



# DEVS Simulation of Spiking Neural Network

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Topic



# Structure

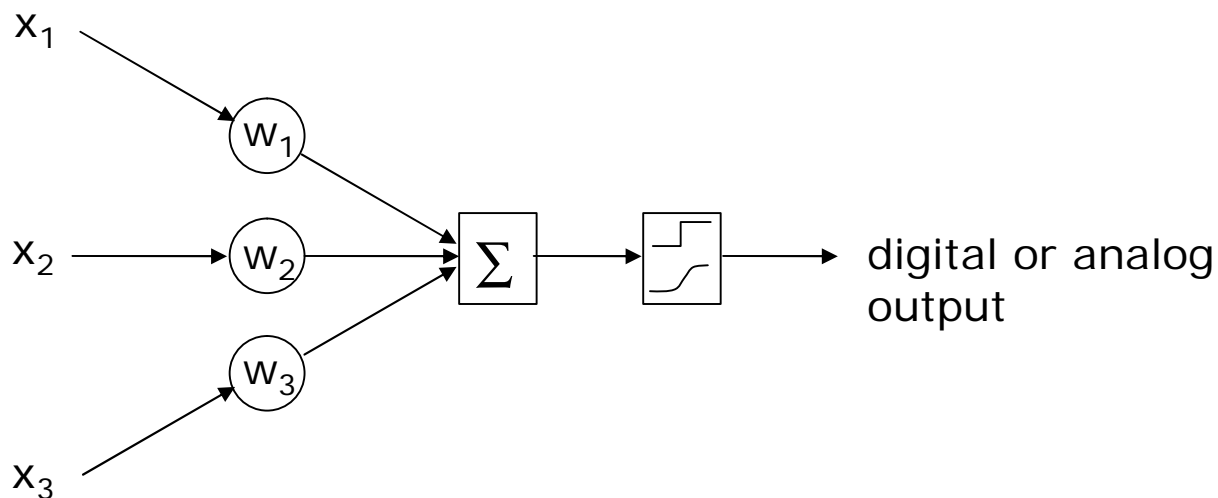
- Spiking Neural Networks
- Discrete Event Simulation
- New model for Event Simulation of Spiking Neural Networks
- New simulation framework
- Current state of research and outlook



„How do we currently compute?“

# 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





*„Why is this not good enough ?“*

# 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



*„How can we do it better?“*

# 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



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„How can we simulate?“

# 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



*"Is there a better way?"*

# Discrete Event Simulation (DEVS)

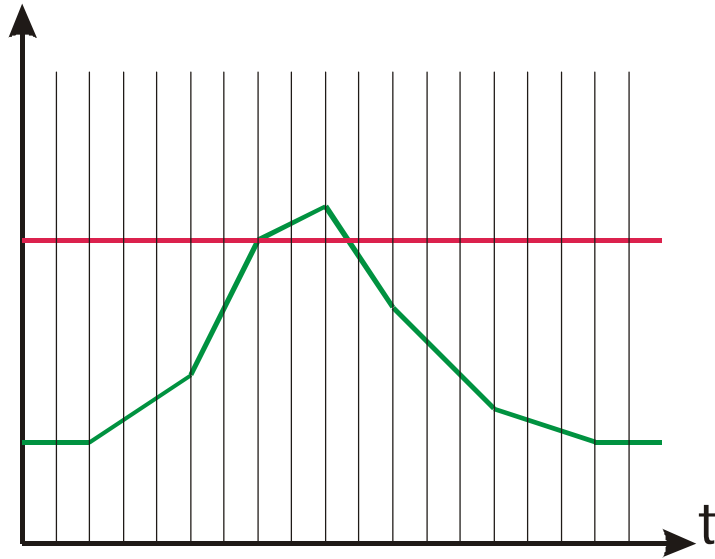
- Event (change of a system state) is the focus
- Simulate only when states change:  
concentrate on important states (critical points  
of the simulation)
- Events can cause subsequent events

