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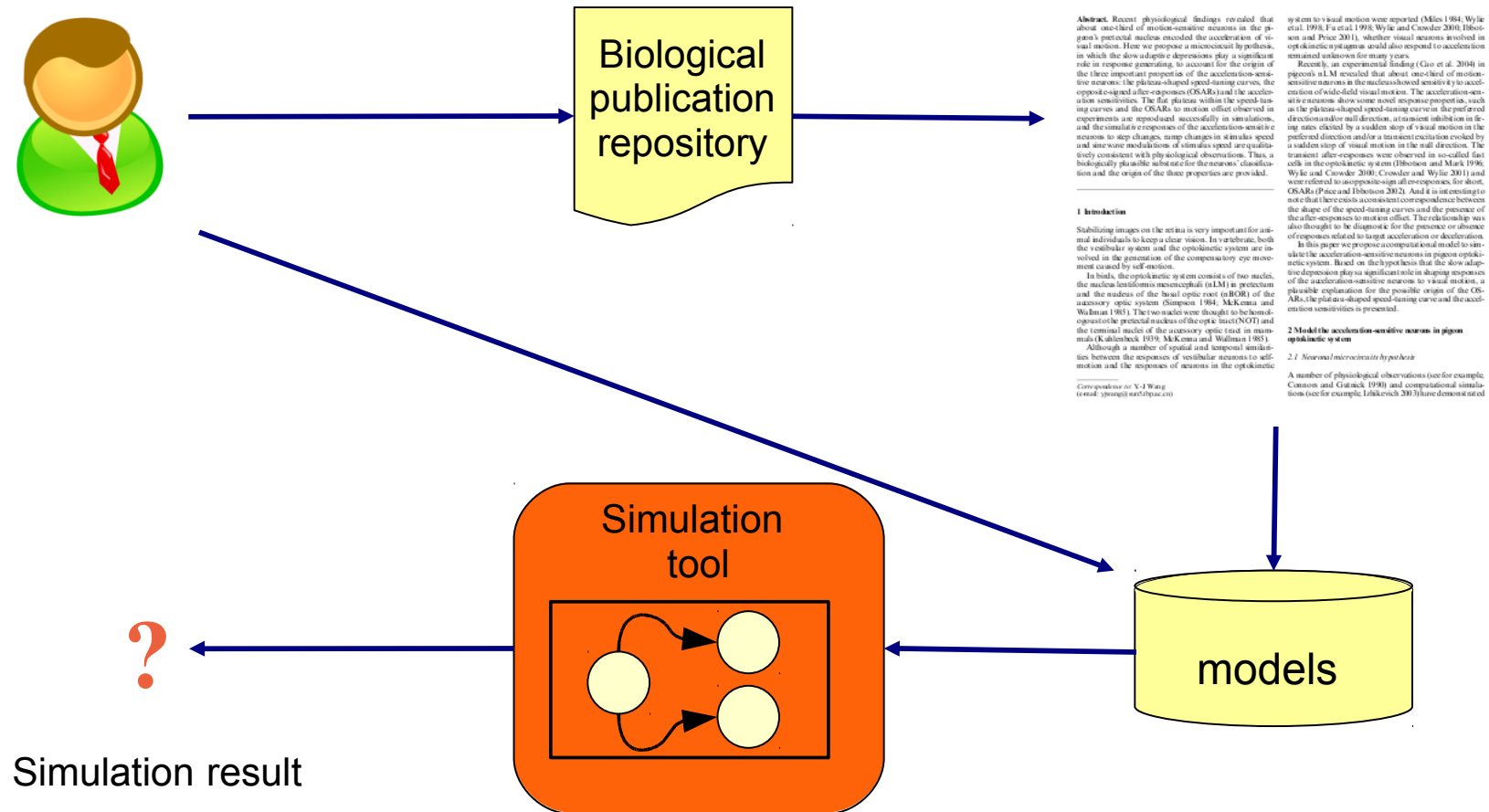


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Te Whare Wānanga o Tāmaki Makaurau

SED-ML Motivation



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Biological
Cybernetics

Modeling the acceleration sensitive neurons in the pigeon optokinetic system

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Abstract. Recent physiological findings revealed that about one-third of motion-sensitive neurons in the pigeon's pretectal nucleus encoded the acceleration of visual motion. Here we propose a microcircuit hypothesis, in which the slow adaptive depressions play a significant role in response generating, to account for the origin of the three important properties of the acceleration-sensitive neurons: the plateau-shaped speed-tuning curves, the opposite-signed after-responses (OSARs) and the acceleration sensitivities. The flat plateau within the speed-tuning curves and the OSARs to motion offset observed in experiments are reproduced successfully in simulations, and the simulated responses of the acceleration-sensitive neurons to step changes, ramp changes in stimulus speed and sine-wave modulations of stimulus speed are qualitatively consistent with physiological observations. Thus, a biologically plausible substrate for the neurons' classification and the origin of the three properties are provided.

