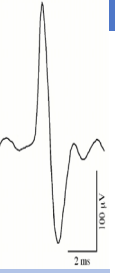

A New Approach to the Fast Simulation of Spiking Neural Networks

Speaker:

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Systems Theory and Information Technology
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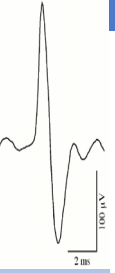
Advisor:

Dr. Michael Affenzeller

Topic



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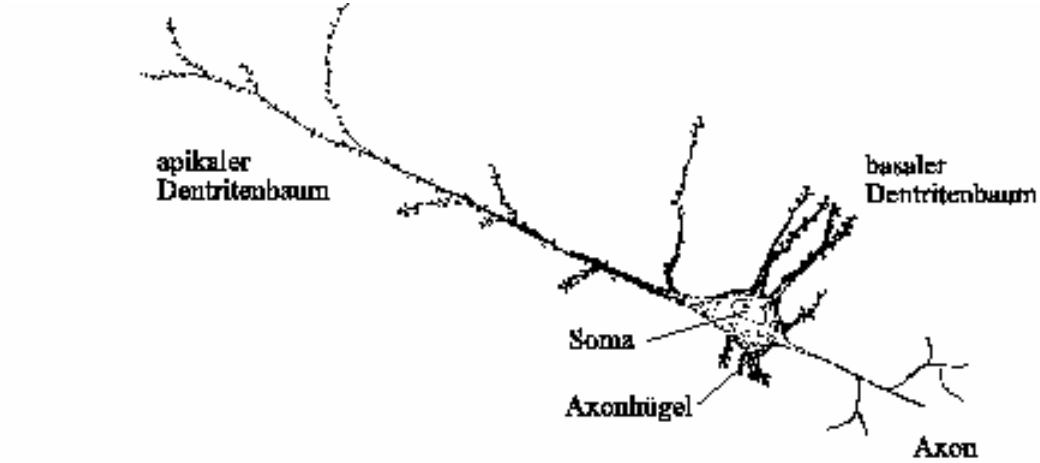
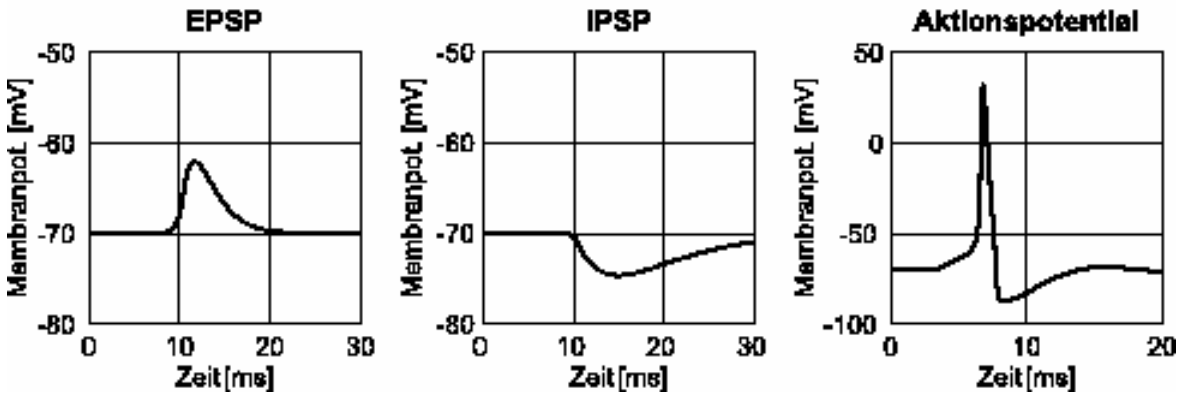
- Spiking Neural Networks
- Discrete Event Simulation
- New model for Event Simulation of Spiking Neural Networks
- New simulation framework
- Current state of research and outlook

Content

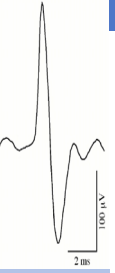
Biological Model





Pictures taken from
http://www.cis.tugraz.at/igi/tnatschl/online/3rd_gen_eng/3rd_gen_eng.html