⇒ can significantly improve simulation speed

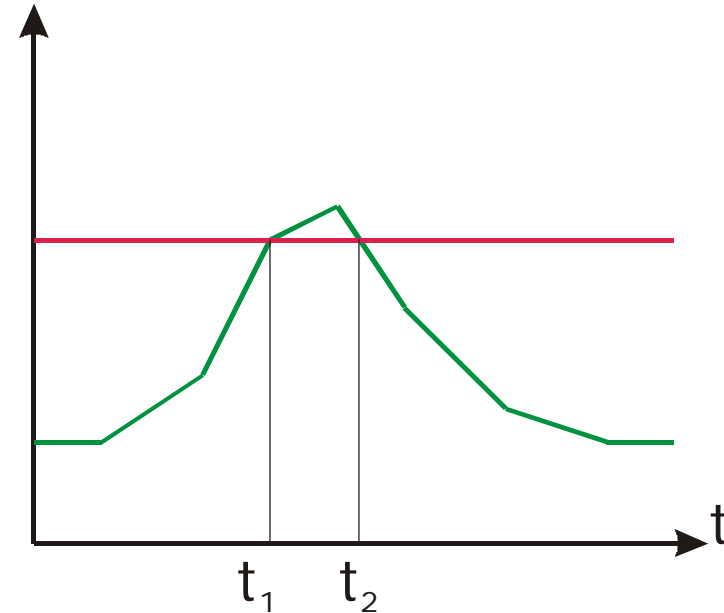


„Now what is the difference ?“

# Comparison of simulation techniques



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



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



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„Can we gain something ?“

# 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



„How can it be done?“

# Connecting SNNs with DEVS

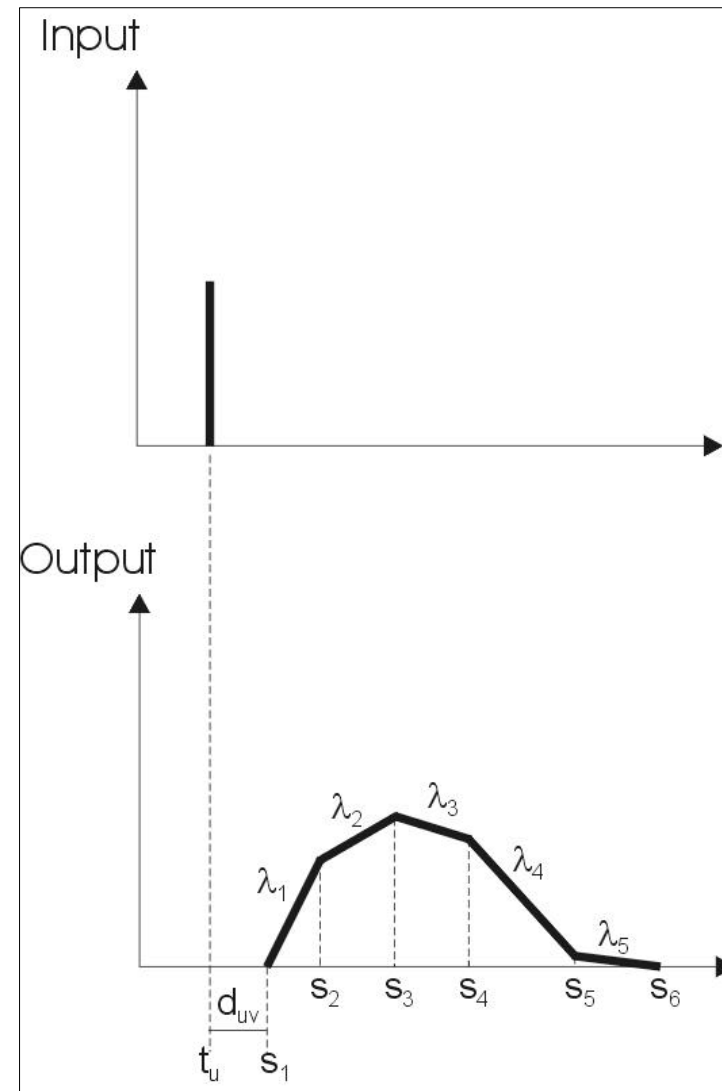
- *Spike* = firing event
- *Neuron fires a spike* = Neuron sends a firing event to all directly connected Synapses
- Synapses forward the event to their post-synaptic Neuron as a response function, depending on their parameters
- When the new Neuron potential exceeds the threshold, a new firing event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