1 Introduction

Stabilizing images on the retina is very important for animal individuals to keep a clear vision. In vertebrate, both the vestibular system and the optokinetic system are involved in the generation of the compensatory eye movement caused by self-motion.

In birds, the optokinetic system consists of two nuclei, the nucleus loquax (NLT) in pretectum and the nucleus of the head optic tract (NHOT) of the accessory optic system (Simpson 1984; McKenna and Wulman 1985). The two nuclei were thought to be homologous to the pretectal nucleus of the optic tract (NOT) and the terminal nuclei of the accessory optic tract in mammals (Kühneltbeck 1979; McKenna and Wulman 1985). Although a number of spatial and temporal similarities between the responses of vestibular neurons to self-motion and the responses of neurons in the optokinetic

system to visual motion were reported (Miles 1984; Wylie et al. 1993; Fuchs et al. 1998; Wylie and Crowder 2000; Hibi et al. 2001), whether visual neurons involved in optokinetic system would also respond to acceleration remained unknown for many years.

Recently, an experimental finding (Gao et al. 2004) in pigeon's NLT revealed that about one-third of motion-sensitive neurons in the nucleus showed sensitivity to acceleration of wide-field visual motion. The acceleration-sensitive neurons show some novel response properties, such as the plateau-shaped speed-tuning curves in the preferred direction and/or null-direction, a transient inhibition in firing rates elicited by a sudden stop of visual motion in the preferred direction and/or a transient excitation evoked by a sudden stop of visual motion in the null-direction. The transient after-responses were observed in so-called fast cells in the optokinetic system (Hibi et al. 1998; Wylie and Crowder 2000; Crowder and Wylie 2001) and were referred to as opposite-sign after-responses, for short, OSARs (Pérez and Hibi 2002). And it is interesting to note that there exists a consistent correspondence between the shape of the speed-tuning curves and the presence of the after-responses to motion offset. The relationship was also thought to be diagnostic for the presence or absence of responses related to target acceleration or deceleration.

In this paper we propose a computational model to simulate the acceleration-sensitive neurons in pigeon optokinetic system. Based on the hypothesis that the slow adaptive depression plays a significant role in shaping responses of the acceleration-sensitive neurons to visual motion, a plausible explanation for the possible origin of the OSARs, the plateau-shaped speed-tuning curves and the acceleration sensitivities is presented.

2 Model the acceleration-sensitive neurons in pigeon optokinetic system

2.1 Neuronal microcircuit hypothesis

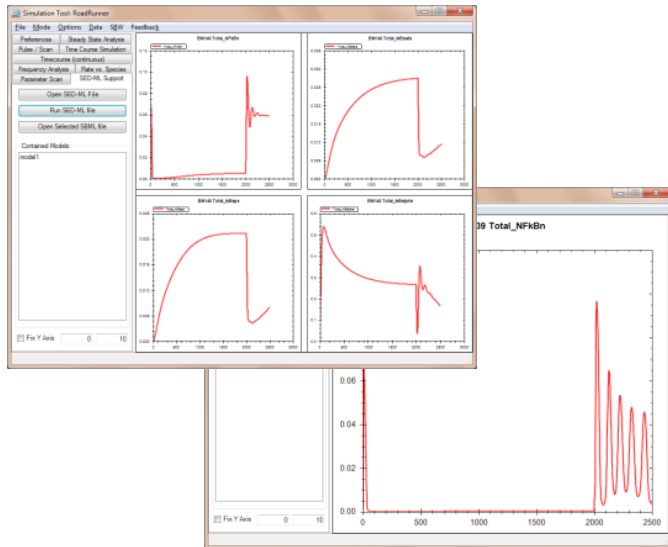
A number of physiological observations (see for example, Connors and Grinvald 1990) and computational simulations (see for example, Linker et al. 2003) have demonstrated

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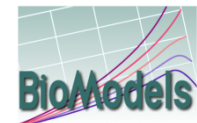
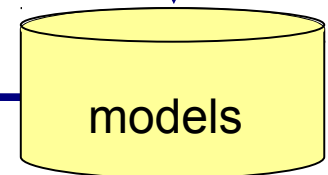
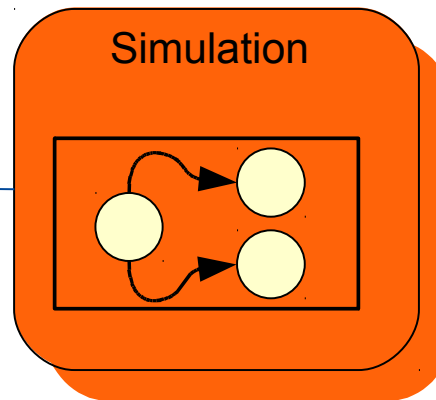
SED-ML Motivation