„Where do we want to go ?“



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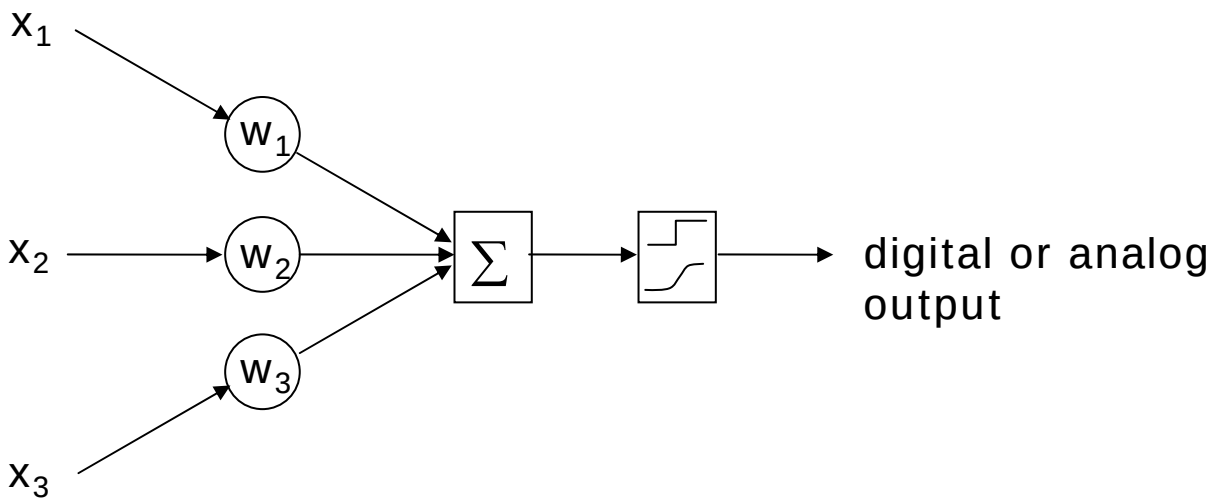
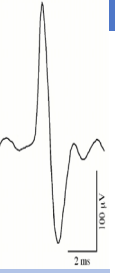
Artificial Neural Networks (ANNs) – Static variant

- Connections between Neurons, transmitting either binary or real values
- Computation of weighted sums over the input values with output function forms output value





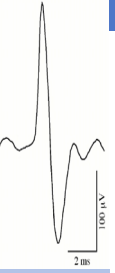
Potential problems with the static model of ANNs

„Why is this not good enough ?“

- Models only the firing rate of Neurons, (over-) simplifying the information transmission between Neurons
- Temporal aspect is not modeled at all

- Temporal coding is at least important for fast visual information processing

⇒ Spiking Neural Networks



„What is different to the known ?“

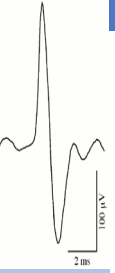
Comparison to (binary) Artificial Neural Networks

Equivalences

- Consisting of Neurons and Connections between Neurons
- Computational power lies in the connections
- Neurons sum up over the inputs
- Neurons are active when threshold is reached

Differences

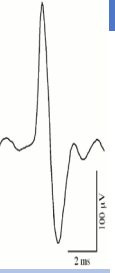
- Connections are more complex (modelled as Synapses)
- Connections have more degrees of freedom
- Neurons sum up time-dependently (integrate)
- Threshold not constant (time-dependent)
- **No restriction in coding**



Advantages of Spiking Neural Networks (SNNs)

- Modeling biological neural networks more closely
  - More degrees of freedom
  - Simple solutions to some problems
- Independence of coding
- Temporal aspect

„How can we do it better?“



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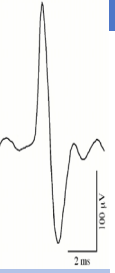
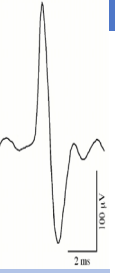


Continuous Simulation

- Normal (continuous) simulation uses fixed or variable time steps
- System states are computed at each time step
- Time steps are global for the whole system, independent of change rate

⇒ inefficient for systems with many system states and low or diverse change rates of these states



