Topic

DEVS Simulation of Spiking Neural Network

Speaker:

Rene Mayrhofer

Institute of Systems Science
Systems Theory and Information Technology
Johannes Kepler University Linz, Austria

Co-authors:

Michael Affenzeller, Herbert Prähofer,
Gerhard Höfer, Alexander Fried

Structure

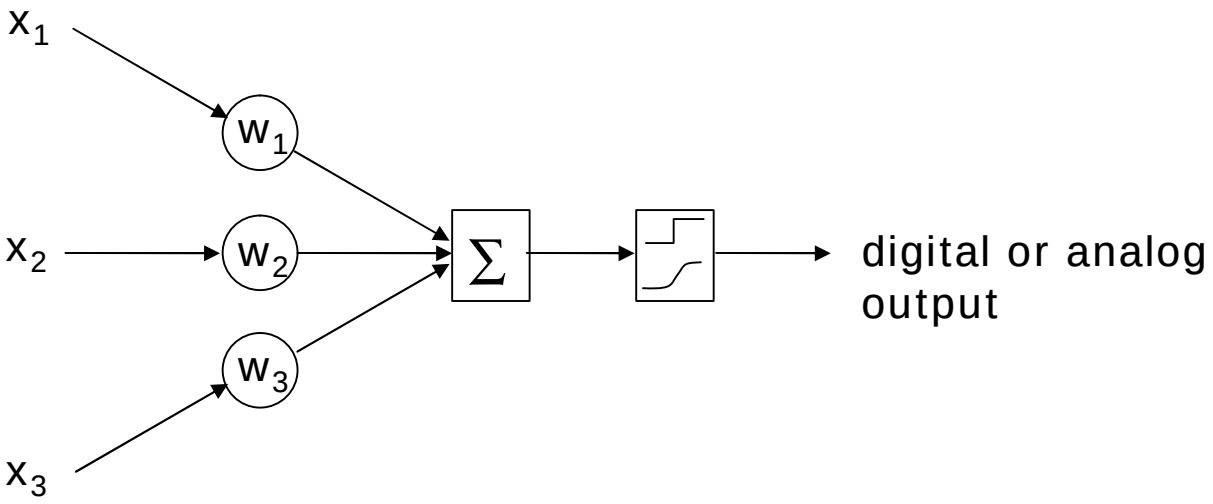
- Spiking Neural Networks
- Discrete Event Simulation
- New model for Event Simulation of Spiking Neural Networks
- New simulation framework
- Current state of research and outlook

Content

„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



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

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)

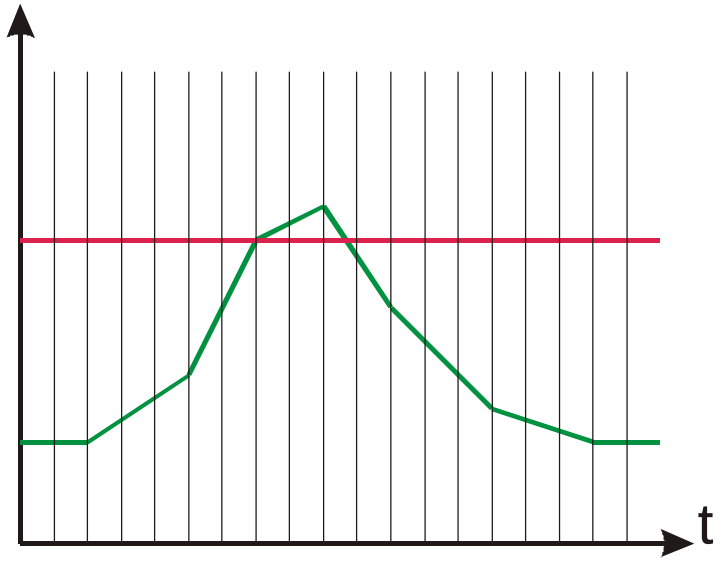
- Event (change of a system state) is the focus
- Simulate only when states change: concentrate on important states (critical points of the simulation)
- Events can cause subsequent events

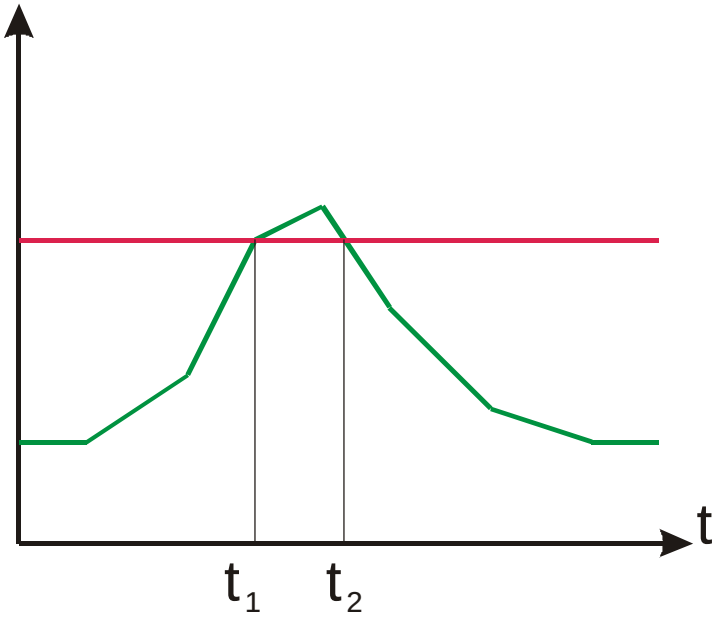
⇒ can significantly improve simulation speed