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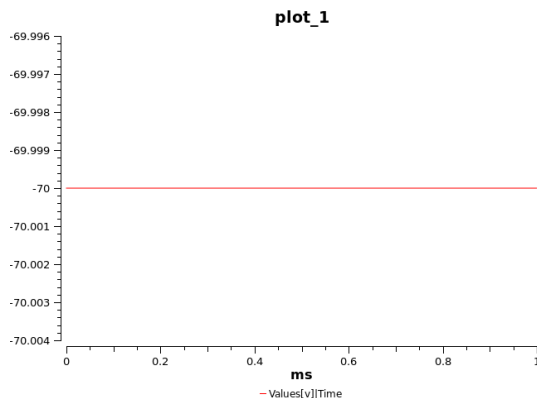
Simulation results (SBW Workbench)



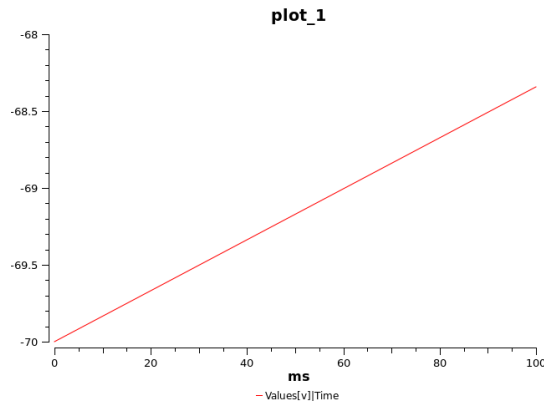
Example

First attempt to run the model, measuring the spiking rate v over time

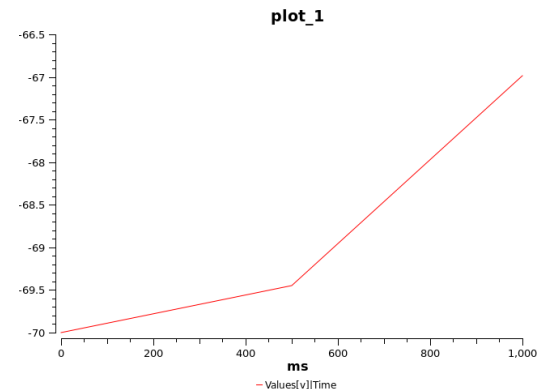
- load SBML into the simulation tool COPASI
- use parametrisation as given in the SBML file
- define output variables (v)
- run the time course



1 ms (standard)



100ms



1000ms

Example

Second attempt to run the model, adjusting simulation step size and duration

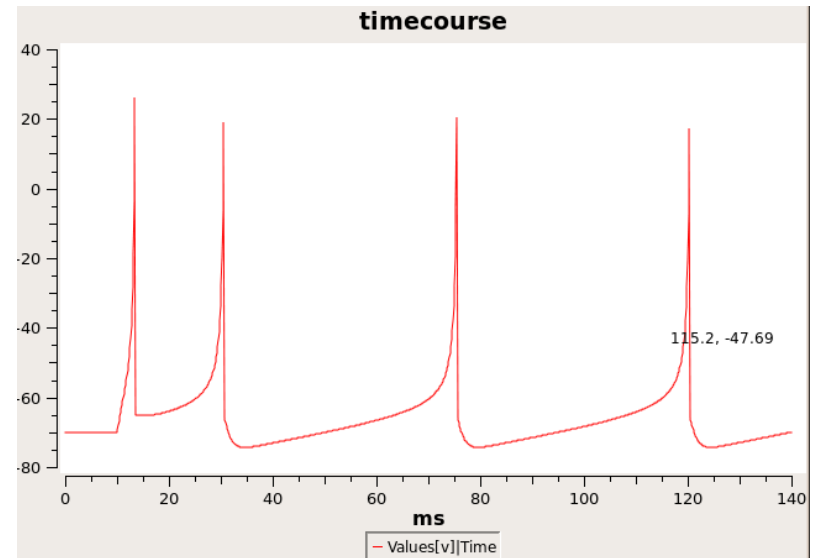
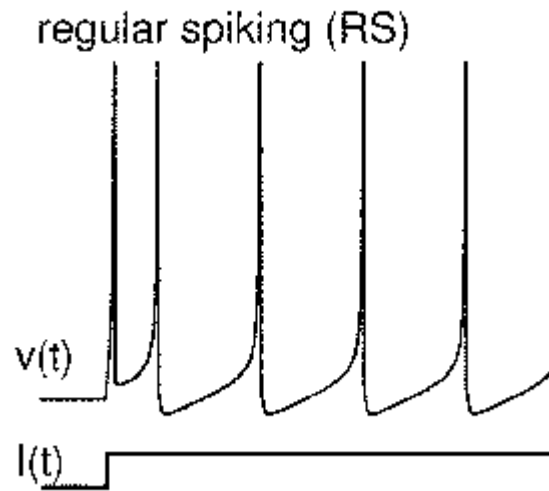


