

A New Approach to the Fast Simulation of Spiking Neural Networks

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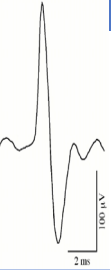
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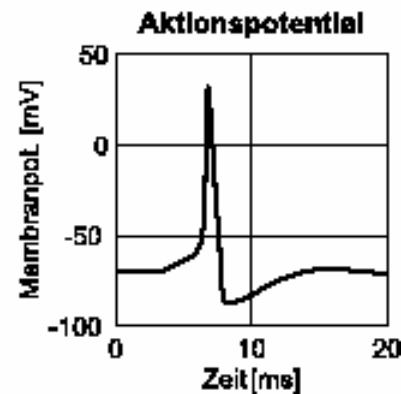
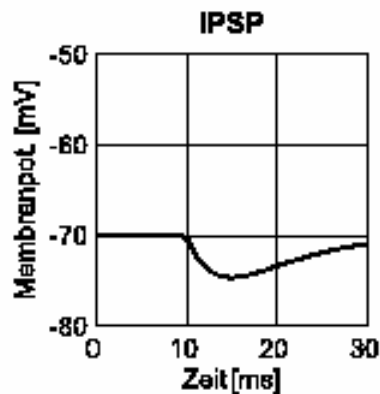
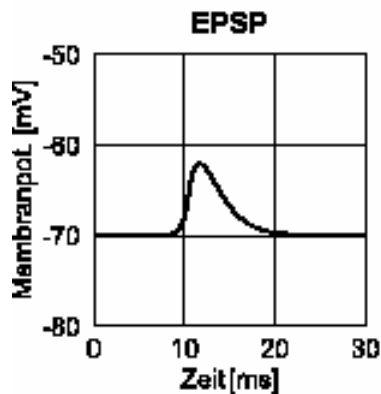
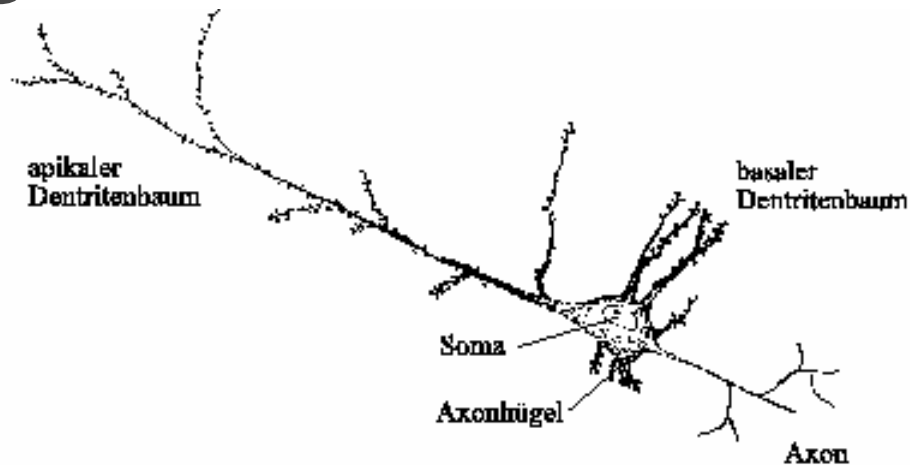
Topic



Structure

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

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?”