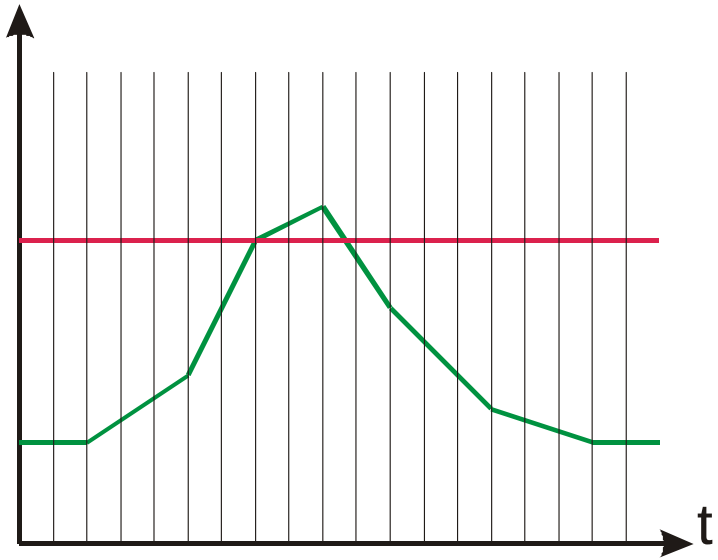
Discrete Event Simulation (DEVS)

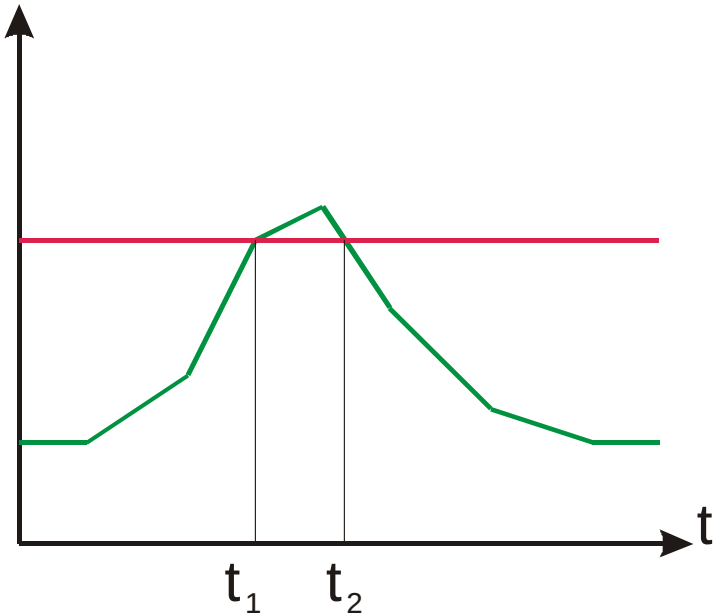
- Event (change of a system state) is the focus
- Simulate only when states change: concentrate on important states (critical points of the simulation)
- Events can cause subsequent events

⇒ can significantly improve simulation speed

„Is there a better way ?“

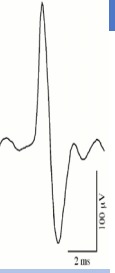
Comparison of simulation techniques





- *Continuous simulation*: compute system state at given time
- *Event simulation*: compute time when system reaches important state

„Now what is the difference ?“



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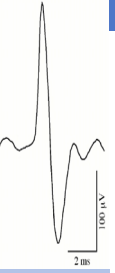
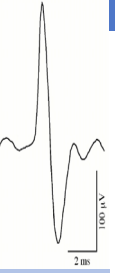


Exploiting the advantages of DEVS

- Continuous simulation is well suited for biological research on Neural Networks
- Currently simulating SNNs is expensive for computational problems
- More efficiency needed for using SNNs in practical applications
- Concentrating on critical points in the simulation ⇒ Event simulation

