Using Python tools for analysis of a mathematical model of after-depolarisation

Jakub Nowacki*, Hinke M. Osinga, Krasimira Tsaneva-Atanasova

Bristol Centre for Applied Nonlinear Mathematics,
Department of Engineering Mathematics,
University of Bristol, Queen's Building, University Walk, BS8 1TR

Abstract

Python combines usability, clarity and extensibility that makes it a language of choice for many projects concerning scientific computations. One of the unique feature of Python is the simplicity of interfacing between different programming languages. This feature have brought Python effectiveness into many established numerical tools, that previously were not necessary user friendly or constrained by the original language limitations. An examples of such a tool is the numerical continuation software AUTO [1]. The recently added Python interface considerably increased its usability and improved the data handling. These changes have created opportunities for the software to be used for various new applications. We present an example of a novel Python/AUTO application to perform an analysis of our model of after-depolarisation.

Understanding the behaviour of a biological model is a fundamental question from both theoretical and experimental point of view. Parameter uncertainty is a common feature of biological systems and therefore exploring the parameter space of a model could often lead to useful predictions. Currently, the vast majority of parameter sensitivity analysis is performed using brute force numerical simulation that could produce inherently incomplete results for example in the case of multi-stability. We propose a novel approach to parameter sensitivity analysis that employs numerical bifurcation theory techniques such as boundary value problem (BVP) formulation.

Our formulation allows us to use numerical continuation tools, such as AUTO, to explore the behaviour of a model under a parameter variation in a nearly continuous way. The continuation method enables us to determine regions in the parameter space where certain model behaviour of interest occurs. Using the BVP formulation we analyse a simplified model of after-depolarisation based on previous studies of a more detailed model of intrinsic excitability of CA1/3 pyramidal neurons [4]. Using the well-posed two point BVP continuation we identify the onset of the ADP and a burst in a form that allows us to perform a two-parameter continuation. This in turn enables us to unambiguously determine the boundaries (in parameter space) of the ADP and bursts with different number of action potentials. To confirm the continuation results we use XPPy [3], a Python interface for XPPAut [2], to perform model simulations. The visualisation of the results of continuation and simulations is done using Matplotlib. Finally our results provide useful predictions for further studies of the intrinsic excitability of pyramidal neurons.

References

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*Corresponding author: `j.nowacki@bristol.ac.uk`