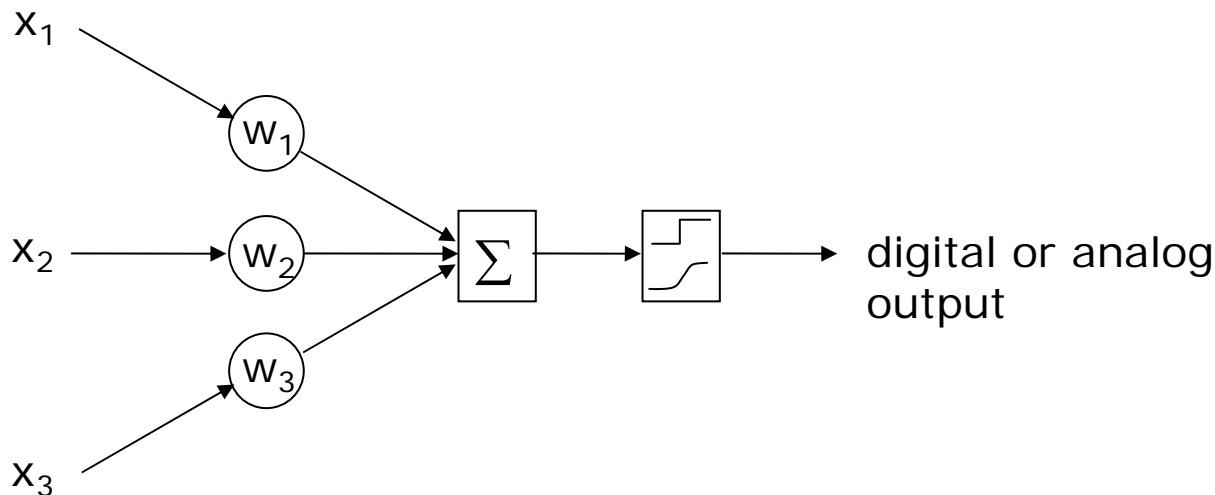


Structure

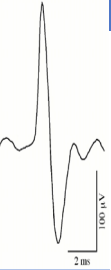
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Artificial Neural Networks (ANNs) – Static variant

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



„How do we currently compute?“

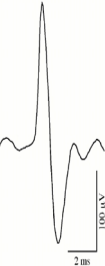


Potential problems with the static model of ANNs

- 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

„Why is this not good enough?“



Comparison to (binary) Artificial Neural Networks

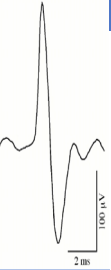
Equivalences

- 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**

„What is different to the known?“



Advantages of Spiking Neural Networks (SNNs)

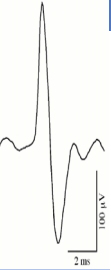
- Modeling biological neural networks more closely
 - More degrees of freedom
 - Simple solutions to some problems
- Independence of coding
- Temporal aspect

„How can we do it better?“



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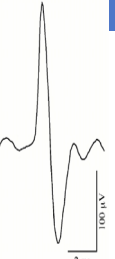


Continuous Simulation

- 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

„How can we simulate?“



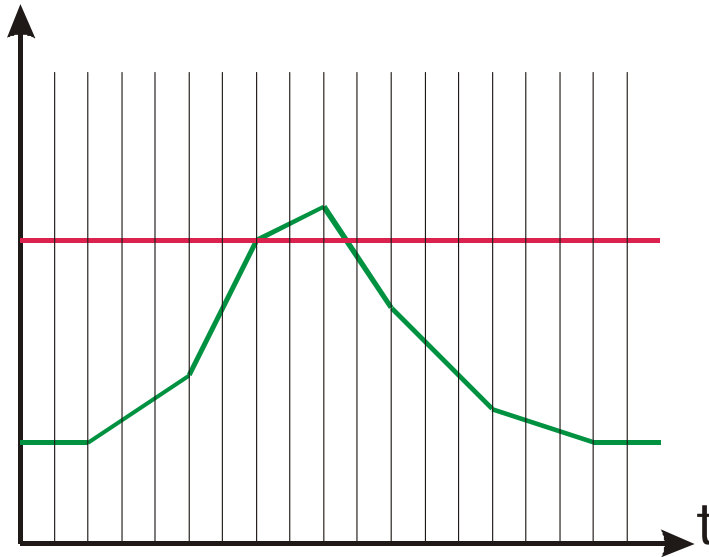
Discrete Event Simulation (DEVS)