„Can we gain something ?“



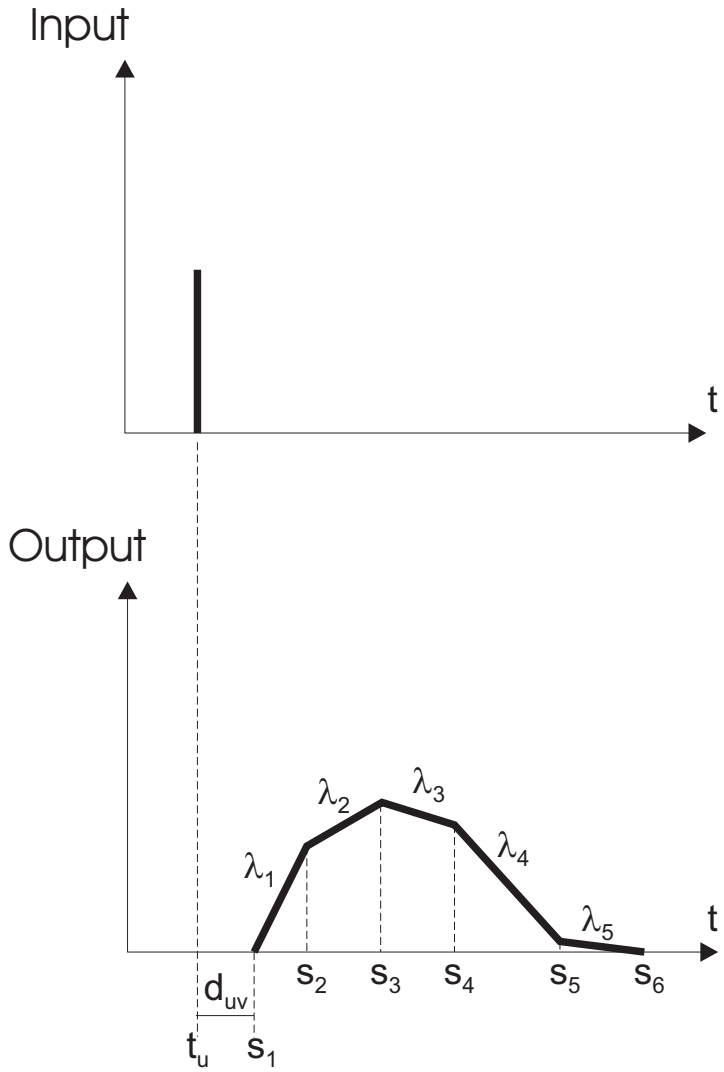
Connecting SNNs with DEVS

- *Spike* = firing event
- *Neuron fires a spike* = Neuron sends a firing event to all directly connected Synapses
- Synapses forward the event to their post-synaptic Neuron as a response function, depending on their parameters
- When the new Neuron potential exceeds the threshold, a new firing event is created

„How can it be done ?“

Simplification of SNNs

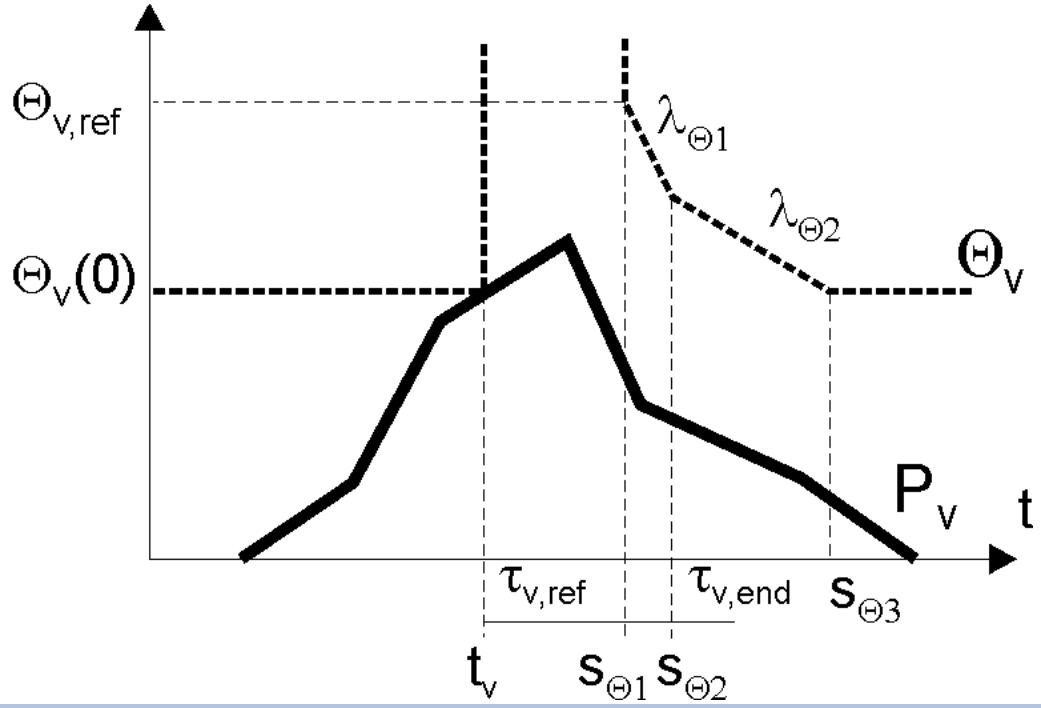
- Spikes (firing events) mark a moment in time, without a shape
- Synapses transform Spikes to (piecewise linear) functions
- Response function is merged with current Neuron potential to obtain future development of the potential (weighted sum)



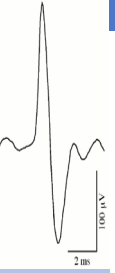
„How can it be done ?“

Simplification of SNNs

- Transition from continuous functions to piecewise linear functions
- Intersection between Neuron potential and Neuron threshold is calculated for finding next firing event