„How can it be done?“

# Simplification of SNNs

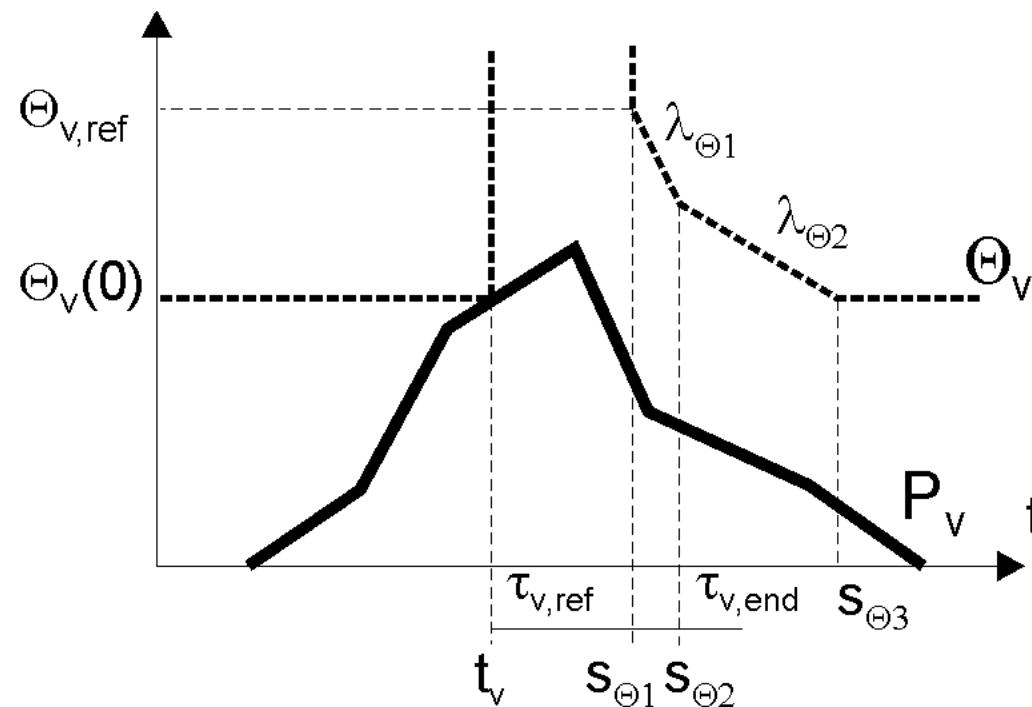
- Spikes (firing events) mark a moment in time, without a shape
- Synapses transform Spikes to (piecewise linear) functions
- Response function is merged with current Neuron potential to obtain future development of the potential (weighted sum)





