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Ca^{2+} triggered vesicle release mechanisms: in silico experiments

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Abstract:
Research in life sciences is benefiting from a large availability of formal description techniques and analysis methodologies. These allow both the phenomena investigated to be precisely modeled and virtual experiments to be performed *in silico.* Such experiments may result in easier, faster, and satisfying approximations of their *in vitro/vivo* counterparts. A promising approach is represented by the study of biological phenomena as a collection of interactive entities through *process calculi* equipped with stochastic semantics. These exploit formal grounds developed in the theory of concurrency in computer science, account for the not continuous, nor discrete, nature of many phenomena, enjoy nice compositional properties and allow for simulations that have been demonstrated to be coherent with data in literature. Motivated by the need to address some aspects of the functioning of neural synapses, we have developed one such model for the case of the *calyx of Held* synapse. Our stochastic model has been drawn from a previously published kinetic model based on ODEs. Simulations confirmed the coherence of the two models. Our model overcomes some limitations of the kinetic model and, to our knowledge, represents the first *process calculi* based model of a presynaptic terminal. We improved the expressiveness of the model, e.g. by embedding easy controls of element concentration time course. The developed model points to specific presynaptic mechanisms.
Taking advantage of the compositionality of our approach, the model is being extended to include descriptions of synaptic plasticity, i.e. activity dependent change mechanisms, which contribute to memory and learning processes. Specifically, the core model has been extended to address issues presenting open problems: we have taken into consideration hypotheses on short-term synaptic enhancement (facilitation) and depression, i.e. plasticity mechanism that are related to memory and learning.
This approach is currently being extended by completing the model with elements of the postsynaptic side. In relation to computer science, we plan to improve the underlying computational model and the linguistic primitives it provides as suggested by the simulations carried out so far, e.g. by introducing a notion of (spatial) locality compatible with stochastic dynamics.
The goal of our approach is to compositionally extend the model so as to represent a whole synaptic terminal.
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