Fig.: COPASI simulation, duration: 140ms, step size: 0.14

Example

Third attempt to run the model, updating initial model parameters

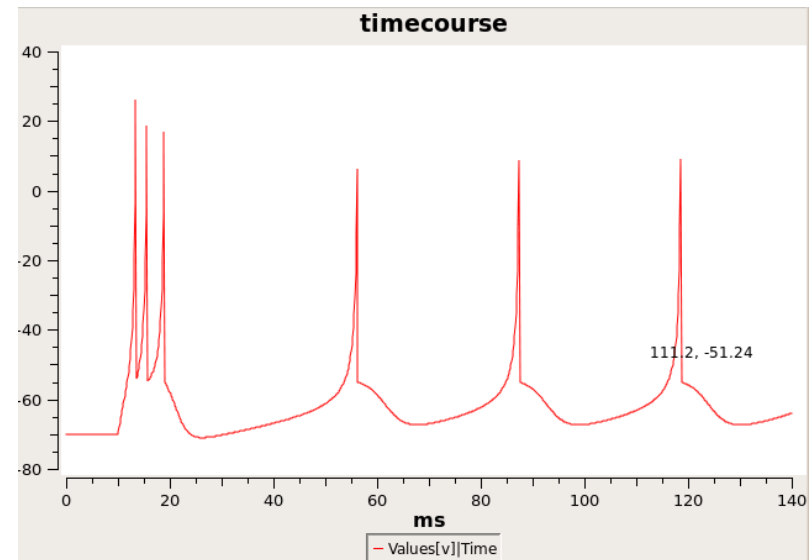
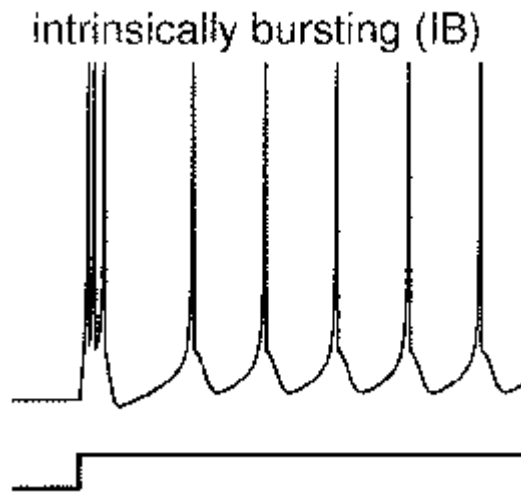



Fig.: COPASI, adjusted parameter values ($a=0.02$, $b=0.2$ **$c=-55$** , **$d=4$**)

Example

www.cellml.org/community/ Workshop Programme -- Cell The Lorenz Attractor, a class The ORd human ventricular The CellML project team -- C

models.cellml.org/e/71/view



Search

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The ORd human ventricular action potential model

This workspace houses a CellML 1.0 encoding of the 2011 O'Hara, Virág, Varró, & Rudy 2011 human cardiac ventricular action potential model (ORd). The original article is available at: <http://www.ncbi.nlm.nih.gov/pubmed/21637795>. This model was encoded based on the Matlab version of the code available from: <http://rudylab.wustl.edu/research/cell/>.

The CellML 1.0 encoding of the ORd model was contributed by Steven Niederer. While the units in the CellML encoding are not yet perfect, it is a match for the Matlab code and matches the simulation output for a single beat perfectly. The figure below shows the output of the simulation experiment [action-potential.xml](#) encoded in [SED-ML](#) using the original version of the model from Steve. This output is generated by running the simulation experiment using the [SED-ML Web Tools](#).

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Model Curation

Curation Status: ★★☆☆

Source

Derived from workspace [An encoding of the human ORd model by Steve Niederer](#) at changeset [a96ef0c61614](#).

