Elephant and NetworkUnit:

frameworks for analysis and validation of neural network models in NEST and neuromorphic systems

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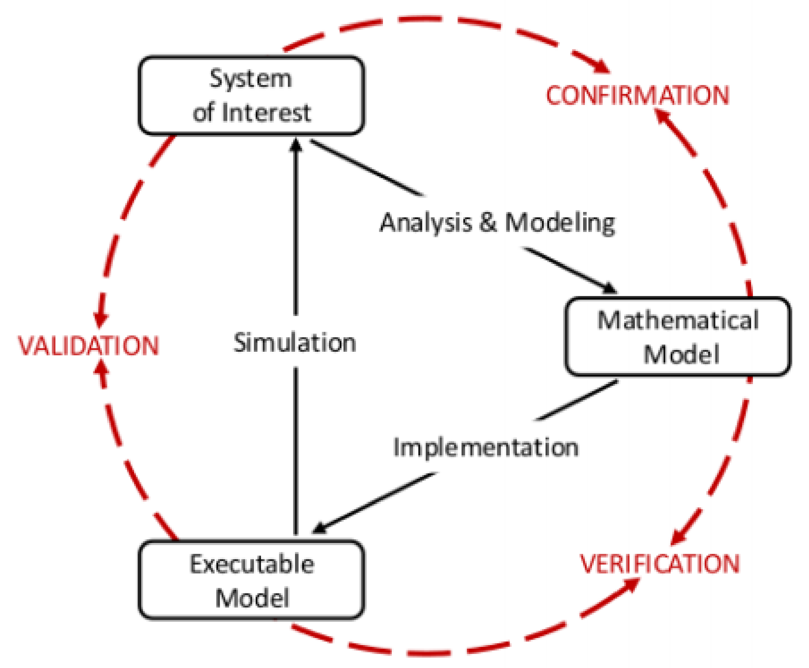
Concept of Validation and Substantiation

A model describes and predicts its **system of interest**, i.e., the entity selected for analysis. The model can be separated into the **mathematical model** (an abstract description) and the **executable model** (the corresponding implementation) which can perform simulations and generate testable predictions. [1][2]

