

Purpose	(i) To investigate some basic neural circuits (ii) To learn how they can perform fundamental maths operations.
Files Required	Octave folders on website.
ILO Contribution	3
Send to Me	
Assignment Info.	
Homework	Read Chapter6

Activities

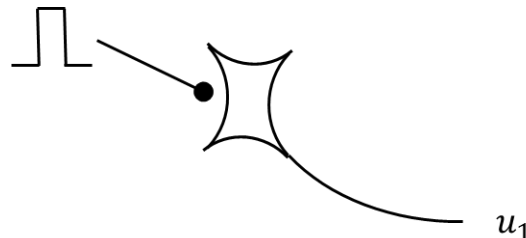
Configuring Octave

Depending on your installation you may need to load a couple of packages like this. You will find out when you run a script and it shouts at you.

```
pkg load signal
pkg load matgeom
```

1 Investigating a Single Neuron with a pulse input (Variable assignment)

Here's the neural circuit with pulse input I and neuron state u_1



Here's the ODE for this circuit:

$$\frac{du_1}{dt} = \frac{1}{\tau}(-u_1 + I)$$

The code to solve this ODE is in the file `rhs_SinglePulse.m`. To open this, scroll in the top left Octave window and double left-click to open. You should see the following line of code which looks like the above ODE

```
dudt(1) = (-u(1) + I)/tau1;
```

The equilibrium solution, obtained when $\frac{du_1}{dt} = 0$, is $u_1 = I$. Of course a pulse has two values, low and high, but this solution will apply for both.

(a) Type `SinglePulse` in the Command window. You will be asked for several parameters. Here's some suggestions to get going

pulse start time	2
pulse end time	4
pulse height	3
tau	0.25
initial state	0
t end	8

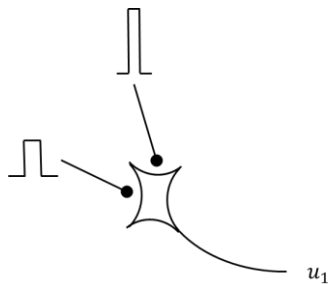
You will see the pulse in red and the state of the neuron-1 in blue. Check that the equilibrium state during the pulse rises to 3.0 and after the pulse falls to 0.0

Let's investigate the effect of changing the time constant "tau" τ . Remember this specifies how quickly a neuron responds, either fast (small tau) or slowly (large tau).

(b) Type **hold on** then run with the above parameters, but with tau 0.1. Leave **hold on** then run again for tau 0.5. Look at the difference in the neuron dynamics, you should observe a change in how quickly the neuron responds.

2 Adding two pulses.

Here's the neural circuit



Here's the ODE for this circuit:

$$\frac{du_1}{dt} = \frac{1}{\tau}(-u_1 + I_1 + I_2)$$

The code to solve this ODE is in the file **rhs_TwoPulseAdd.m** You should see the following line which looks like the above ODE

$$\mathbf{dudt(1) = (-u(1) + I1 + I2)/tau1;}$$

The equilibrium solution, obtained when $\frac{du_1}{dt} = 0$, is $u_1 = I_1 + I_2$. In other words, this neural circuit will add two pulses. The time constant **tau1** has been set to 0.1 so the neuron responds fairly quickly.

(a) Run **TwoPulseAdd.m** Make two pulses that overlap perfectly, i.e. both have start time = 2, and end time = 4. Give them different heights. Check that the circuit adds the pulses

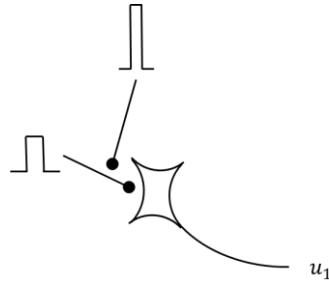
(b) Repeat but with a partial overlap, e.g. one pulse from 2 to 4 and the other 3 to 5. Give them different heights. See what happens

(c) See what happens when there are two pulses that do not overlap, e.g., one pulse from 2 to 4, and the second from 3 to 5.

(d) How would you modify the code to subtract two values, say $I_1 - I_2$? Have a go at making the change in the script `rhs_TwoPulseAdd.m`

3 Multiplying two pulses.

Here we use the *shunting* effect of the output of one neuron on the output of another.



Here's the ODE for this circuit (note I have shown the multiplication explicitly which is unusual)

$$\frac{du_1}{dt} = \frac{1}{\tau} (-u_1 + I_1 * I_2)$$

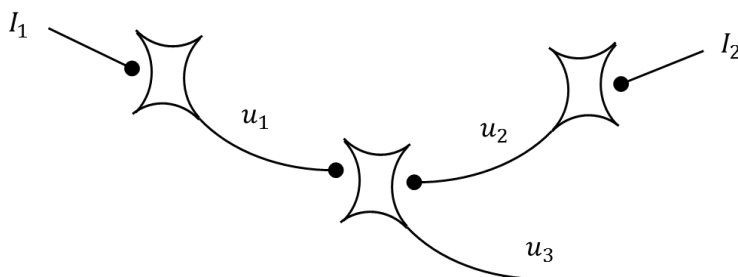
(a) Open the file `rhs_TwoPulseMult.m` in the Octave editor, and complete the line of code

`dudt(1) =`

so the circuit will multiply I_1 and I_2 . Chapter 6 will help if you're really stuck

(b) Investigate this circuit (in the spirit of Task 4) to check it indeed can multiply two pulses (with some caveats) using `TwoPulseMult`.

4 Sensor Neurons with Addition



This circuit has two neurons connected to the input sensors. They excite a third neuron whose purpose is to add the outputs from the sensor neurons. It's a common circuit in living systems which often have an input layer of sensory neurons, an output layer of motor neurons, and some processing neurons in the middle. Here's the ODEs for this circuit:

$$\frac{du_1}{dt} = \frac{1}{\tau}(-u_1 + I_1)$$

$$\frac{du_2}{dt} = \frac{1}{\tau}(-u_2 + I_2)$$

$$\frac{du_3}{dt} = \frac{1}{\tau}(-u_3 + u_1 + u_2)$$

(a) Write down the equilibrium expressions for u_1 , u_2 and u_3 , and prove that if all is well, in equilibrium,

$$u_3 = I_1 + I_2$$

(b) Open up the file **rhs_TwoSensorAdd.m** and add code for the above neurons by completing the following lines

dudt(1) =

dudt(2) =

dudt(3) =

(c) Now run the script **TwoSensorAdd** and make investigate the addition of sensor neuron values. Give two different values for the inputs.

In the next worksheet we shall apply some of this work to a particular robot, a Braitenberg Vehicle.