Downloads

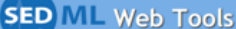
Complete Archive as .tgz

Navigation

- Ohara_Rudy_2011.cellml
- action-potential.xml

Simulate

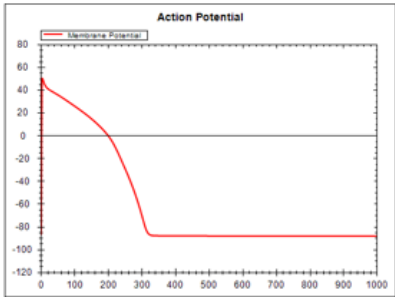
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Home Create Edit Details Simulate Validate About

Simulate

Action Potential



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7

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The Lorenz Attractor, a classical mathematical model

This workspace houses a CellML encoding of the 1963 Lorenz model which became a well-known demonstration of deterministic chaos. The original article DOI is [10.1175/1520-0469\(1963\)020<0130:DNF>2.0.CO;2](https://doi.org/10.1175/1520-0469(1963)020<0130:DNF>2.0.CO;2). This model was encoded based on the Octave code available in the related [Wikipedia article](#).

An [OpenCell 0.8 session file](#) is available. [SED-ML](#) can also be used to simulate this model, the simulation description is in [Lorenz_1963_sedml.xml](#), and the simulation experiment can be run using the [SED-ML Web Tools](#). The figures below show the results from OpenCell and from using [SED-ML](#).

Model Curation

Curation Status:



OpenCell:



Source

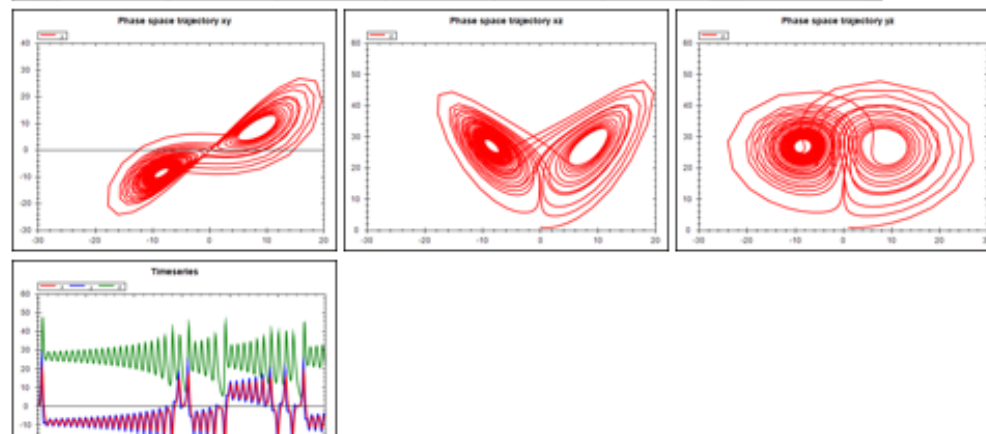
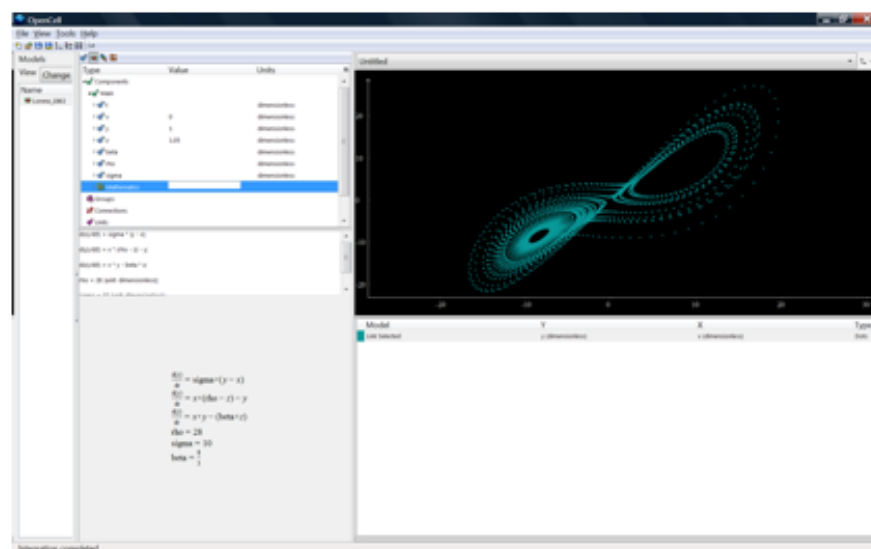
Derived from workspace [Deterministic Nonperiodic Flow](#) at changeset [1cdf5c612924](#).