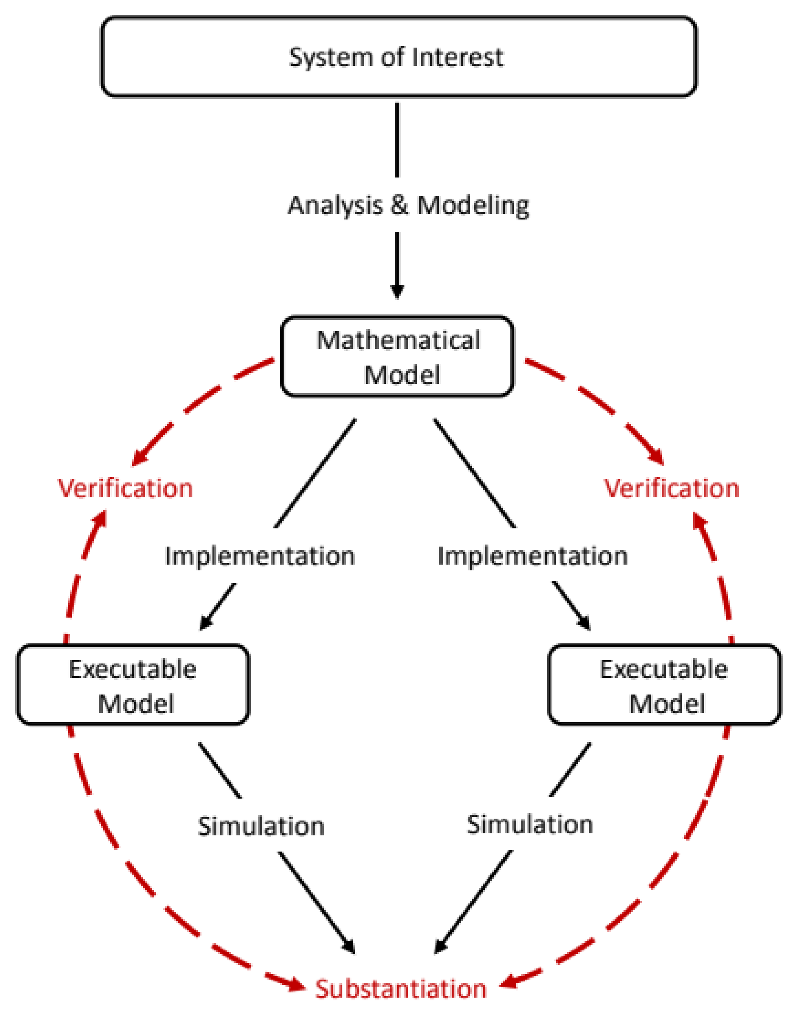


Confirmation: Assesses the plausibility of modeling choices and premises.

Verification: Ensures that the implementation is a correct representation of the mathematical model, concerning the code and the calculations.

Validation: Establishes confidence in the model by testing whether its prediction accuracy is in acceptable agreement with the system of interest.

Substantiation: Defined here as the evaluation and quantifying the level of agreement between two executable models. *In practice, substantiation is equivalent to validation and differs only in its interpretation.*



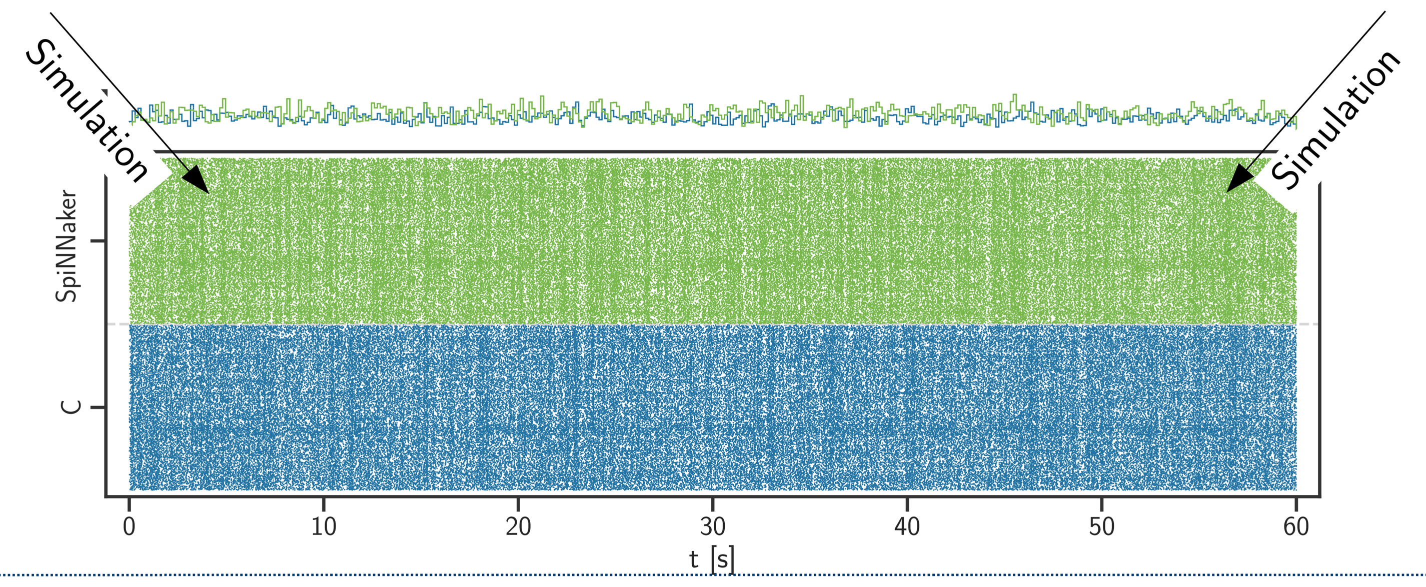
Showcase Model Implementation

Mathematical Model
polychronization network model by Izhikevich [3]
800 exc./200 inh. spiking neurons
random connectivity; out-degree=100;
random input; integer delays;
trained with STDP; measured without STDP

