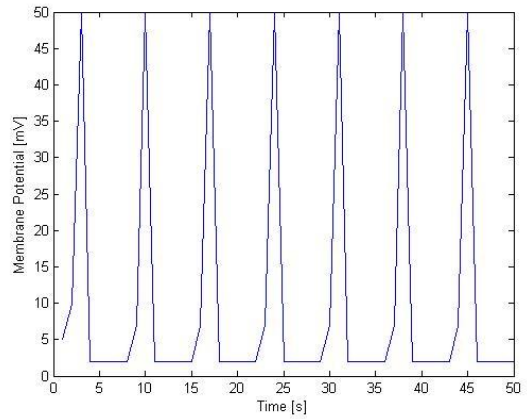


Figure 5: Leaky integrate-and-fire neuron model with synaptic current $I=5nA$.

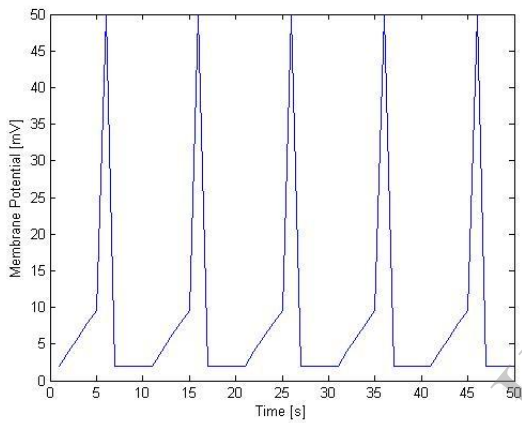


Figure 3: Leaky integrate-and-fire neuron model with synaptic current $I=2nA$.

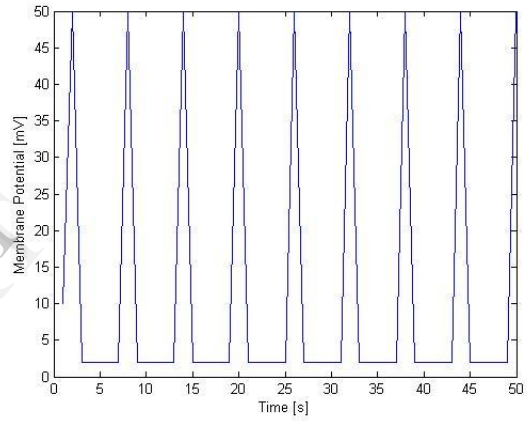


Figure 6: Leaky integrate-and-fire neuron model with synaptic current $I=10nA$.

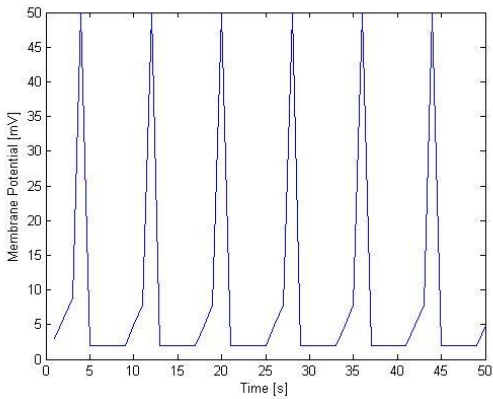


Figure 4: Leaky integrate-and-fire neuron model with synaptic current $I=3nA$.

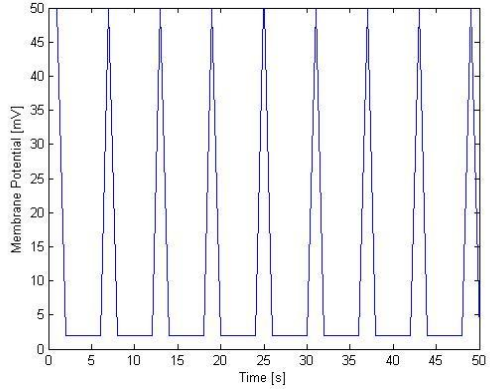


Figure 7: Leaky integrate-and-fire neuron model with synaptic current $I=50nA$.

6. Discussion and Conclusion

The integrate-and-fire neuron model has proven useful in addressing many of the questions about how neurons and neural system process information. We can conclude here that after certain synaptic current for example in figure 5-7 we passed different synaptic current to the circuit but the spikes generation of number of spikes are constant. So in the leaky integrate-and-fire neuron model the behaviour and dynamic characteristics of this neuronal model.

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8. References

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