# Appendix

## E-GLIF model solution and parameter space

Considering the matrix form of the ODE system describing the model dynamics (Equ. 1):

(A )

the general solution is:

(A )

where:

, , are arbitrary constants depending on the initial conditions

are the eigenvalues of the coefficient matrix, with values:

= , (∈ R-) (A 3)

= (A )

= (A )

, , are the eigenvectors associated to each eigenvalue

, , are the stationary solutions for each state variable.

For the membrane potential, the solution is (Hertäg et al., 2012):

(A )

Specifically:

(A )

, (A )

the first component of the eigenvector associated to the eigenvalue .

, (A )

the first component of the eigenvectors associated to the eigenvalues and , respectively

Considering that *k1* is real and positive, the dynamics of the solution depends on the discriminant:

(A )

1. exponential and stable solution; the following conditions need to be verified:
   * ⇒ ∈ R (the solution is exponential)
   * *<* 0 (the solution is stable)

In addition, we need to verify that *Vm\_inf* ∝ *Ie+Istim,* i.e. *Vm\_inf* is proportional to the total input current through a positive coefficient, to have a coherent value of steady state membrane potential.

These conditions result in the following constraints on parameters:

*⇒* (A )

1. oscillatory solution; the following conditions need to be verified:
   * ⇒ *∈ C* (the solution is oscillatory);
     + If *Re[] = 0* ⇒ the oscillations have null damping;
     + If *Re[] < 0* ⇒ the oscillations are damped and the solution is stable.

Analogously to the previous case, we need to verify that *Vm\_inf* ∝ *Ie+Istim* through a positive coefficient.

The resulting constraints among parameters are:

*⇒* (A )

In this case, oscillations depend on the imaginary part of the eigenvalues () and thus have angular frequencyand related frequency.

The analytical solution was exploited in the E-GLIF optimization process to define the cost function and the parameter constraints.

During PyNEST simulations, the neuron model response over a membrane potential threshold was approximated to a spike. For neurophysiological realism, a spike was generated at time *tspk* depending on the escape rate function (Equ. 2) accounting for stochasticity and the refractory interval, if:

(A 13)

where *rnd* = random number in the interval [0, 1]

# E-GLIF optimization for cerebellar Golgi cells: parameter constraints

In order to obtain the expected neurophysiological behavior when simulating cerebellar GoCs, E-GLIF optimization took into account multiple parameter constraints. Specifically:

Nonlinear constraints:

Negative discriminant ( to obtain an oscillatory membrane potential (as described in Appendix, I):

(A 14)

Controlled *Vm* oscillation frequency: 3 < *fOSC < 8 Hz*, where *fOSC* is defined in Section 2.1.

Controlled amplitude of oscillations (), during the intervals , ,of the zero-current phase (*Istim* = 0 pA) and during the hyperpolarizing interval *hyp* (with *Istim = inh*):

(A 15)

(A 16)

to constraint the occurrence of the first spike event during the zero-current phase, so to trigger all the spike-reset-update mechanisms.

Linear constraints:

GoC show faster dynamics of the sodium ion current with respect to potassium one (accounted for by the current updates *A1* and *A2*):

pA (A 17)

Parameter bounds:

Not-damped *Vm* oscillations (see Appendix, I):

(A 18)

After , negligible contribution of the depolarizing current *Idep*, during the zero-current phase (*Istim* = 0), to avoid interference with the neuron spontaneous activity, being *Idep* the depolarizing spike-triggered current, with decay *k1*:

(A 19)

Realistic values of *Idep* and *Iadap* based on the neurophysiological values of sodium and potassium ion currents (Solinas et al., 2007a):

, **<** 500 pA (A 20)

Limited values of the endogenous current:

< 50 pA (A 21)