**Graded assignment 1**

For this assignment, you will design a simple neural network to perform sound localization through interaural time differences. Follow the steps below as you do this. Everything can be done with a calculator or excel. Of course if you like to program you are welcome to do so, just please don’t submit code, just the written explanations and results.

1. Look up what interaural time difference is and how it is thought to be involved in sound localization. Describe what you learn in a concise paragraph

2. In what brain area is this computation thought to happen? What type of evidence is there for your answer (list three points).

# 3. Briefly describe the Jeffress model for processing interaural time differences. “The analysis of interaural time differences in the chick brain stem” by [Richard L. Hyson](http://www.ncbi.nlm.nih.gov.proxy.library.cornell.edu/pubmed/?term=Hyson%20RL%5Bauth%5D)\* [Physiol Behav. 2005 ; 86(3): 297–305.](http://www.ncbi.nlm.nih.gov.proxy.library.cornell.edu/entrez/eutils/elink.fcgi?dbfrom=pubmed&retmode=ref&cmd=prlinks&id=16202434) provides a good summary of this model.

# 4. What are two main assumptions of this model and how realistic do you think they are?

# 5. Now you will use a leaky integrate and fire neuron to demonstrate how the coincidence detection part of this model would work. Follow these steps:

# a. Write down the equation of a leaky integrate and fire neuron

# When you solve this differential equation, one solution is:

# v(t) = v(t-1) \* exp (-t/) + (1 - exp (-t/)) \* I\*R where v is the membrane voltage, t your sampling step,  the time constant RC), I an input current and R the input resistance. In our example here, assume R = 1. The derivation of this solution is explained in the mathematical aside that I provided to you. What this solution tells you is how to find the voltage at a given time step from the voltage at the previous time step, the time constant and the current input. Using this voltage, with a given threshold you can obtain the timing of each action potential. In the following assume ms for time, mV for voltage and that the membrane resting potential = 0mV (its usually -60mV but you could consider it to be at 0 and just adjust other parameters.

# To practice, please use a constant input I of amplitude 10, a time constant of 20ms, a time step of 1ms. Set the initial value of v to zero mV (v(t=0) = 0.0) and graph the evolution of v(t) over 50 time steps. How long would it take to reach a threshold of 5, 7.5 or 10 mV? Will it ever reach 10mV?

# Assuming your neuron spikes when it reaches threshold and then integrates up the input again, how fast would it approximately spike for thresholds of 2.0, 4.0 and 8.0 mV? Hint: you can do all of this in excel, and to find the frequency you really only have to find the interval from t=0 for the neuron to reach threshold.

# If you used inputs that create voltage changes of 10, 12, 14 mV and a threshold of 5mV and keep your time constant at 8ms, how fast would your neuron spike for each of these inputs?

# b. Now assume that instead of having a continuous input you have inputs from spiking neurons. The input from a spike = 12.0 (in units of current, which turn into voltage when multiplied by R (R=1)). Assume that the time constant  = 2 ms and your sampling step t = 1ms. The firing threshold of the postsynaptic neuron = 5.0. The voltage at time t=0 is zero. How close in time do two spikes have to occur to make the postsynaptic neuron fire an action potential? To figure this out, you have to calculate the voltage at each time step in response to the two incoming spikes and see when the threshold would be reached. Make a graph that shows how quickly the threshold is reached depending on how close two spikes are.

# d. Now make the time constant larger. What is the largest time constant you can use and still make the postsynaptic neuron fire in response to two subsequent spikes?

# e. Which parameters could you change to achieve firing for larger time constants?

# f. Assume that neurons that feed into your delay lines for Jeffress’ model fire one action potential at each cycle of an auditory input (see figure). Create a system of 5 postsynaptic neurons, receiving inputs from both ears and using delay lines, that can detect 5 different interaural differences from the two ears at one single wavelength. To do this you will need to find a good match between time constant, amplitude of spike and wavelength. In this network, all the postsynaptic neurons should have the same parameters, the only thing that varies should be the delay lines arriving at the postsynaptic neurons.

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# You need to have a schematic of your network, indicate the wavelength of the auditory input and show how each postsynaptic neuron detects a specific difference between the left and the right ear. Make a graph, a drawing or describe in a paragraph. Make sure you give the values for all the parameters. Depending on how you choose your parameters, your neurons may respond to more than one timing difference. Show the range of interaural time differences each neuron responds to.

g. What is the range of signal frequencies at which your network can work and why? Hint: if frequency is too high, to subsequent spikes from the same ear may make your postsynaptic neurons fire!

h. Bonus. How could you make the detection of wavelengths more specific?