A Continuous-Time Dynamical System Describing both Rate Encoding and Spiking Neurons

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Introduction

- We introduce a two-dimensional nonlinear system, modeling a wide range of dynamic properties of spiking neurons.
- By altering key parameters of this system, its dynamics become identical to those of a time-continuous rate-encoding model.
- Differences of the dynamical properties of single units as well as of network structures under these two regimes can be treated within the same mathematical framework.

Neuron Model

The model consists of a two-dimensional non-linear system given by

$$\tau_x \dot{x} = f(x) - y \qquad f(x) = s\sigma\left(a\left(x - s/4\right)\right)$$
$$\tau_y \dot{y} = g(x) - y \qquad g(x) = g_0\sigma\left(a_g\left(x - I\right)\right) - \Delta_y$$
$$\sigma(x) = \left(1 + \exp(-x)\right)^{-1}$$

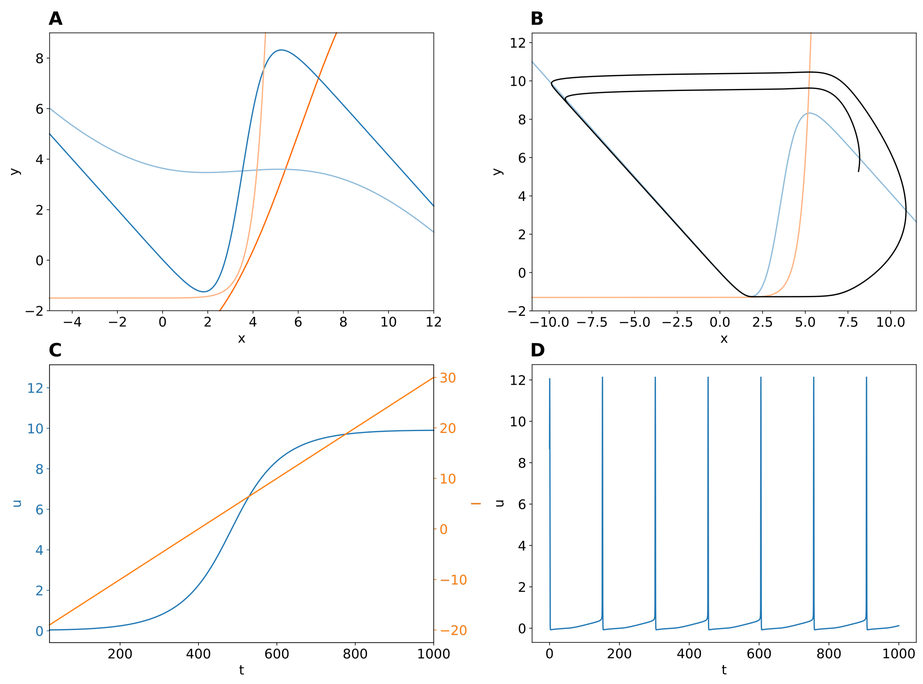

Figure 1: A: x/y-nullclines (blue/red) of the dynamical system for parameter sets generating spiking/non spiking behavior. B: Phase plane trajectory for the spiking dynamics. C/D: Dynamics of readout variable u for the spiking/non-spiking case.

Results

- A wide range of different types of spiking dynamics can be reproduced by this generic system.