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Autonomous robotics

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# Essay Exercise 6 Timing

This is an essay exercise, which gives you double bonus points (triple if you do the bonus task at the bottom). It is due in two weeks, on Monday, July 6. The exercise comprises a reading and then providing a structured text that addresses questions listed below. The goal is that you write actual text, complete sentences, not just keywords or equations. The text must but organized to provide an introduction, the core statements, and a conclusion, so that a imagined reader can understand the text without having read the paper.

Read the review article "Timing, Clocks, and Dynamical Systems" by Schöner (*Brain and Cognition* **48**:31-51(2002)), the paper is available as a pdf download on the course web page). You can safely drop section 3.1. For additional, but optional background information, read the fairly advanced review paper "Phase-response curves and synchronized neural networks" by Smeal, Ermentrau, and White (*Philosophical Transactions of the Royal Society B* **365**:2401-2422 (2010)) also available on the web page. The first two pages may be particularly helpful.

1. Phase resetting is a phenomenon in which, following a perturbation, a rhythm returns to its preperturbation cycle time, but is permanently shifted against the original, unperturbed rhythm. Discuss and illustrate this notion combining Figure 2 and Figure 6, framing the rhythm in terms of a neural oscillator.

2. Describe an experiment, in which you ask people to make periodic finger movements and then perturb them in some way. How can you tell perturbations that affect the underlying timer from perturbations that do not?

3. When two neural oscillators are coupled, and one of them is perturbed, does phase resetting occur? Are there conditions, under which it would not occur?

4. The "Amari oscillator" of Equations (6) and (7) can be understood by identifying the fixed points to which the system moves within each quadrant. To understand that, approximate the sigmoid function as a step function. For each quadrant (1) $u > 0$, $v > 0$, (2) $u > 0$, $v < 0$, (3) $u < 0$, $v < 0$, (4) $u < 0$, $v > 0$, the equation is thus linear with different constant offsets. Compute the fixed point (solution of $\dot{u} = \dot{v} = 0$) in each quadrant. For the right choices of the coupling parameters, the fixed point for each quadrant lies in the neighboring quadrant.The vector-field in each quadrant "points" toward the fixed point, which drives all initial values in that quadrant in the direction of the neighboring quadrant. Make a sketch of that vector-field and argue intuitively why a limit cycle may emerge. [An additional resource is the 1977 Amari paper available on the course web page]

5. Bonus (valid one complete bonus point load) for those who have access to Matlab (free at RUB, see Matlab under A-Z on `http://www.it-services.rub.de`). Download the two files from the course web page:

   `singleNeuronInteractiveSim.m` and `sigmoid.m`

   You may alternatively, download the Matlab package Cosivina here:

   `http://www.dynamicfieldtheory.org/cosivina`

   and find the code

   `launcherTwoNeuronSimulator.m`

   This is also an option for those who can't get access to Matlab (see instruction on the Cosivina page).

   In both cases, run the simlator. Control with the sliders the resting levels and inputs of the two neurons to build the equations (6) and (7). One neuron plays the role of the exitatory, the other of the inhibitroy neuron. Try to make the two neurons oscillate. You can use the information in the appendix of the paper Schoner (2002) to find the right parameter values. Document your simulation results by writing a coherent account of the simulation experiments, stating your goal, the model, what you observed/looked at, what parametric manipulation you made, what the results where (how your observations depended on your parameter changes).