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Navigation

[The Lorenz Attractor, a classical mathematical model](#)



SED-ML Level 1 Version 1

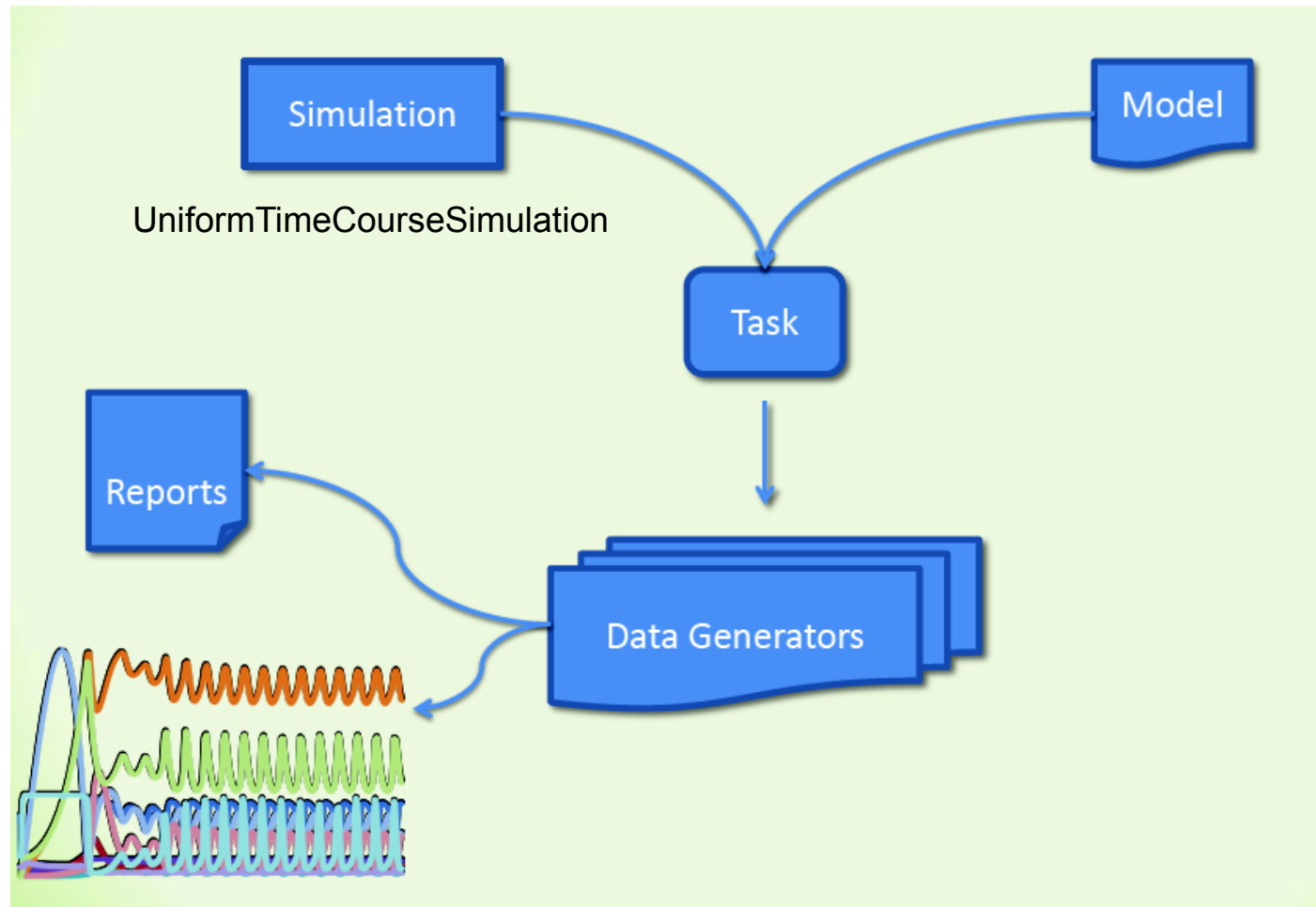
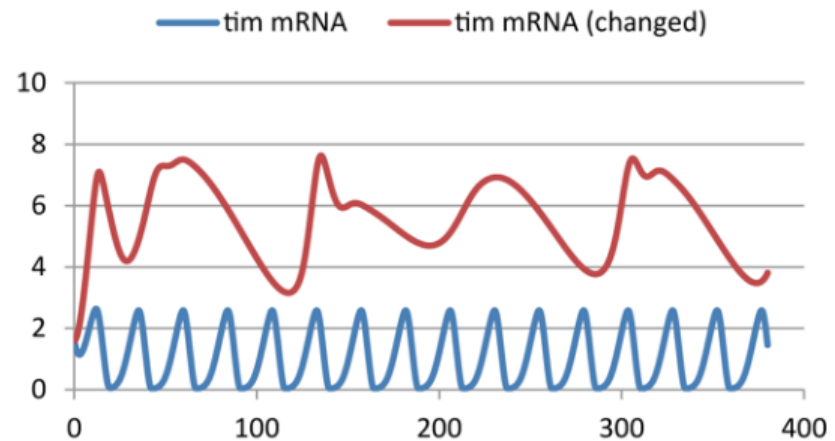
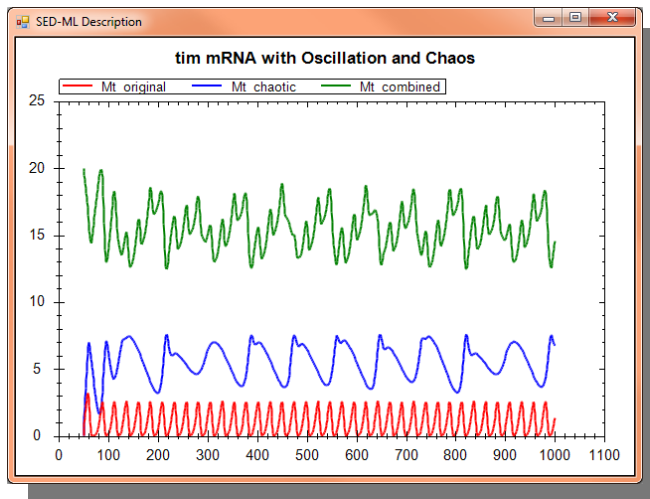