Implementation — Implementation

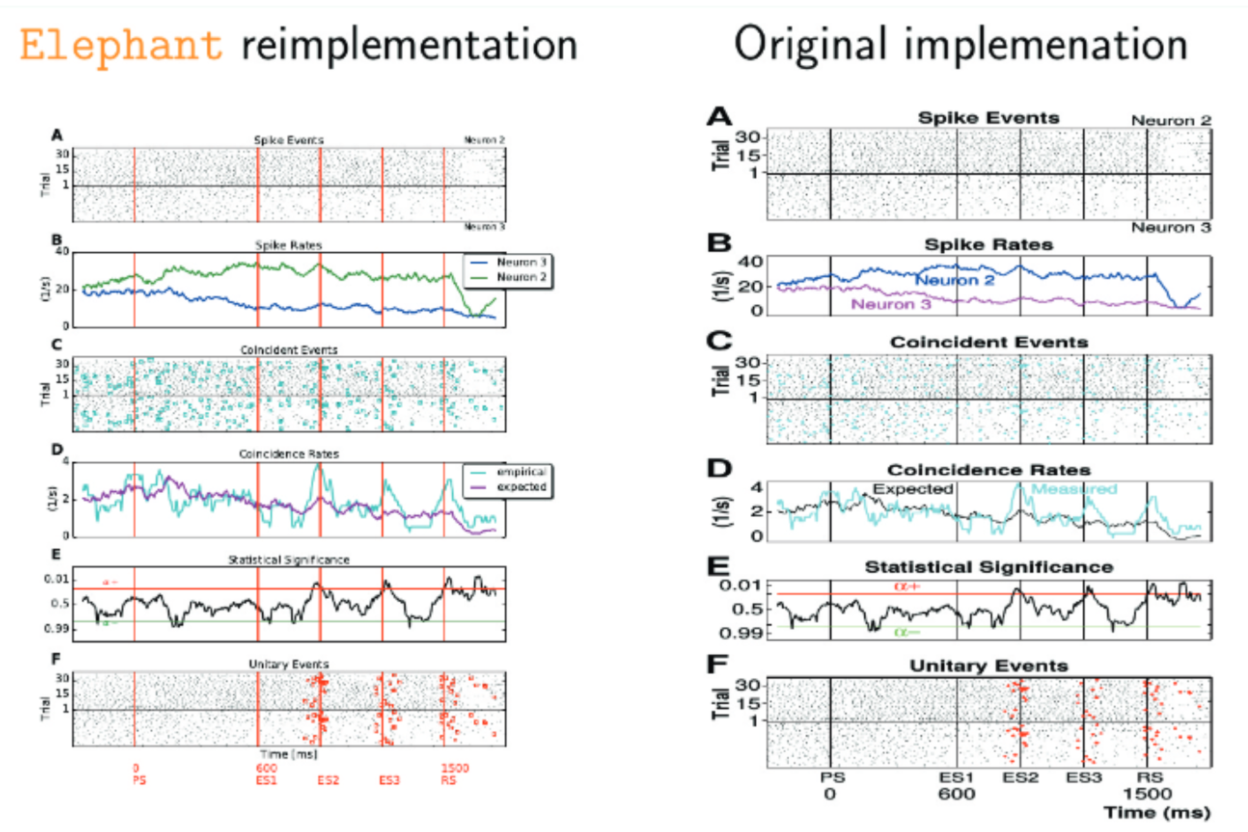
Executable Model
custom C code from [3],
refactored, 1ms time steps

Executable Model
SpiNNaker neuromorphic system:[4],
fixed point variable representation [5]