# 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?“



„What do we gain from this ?“

# 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



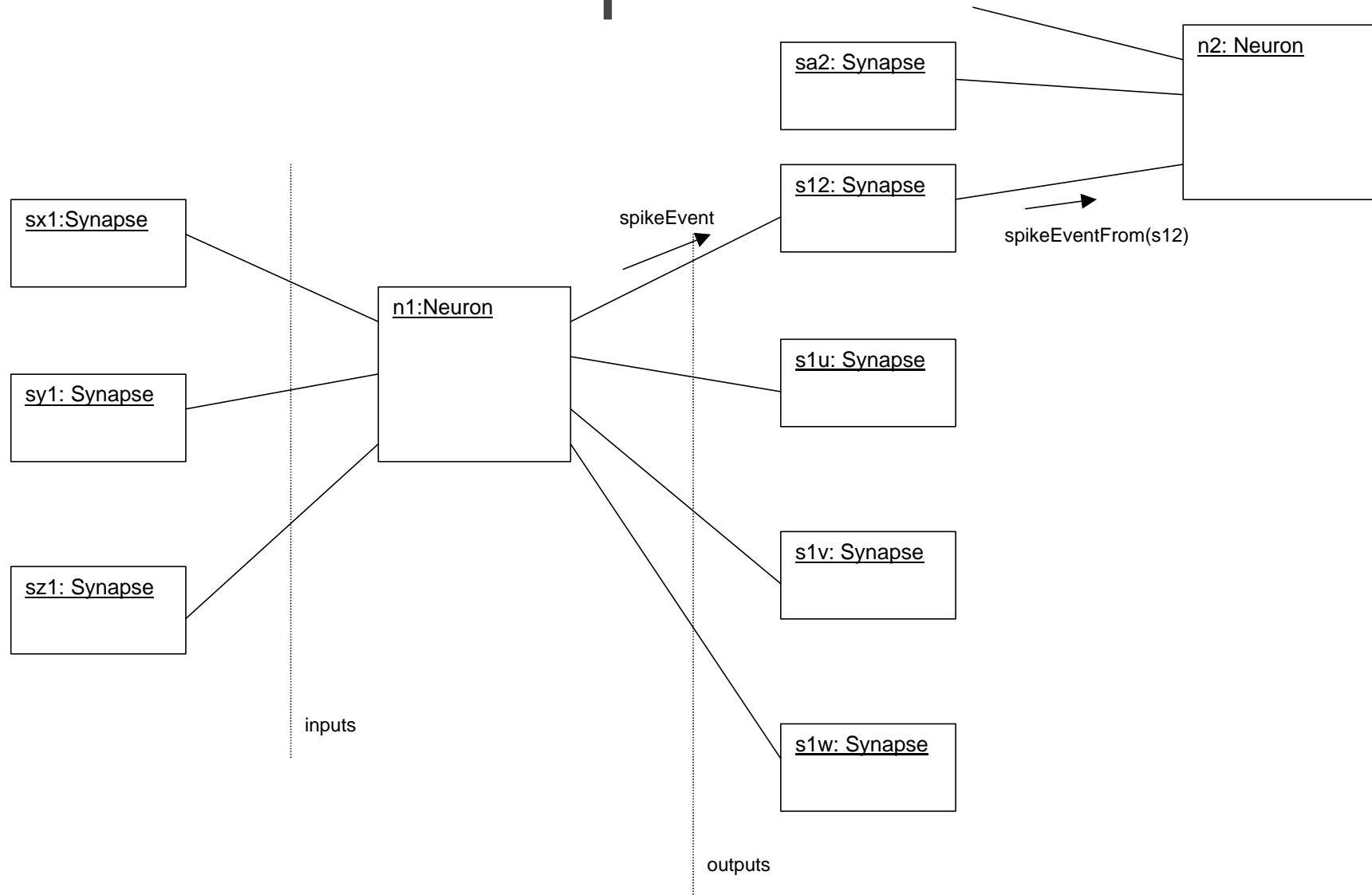
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# Basic Concept