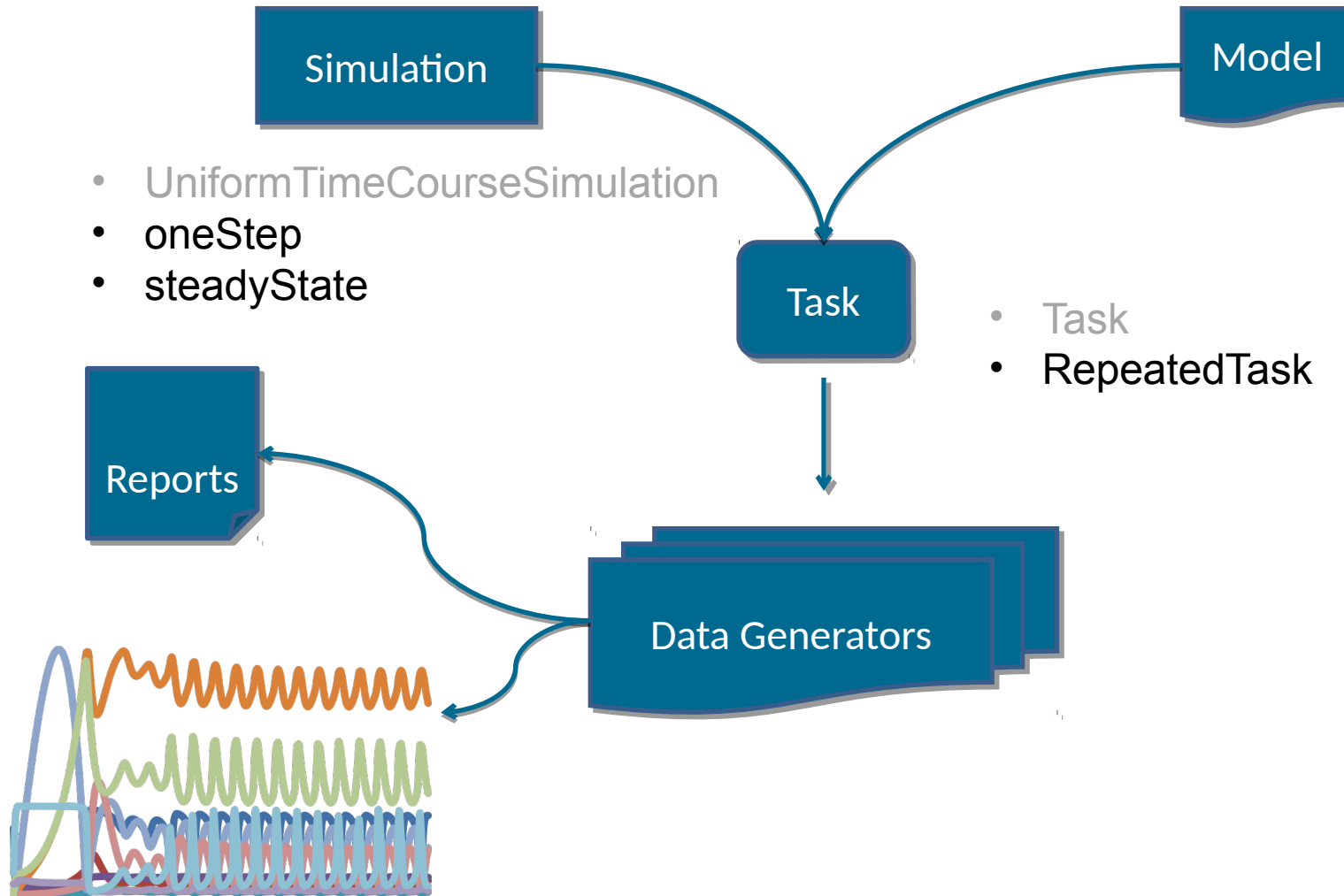
Figure: SED-ML structure (Waltemath et al., 2011)