- 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

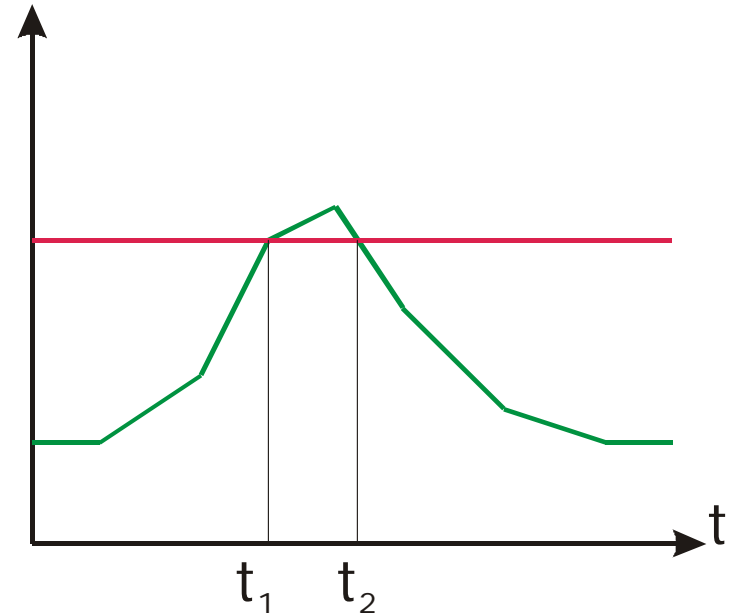
⇒ can significantly improve simulation speed

"Is there a better way?"

Comparison of simulation techniques



- *Continuous simulation:* compute system state at given time



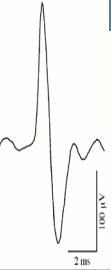
- *Event simulation:* compute time when system reaches important state

„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 \Rightarrow Event simulation

„Can we gain something ?“



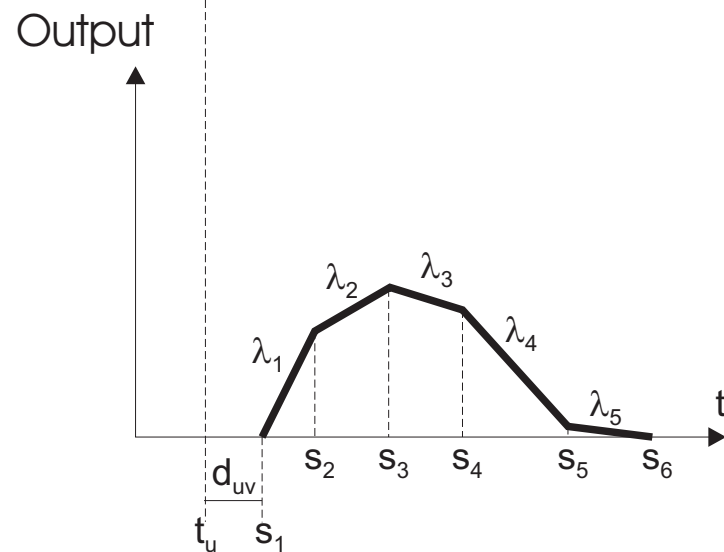
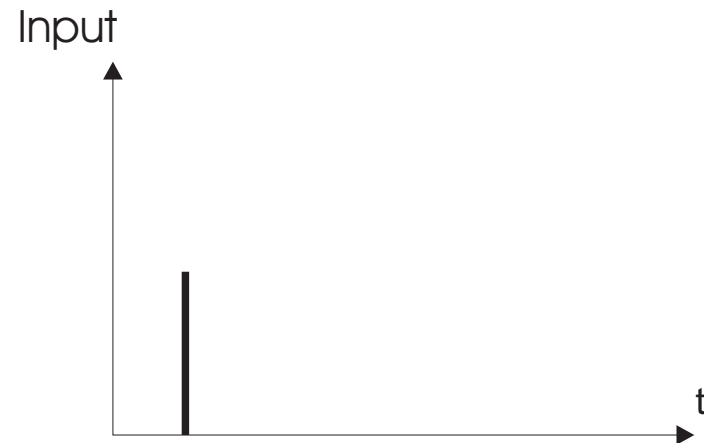
Connecting SNNs with DEVS