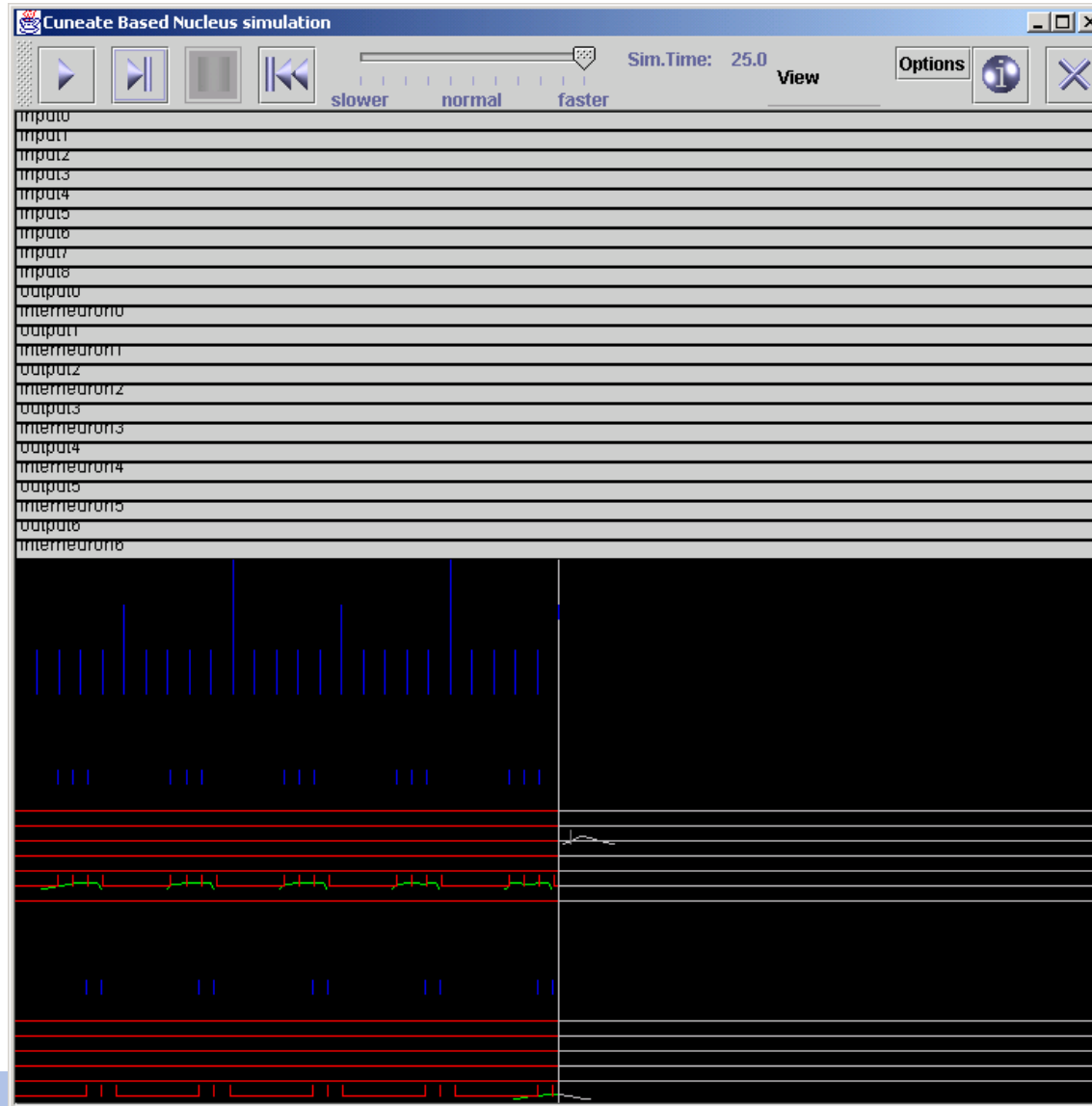
„How is it implemented?“





# Simulator

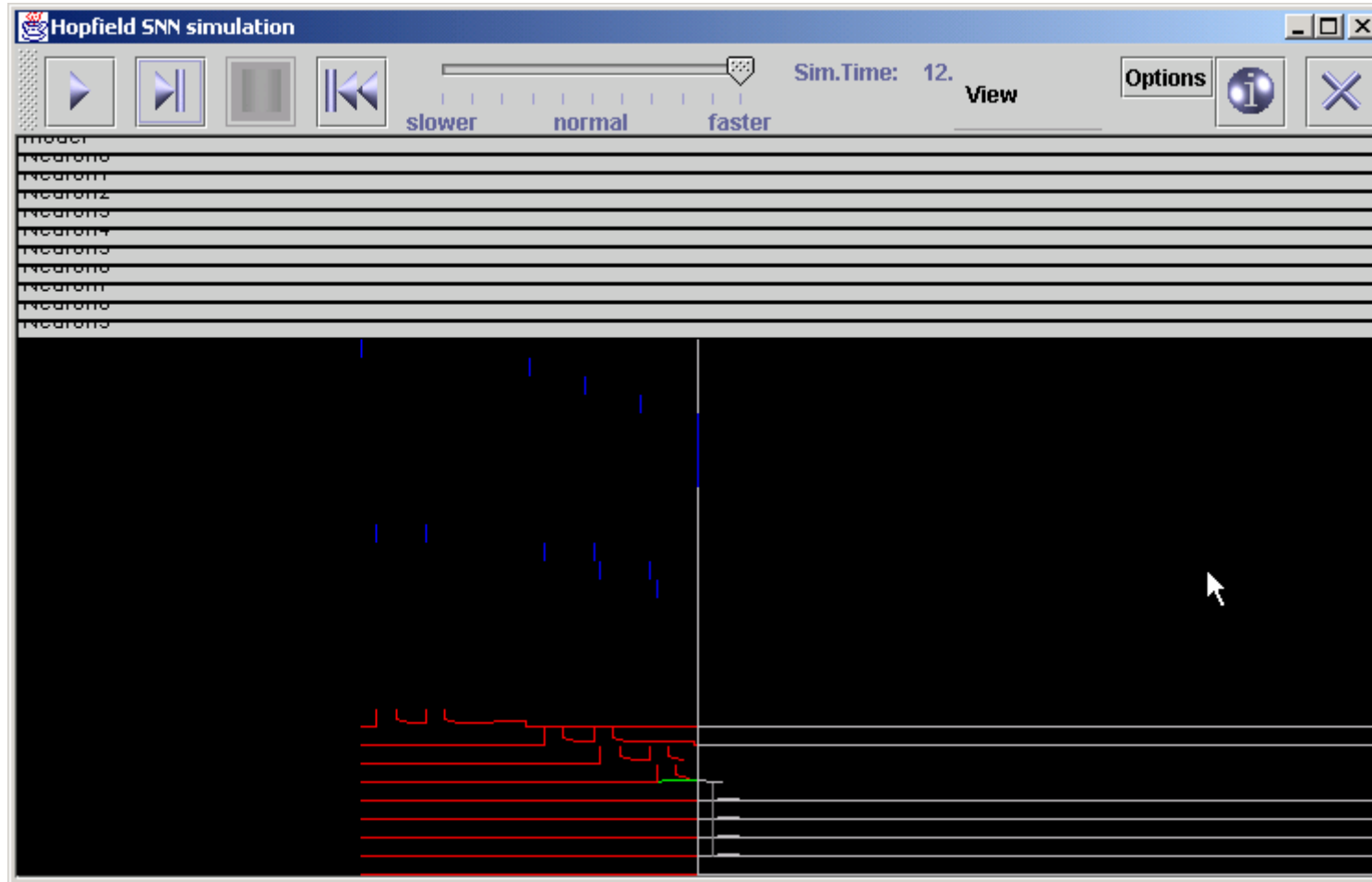
*„Does it really work?“*





# Simulator

„Does it really work?“





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*"Where are we now?"*

# Current state of research

- Basic framework is complete
- Biologically inspired implementation of a Cuneate Based Nucleus Network
- Implementation of a Hopfield network is currently in work
- Simulation technique is stable and working



*„Where will we go ?“*

# Future research

- Extending the simulation framework as needed
- More example simulations, focusing on image processing
- Qualitative and quantitative comparison with continuous simulation
- Determining the new maximum network size for real time simulations
- Finding optimal parameters for most efficient simulation while retaining qualitative features



„What is known until 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.



Thank you for your  
attention