SED-ML Level 1 Version 1

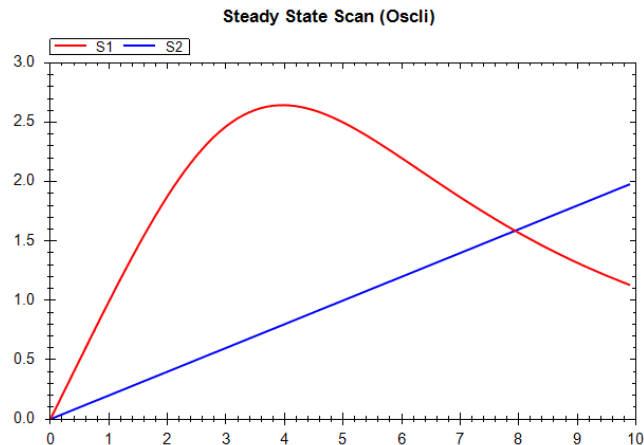
- Carry out multiple time course simulations
- Collect results from these simulations
- Combine results from these simulations
- Report / Graph the results



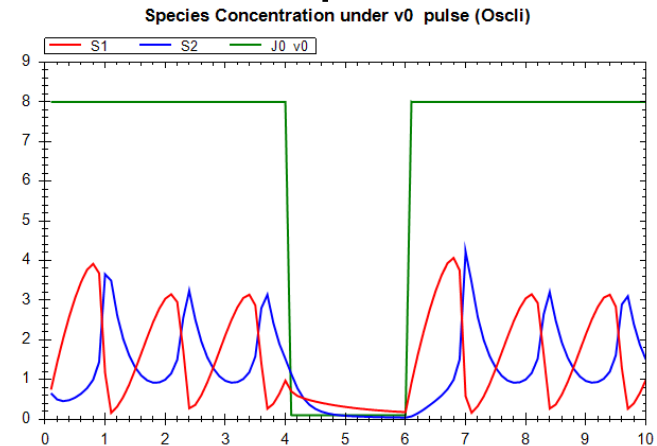
SED-ML Level 1 Version 2



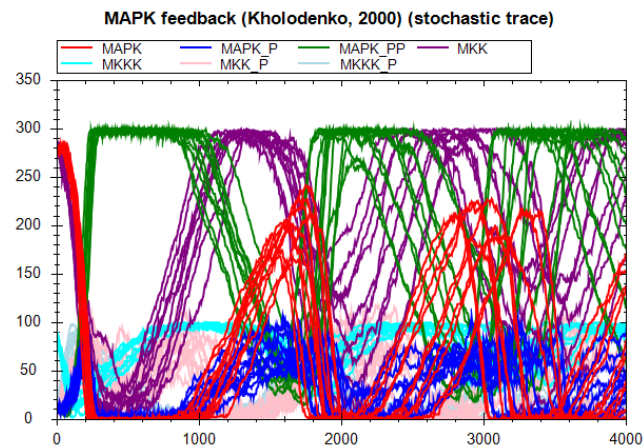
Parameter Scan



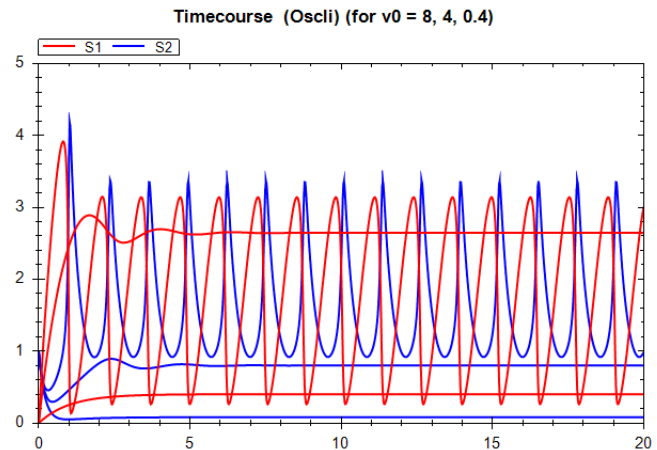
Pulse Experiments



Repeated Stochastic Traces



Time Course Parameter Scan



SED-ML next version

- Focus on the integration of “data” with SED-ML, e.g.,
 - experimental data for use in model fitting, parameter estimation
 - simulation data for testing implementations
- Adoption of NuML as standard data description format
 - <https://code.google.com/p/numl/>
 - XML description of underlying data (initially CSV).
 - provides a common data abstraction layer for SED-ML to utilise.