- *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?“

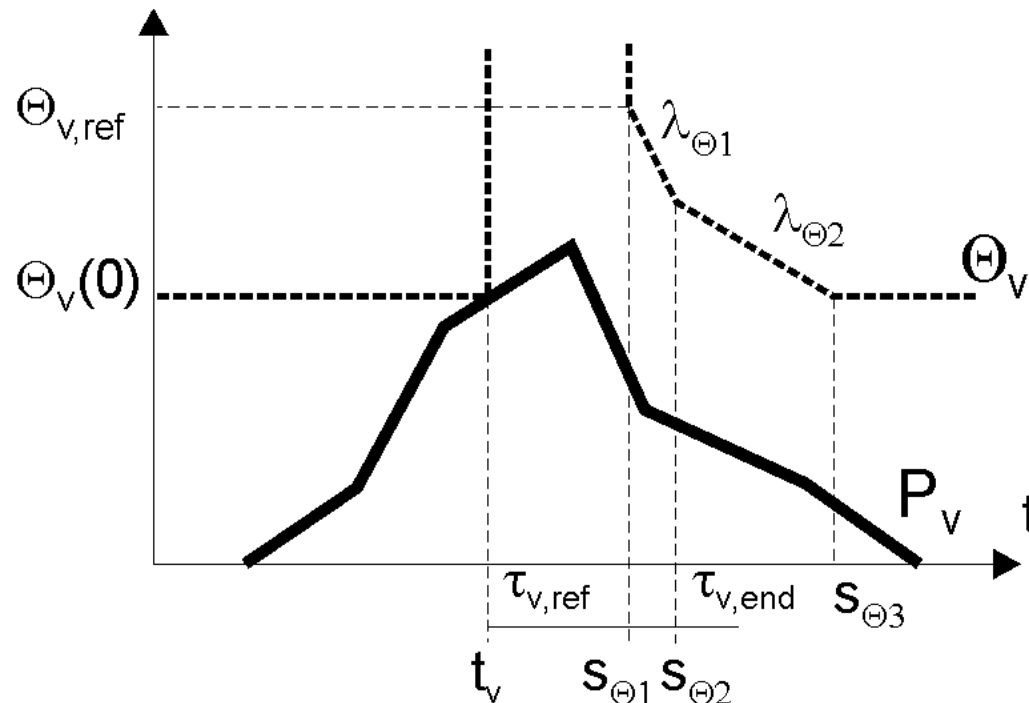
Simplification of SNNs

- 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)

