Home Assignment 2: Pupil Reflex Dynamics

November 3, 2014

Preparation: Go through the exercises in Chapter 4 of the exercise manual.

The light intensity adaption mechanism of the visual system is partly controlled by adjusting the size of the iris. In this home assignment the model developed by Stark will be investigated. The model is a simplified linearization, but serves a decent approximation for small signals. From open-loop experiments, described in [J. Neurophysiol 22: 156-164, 1959], the following generic transfer function model was suggested between the relative increase in light intensity (input) and relative increase in pupil area (output):

$$G(s) = Y(s)/U(s) = -\frac{0.16e^{-0.18s}}{(1+0.1s)^3} \tag{1}$$

1. Give a state-space representation of the system. Confirm your result by using the `ss` and `tf` Matlab commands.
2. Plot impulse response (`impulse`), step response (`step`) and Bode plots (`bode`) of the open-loop system. What are the physiological interpretations of each plot?
3. What is the amplitude margin of the system?

Normally the system is in closed-loop, i.e., the closing or opening of the iris affects the amount of incoming light to the retina in a one-to-one ratio. Stark investigated the behavoir of the pupil reflex by artificially increasing the gain of the feedback loop by shining a light beam at the edge of the iris, thereby altering the ratio between iris opening and the corresponding increase in light intensity on the retina.

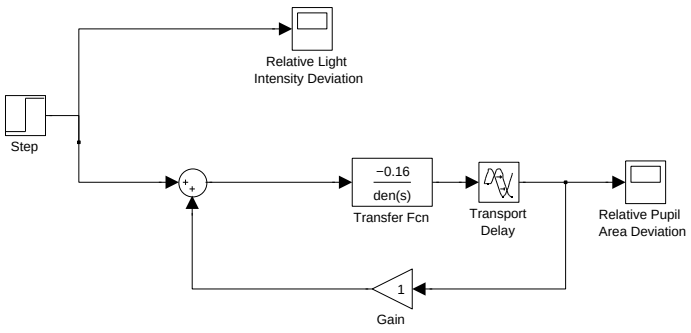

Figure 1 Closed-Loop System Model in Simulink

4. Build a Simulink model of the closed-loop system as depicted in Fig. 1. In the top scroll menu: go to Simulation/Configuration parameters and set the step size fixed to 0.01 and the solver to ode4(Runga-Kutta). Simulate the system with different values of the gain. Look at the output and determine the frequency of the oscillations when the system becomes unstable. At what gain and frequency does the system become unstable? How does this frequency correspond to the Bode plot of the open-loop system? Compare your simulation results with the calculated amplitude margin.