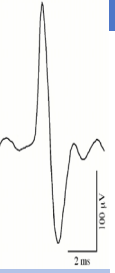
„How can it be done ?“



Advantages of the new model

- Possibly significantly higher simulation speed and better scalability
- High flexibility in modeling
- Well suited for reactive systems
- Well suited for teaching purposes

„What do we gain from this ?“



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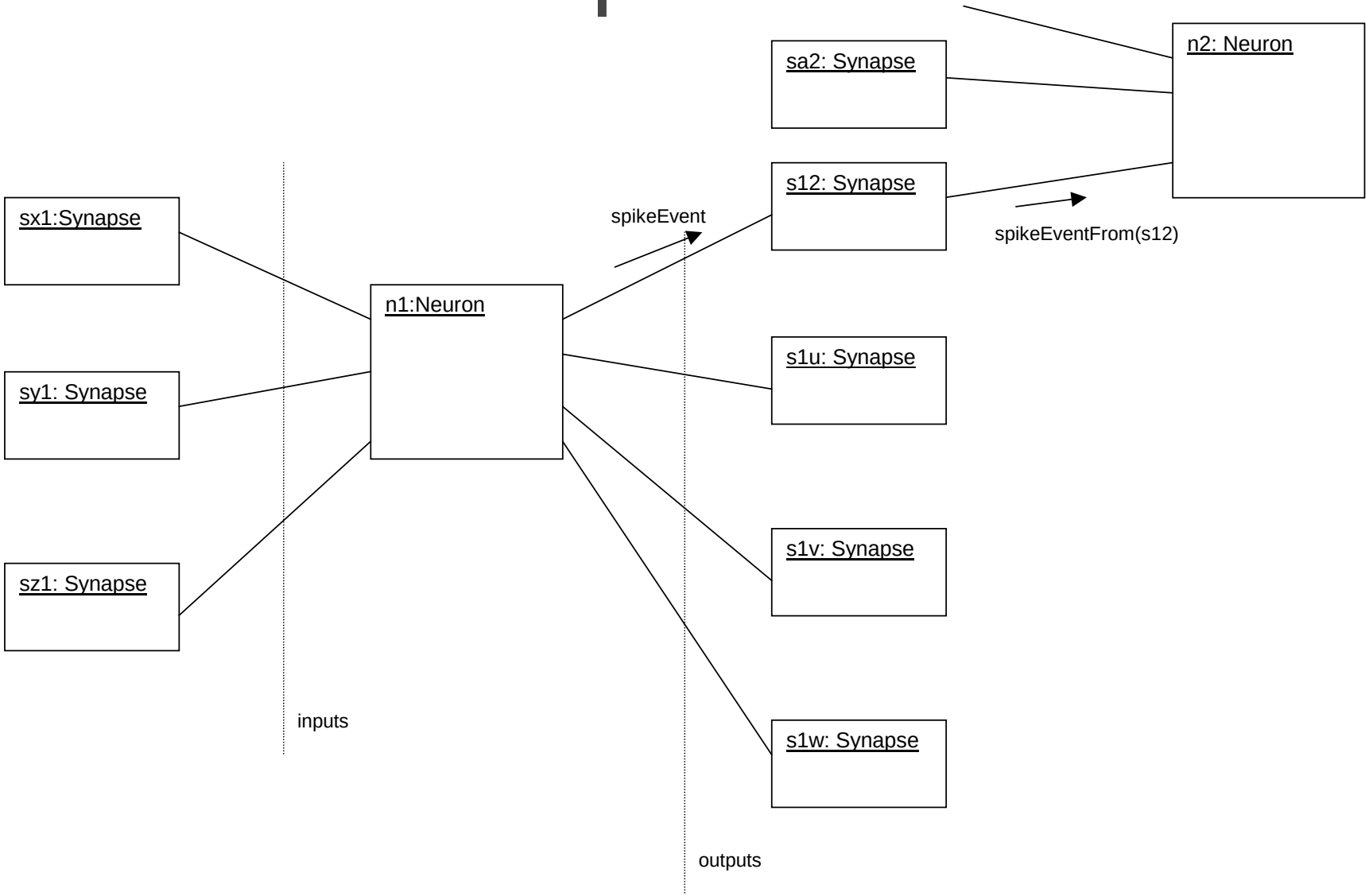
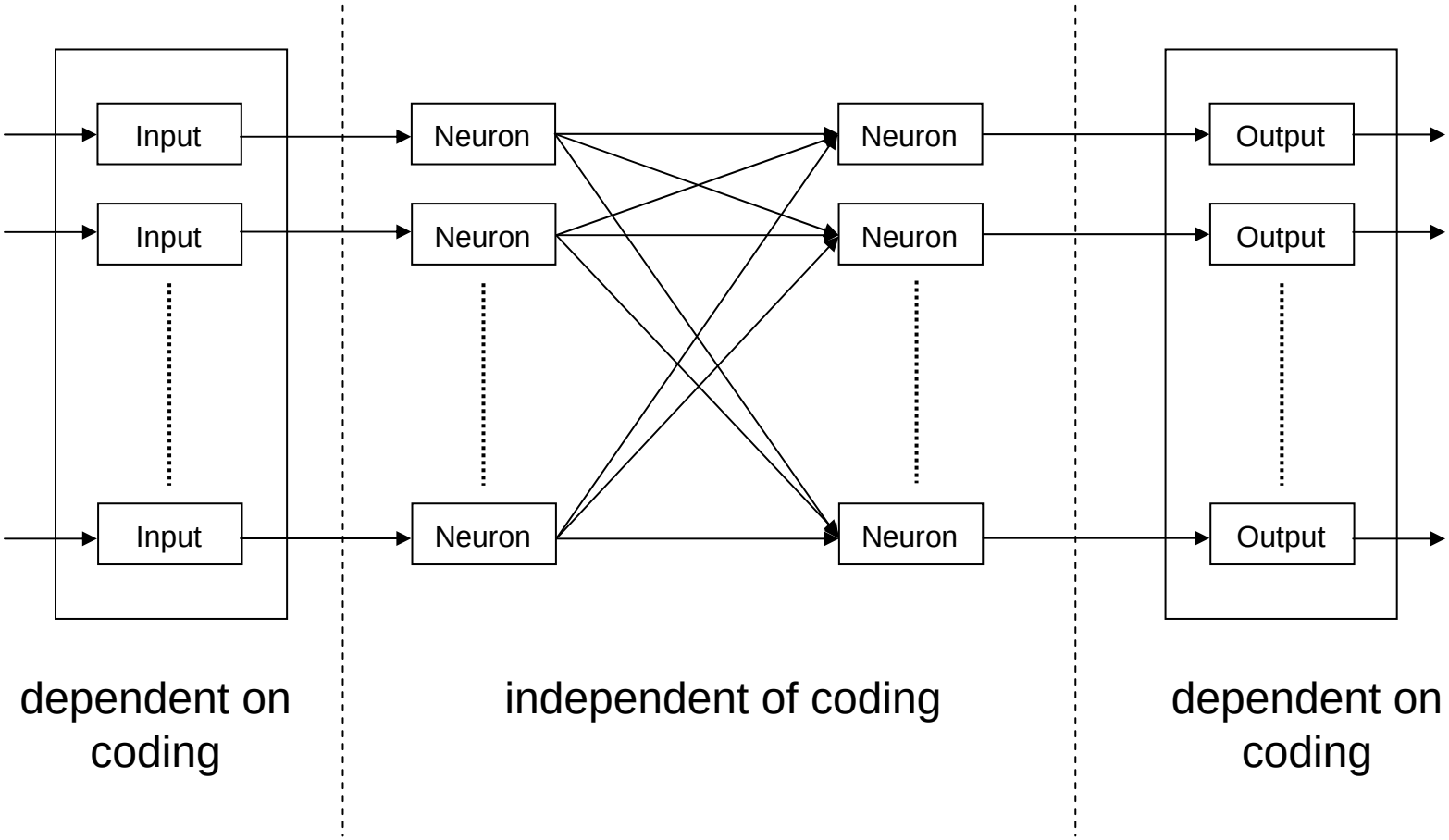
Basic Concept