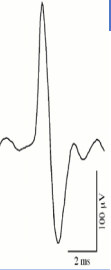


Simplification of SNNs

- 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

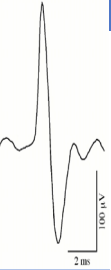
„What do we gain from this ?“



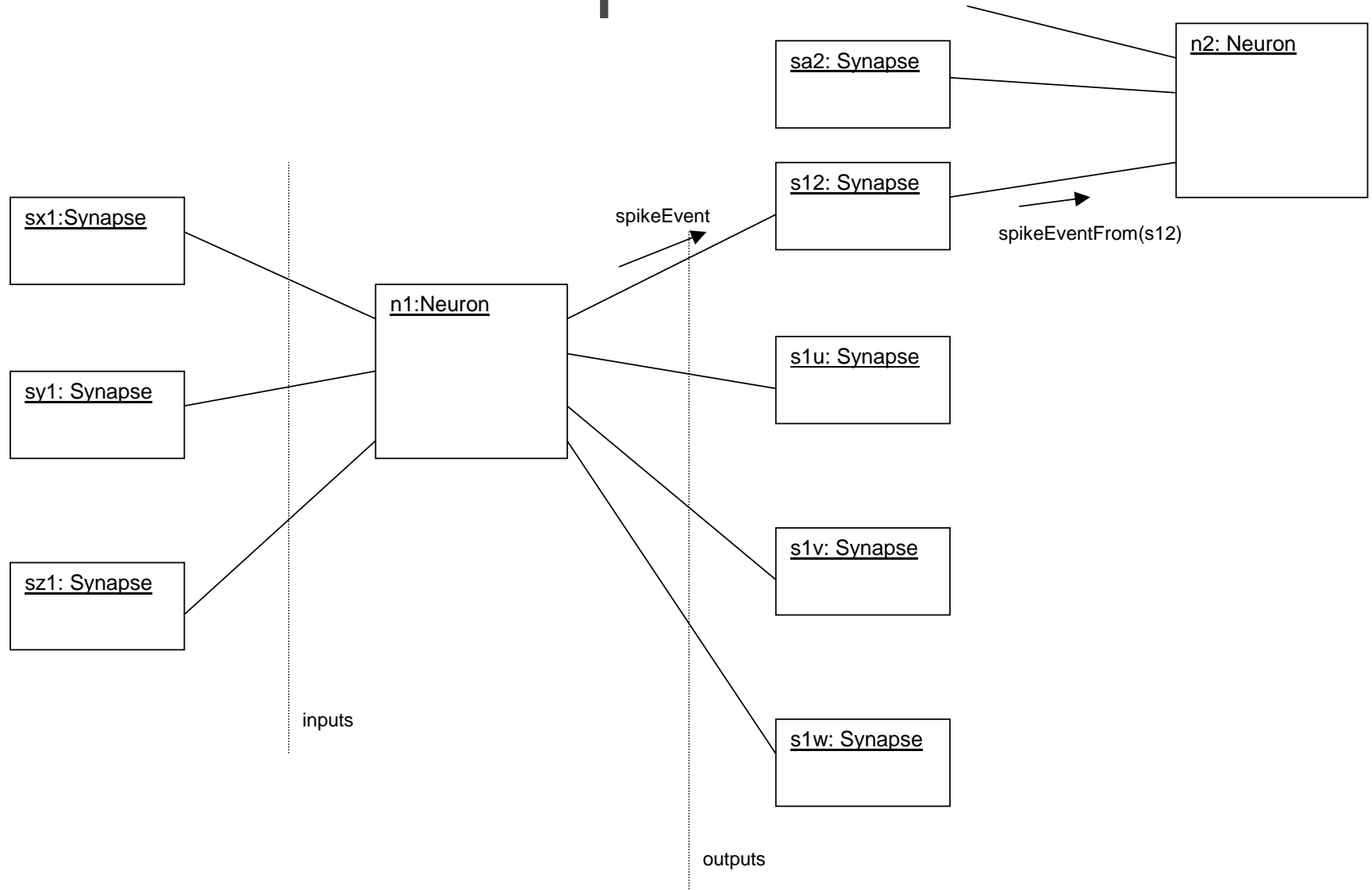
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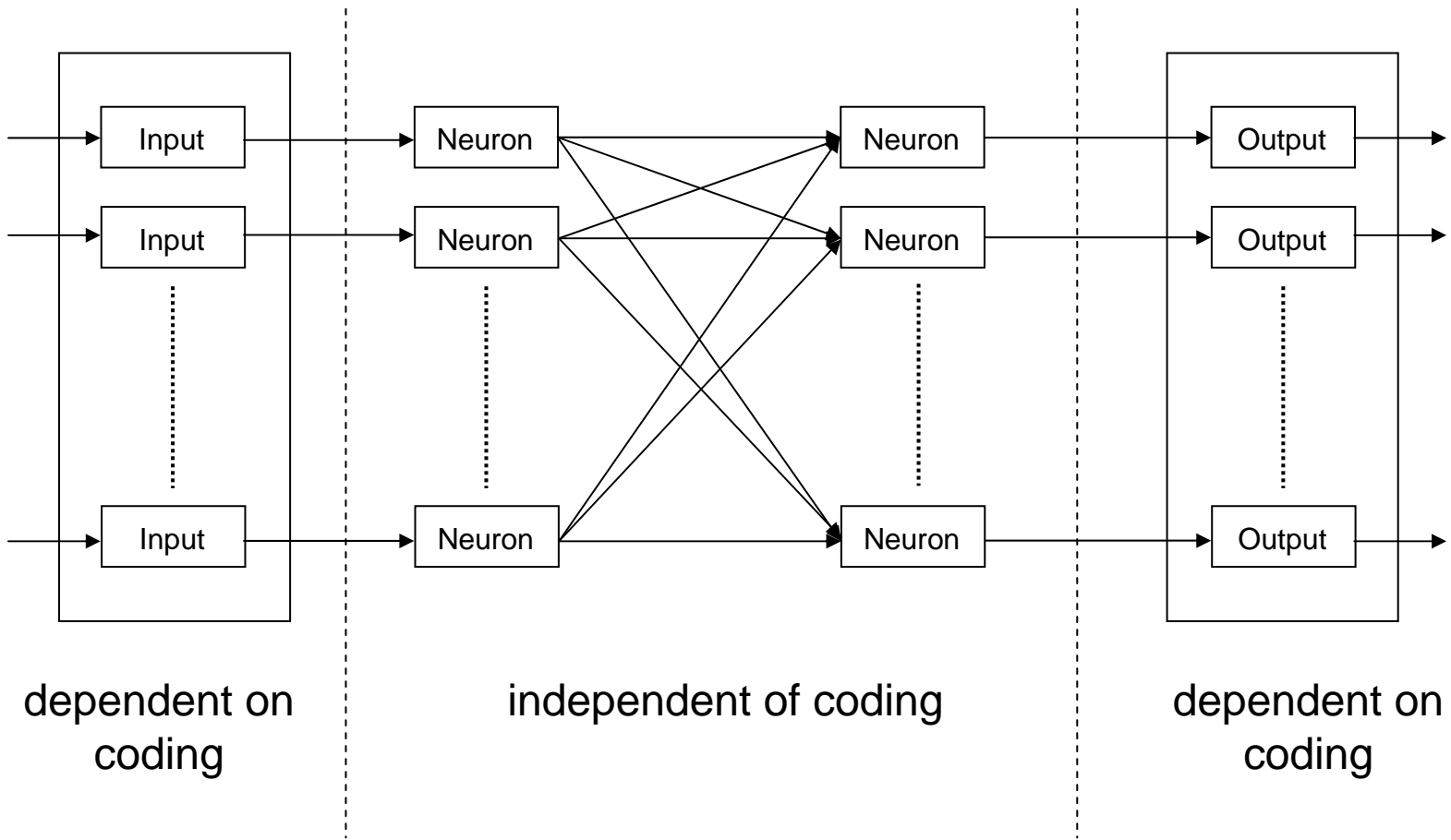
Basic Concept



