Introduction to Computational Neuroscience (Spring 2018)

A Firing Rate Model for Activity Episodes in Developing Networks

---

In this exercise we will explore the dynamic properties of the firing rate model of Tabak et al. for episodes of neural activity in developing networks.

Exploration

Download the file s_model.ode from my web site. This code contains a planar model for the activity level of a neural population, a, and the synaptic efficacy s. Details of the equations were discussed in class. Noise is implemented in XPPAUT using the "wiener variable", denoted wi in the code (the auxiliary variable is called *noise*) . This calls a random number generator that samples from a normal distribution with mean 0 and standard deviation of $\sqrt{dt}$. This ensures that if you decrease the size of the size step you will also decrease the range of the noise. The wiener variable is then multiplied by n, so in the end noise=$n * wi$.

(1) Run the model and you should see several episodes of activity. The time course of a is in black and the time course of s is in red. Turn off the noise by setting the parameter $n = 0$. Do you still see episodes of activity? Open up a second window with s on the x-axis and a on the y-axis and rerun (set min and max parameters to 0 and 1, respectively, and type "gd" or graphics stuff delete to get rid of the red line). Superimpose the nullclines. Explain the dynamics of the deterministic system in terms of the nullclines. Now add the noise back and rerun (use Initialconditions Last), but keep the nullclines from the deterministic case (don't refresh the phase plane screen). In this way you can see in the phase plane the effects of noise in the termination of each silent phase and each episode.

(2) What prediction does this model make about the effects of noise on the s time course?

(3) Lower the synaptic coupling strength by reducing the synaptic weight parameter w from 0.8 to 0.7 (with noise on). How does this affect the period of the episodic activity? How does it affect the **duty cycle** (episode duration divided by inter-episode duration)? Why does it have this effect? (Hint: Look at the nullclines in the phase plane, with noise turned off. The rate of change of s is proportional to the horizontal distance between the phase point and the s nullcline.)

(4) Lower the synaptic weight from 0.7 to 0.65 (with noise on). How does this reduction in the coupling strength affect the episode time course? Look at the trajectory in the phase plane as above to explain the changes that occurred due to the reduction in coupling strength. Would you still consider the activity episodes to be a noisy limit cycle?

(5) Now reduce the coupling strength to $w = 0.6$. What effect does this have on the episodes? Why? Can you rescue the episodic activity without changing the coupling strength or other parameters in the deterministic portion of the model?

(6) Construct a stationary bifurcation diagram with the deterministic model (noise off) using synaptic weight as the bifurcation parameter. What type of bifurcation occurs and at which value of w (call this value w_c)?

(7) If you increase the θ parameter (called $th0$) to 0.18 what effect does this have on the critical coupling strength w_c? Check this by creating a new bifurcation diagram. Why does it have this effect?