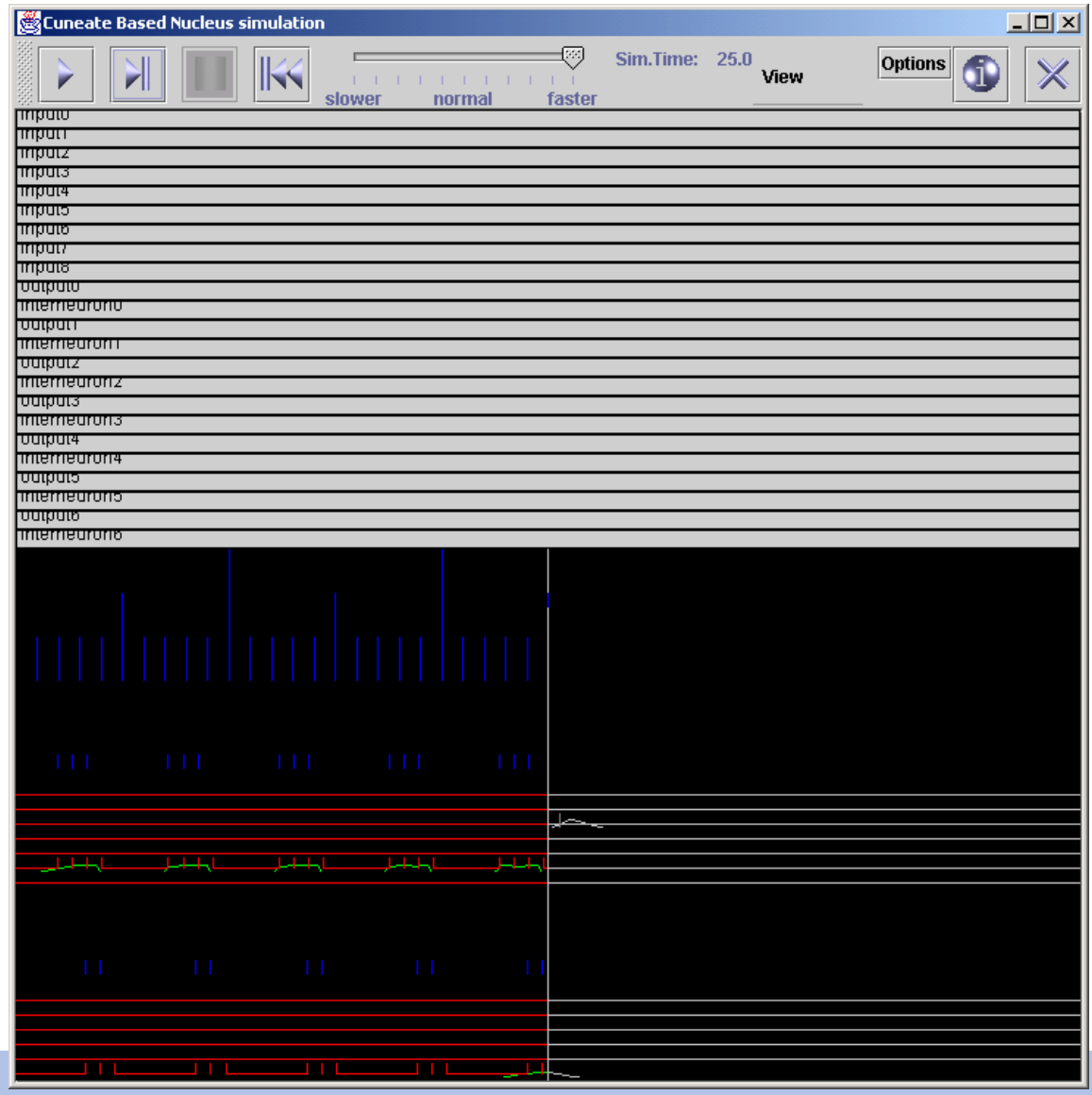
„How is it implemented ?“

Network in- and outputs



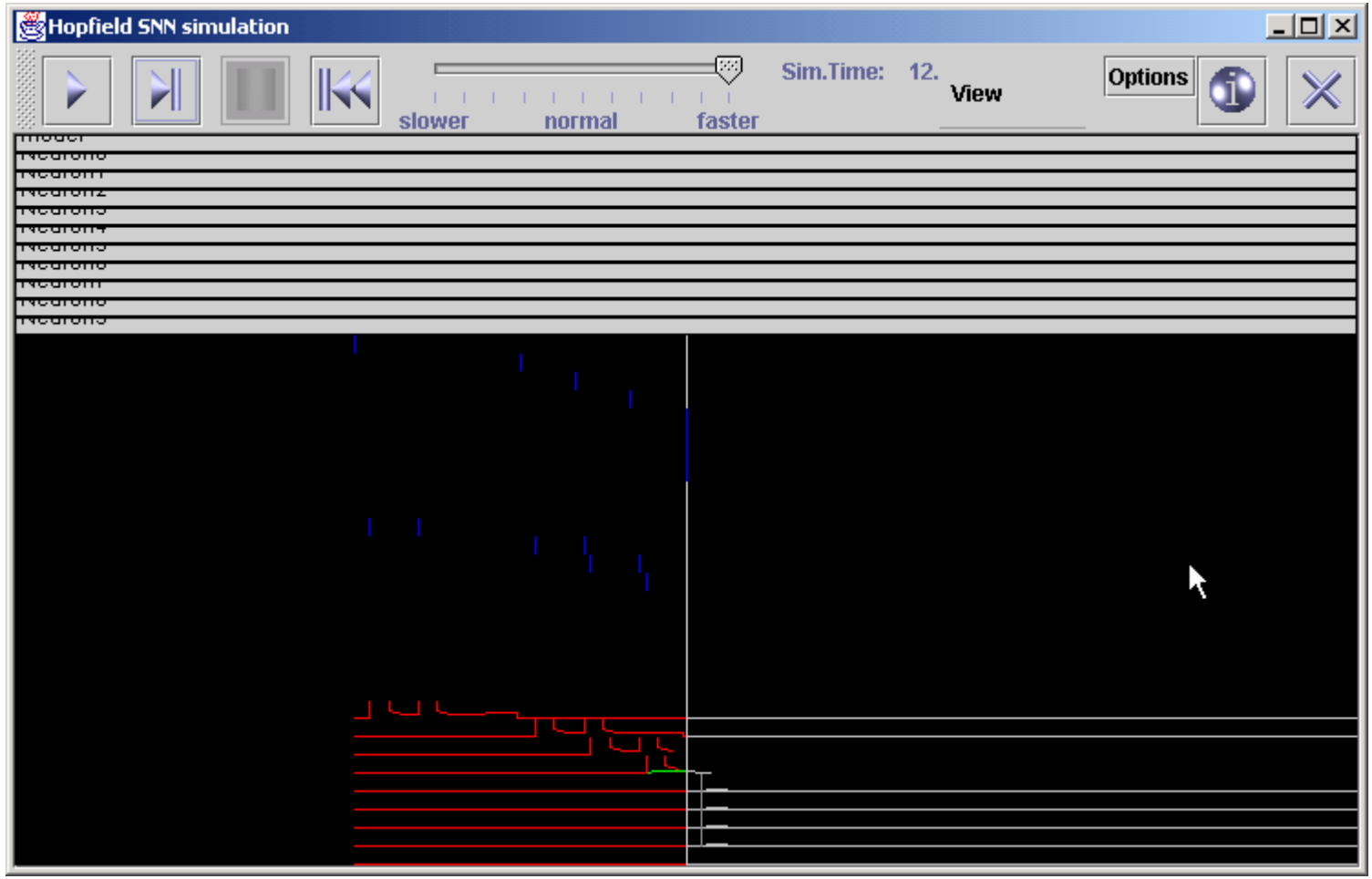
„How is it implemented ?“

Simulator

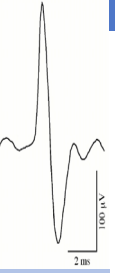


„Does it really work ?“

Simulator



„Does it really work ?“



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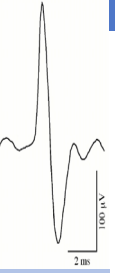
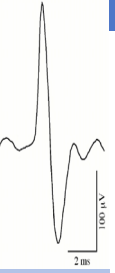


Current state of research

- Basic framework is complete
- Biologically inspired implementation of a Cuneate Based Nucleus Network
- Implementation of a Hopfield network is finished, but not fully working
- Implementation of a SOM network is complete, more testing and interpretation of results needs to be done

- Simulation technique is stable and working

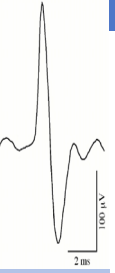
„Where are we now ?“



Summary

- Spiking Neural Networks offer advantages over Static Neural Networks.
- Event simulation of Spiking Neural Networks can allow the use in practical applications.
- The proposed technique is based on a new formal model and already works in example simulations.
- The fast simulation of Spiking Neural Networks is just at the beginning, much remains to be done.

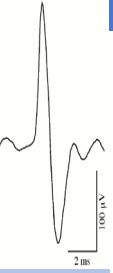
„What is known until now ?“



State of the diploma thesis

- Abstract, Introduction: **50%**
- Theoretical Foundations: **95%**
- Model: **95%**
- Framework: **95%**
- Experimental Results: **90%**
- Advanced Techniques: **40%**
- Conclusion and Future Perspectives: **30%**

- Comparison with GENESIS: currently only few results, planned for future work



Thank you for your attention