„How is it implemented?“

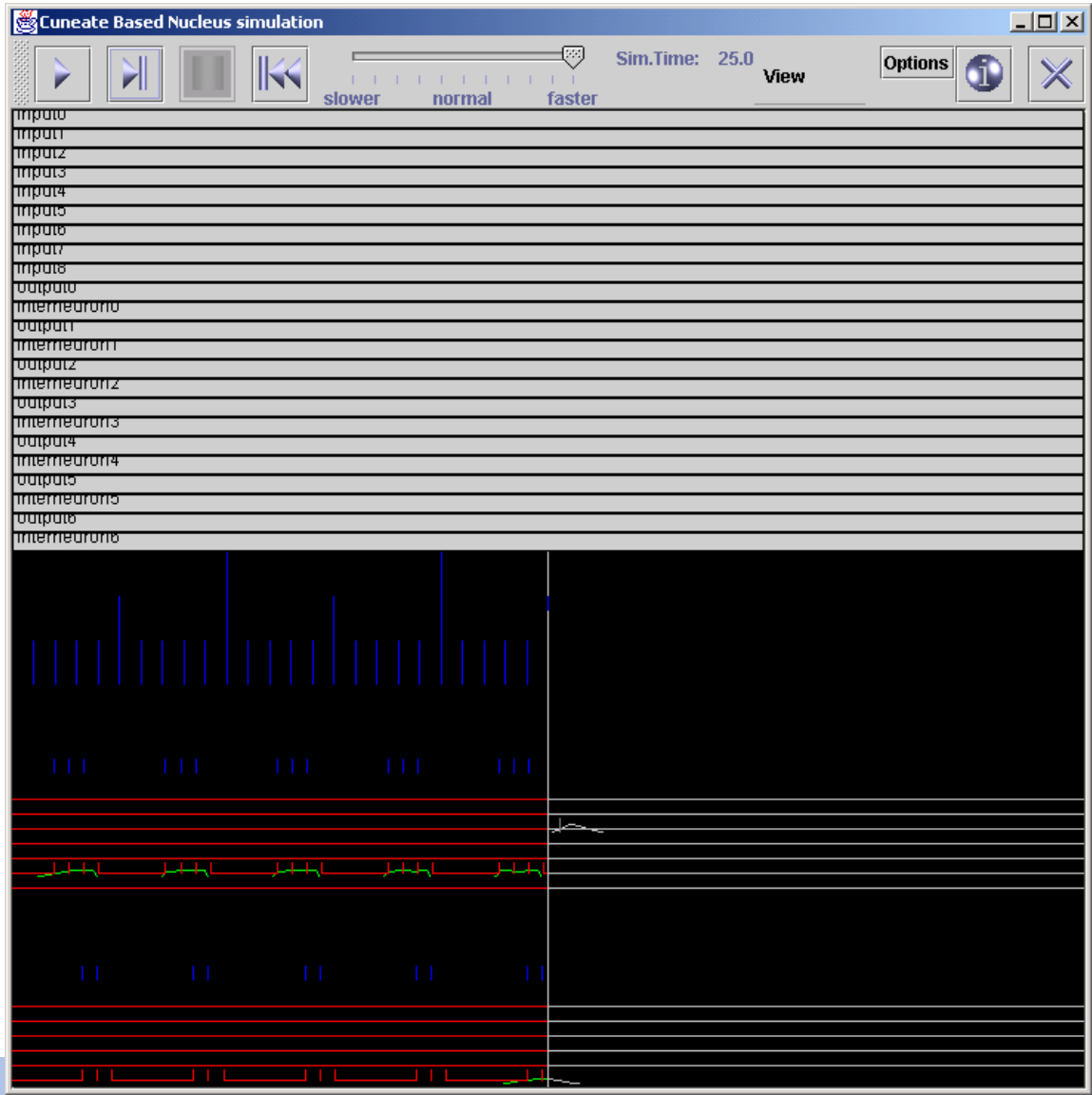


Network in- and outputs



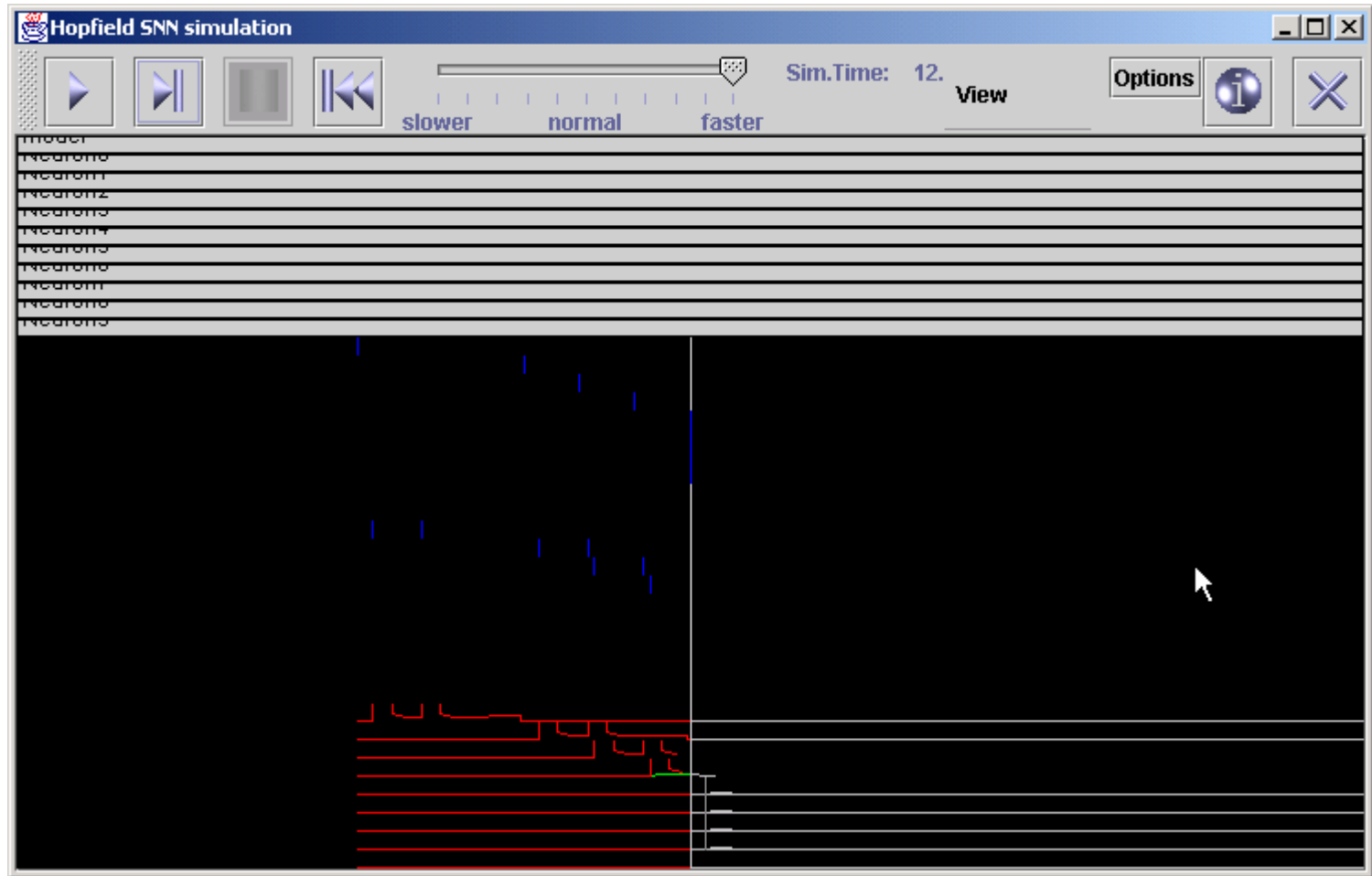
„How is it implemented?“

Simulator

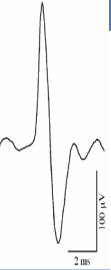


"Does it really work?"

Simulator



"Does it really work?"



Structure

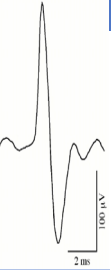
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Current state of research

- 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.

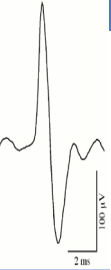
„What is known until now?“



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