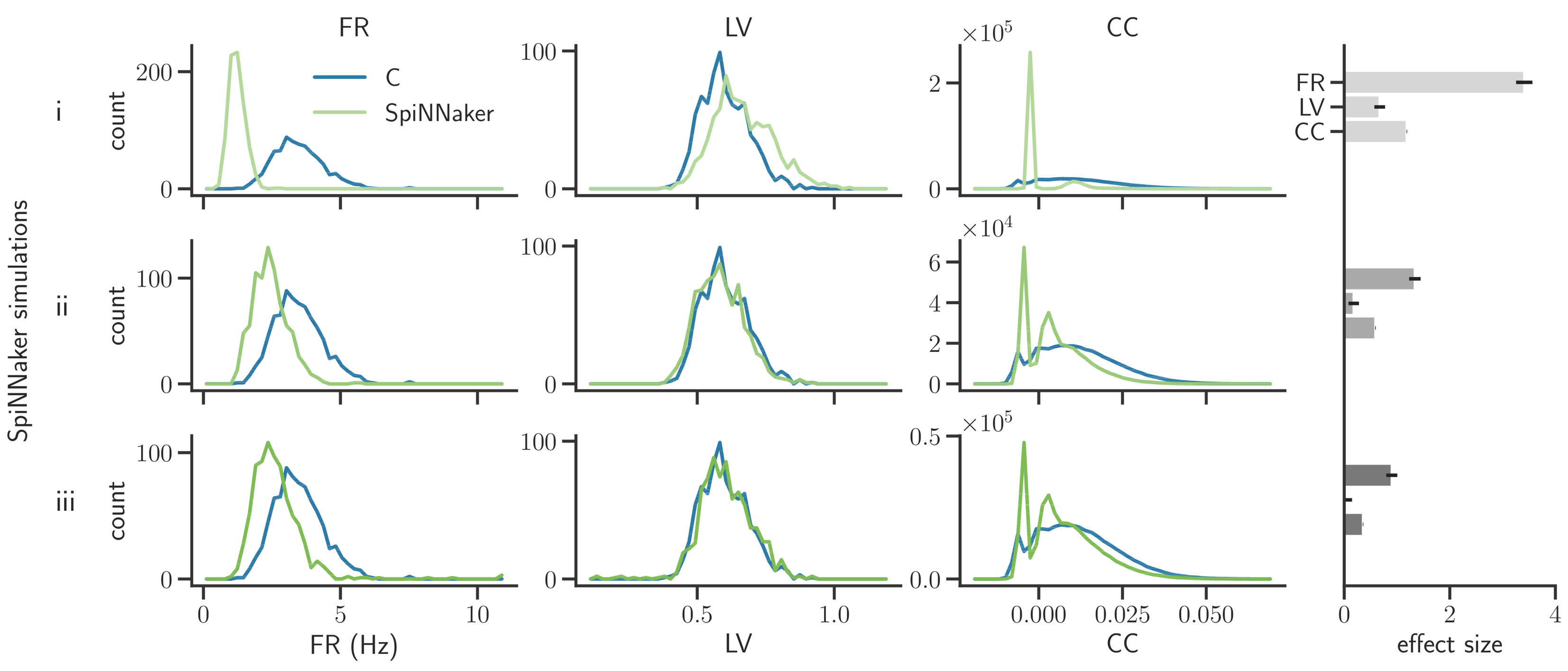
Method Validation in Elephant

Elephant (RRID:SCR_003833) [6] provides diverse methods to analyse brain dynamics of electrophysiology experiments and brain simulations.
The methods are tested against the results obtained from reference implementations [7]. Unit tests and CI integration verify that results stay the same over different versions of Elephant.

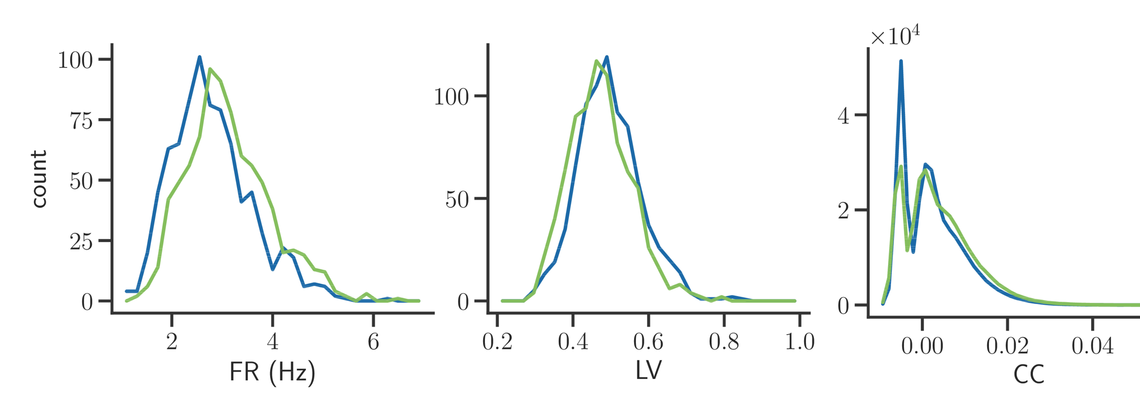


Substantiation via Iterative Model Validation Tests

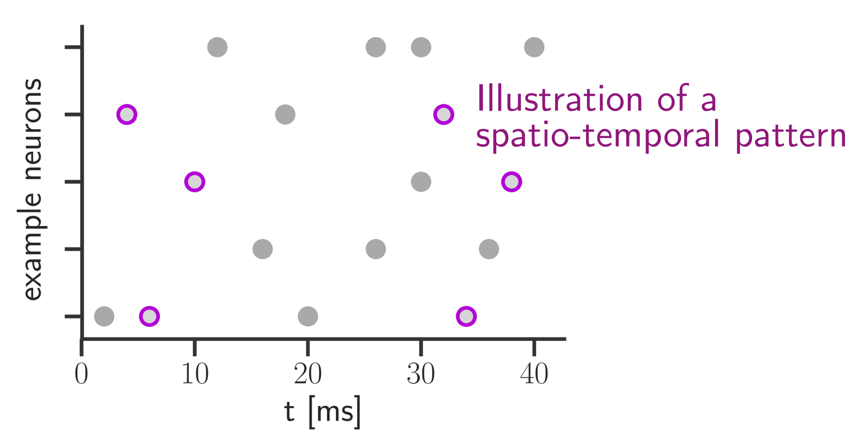
Step-wise alignment of the neuromorphic model implementation to the C model informed by network-level validation testing [8] (implemented in NetworkUnit [9]):
(i) uses an ESR ODE-solver,
(ii) adapts Izhikevich's neural dynamics algorithm,
(iii) uses a more exact fixed step-size forward Euler ODE-solver.

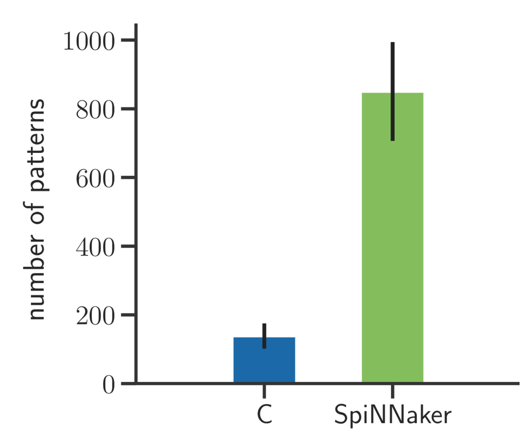


The iterative improvement is repeated until an acceptable agreement (for the intended application) is reached.



However, despite good agreement of other measures, complex measures such as the pattern density (detected with SPADE [10]) is not yet consistent.





Model Substantiation Take-Aways:

→ Validation tests can guide model development.
→ Multiple measures are needed for a comprehensive validation.
→ Agreement of complex measures does not entail agreement of simpler measures.
→ The appropriate level of agreement depends on the intended application.

References

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