„Is there a better way ?“

„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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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 ?“

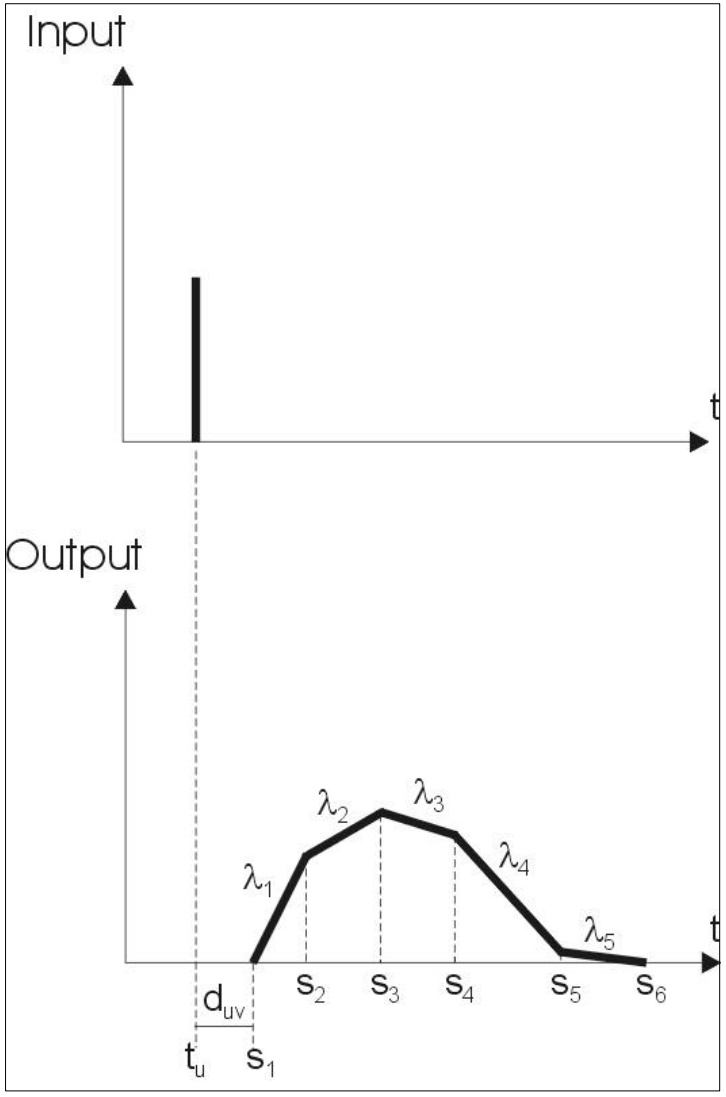
Connecting SNNs with DEVS

- *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

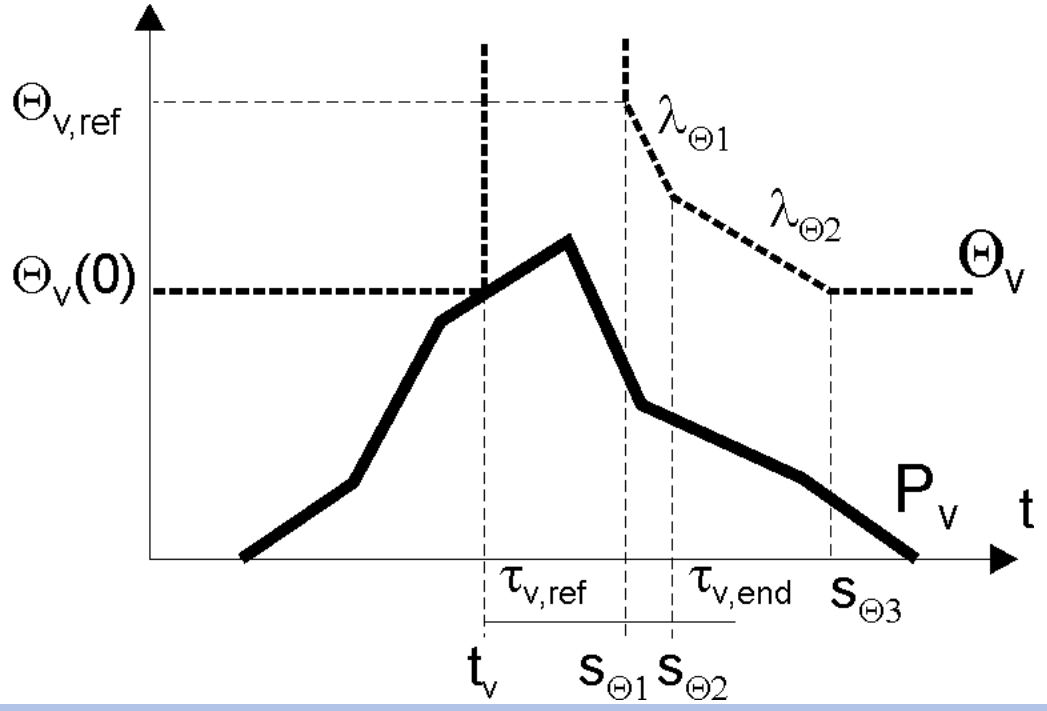
- Spikes (firing events) mark a moment in time, without a shape
- Synapses transform Spikes to (piecewise linear) functions
- Response function is merged with current Neuron potential to obtain future development of the potential (weighted sum)



„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 ?“

„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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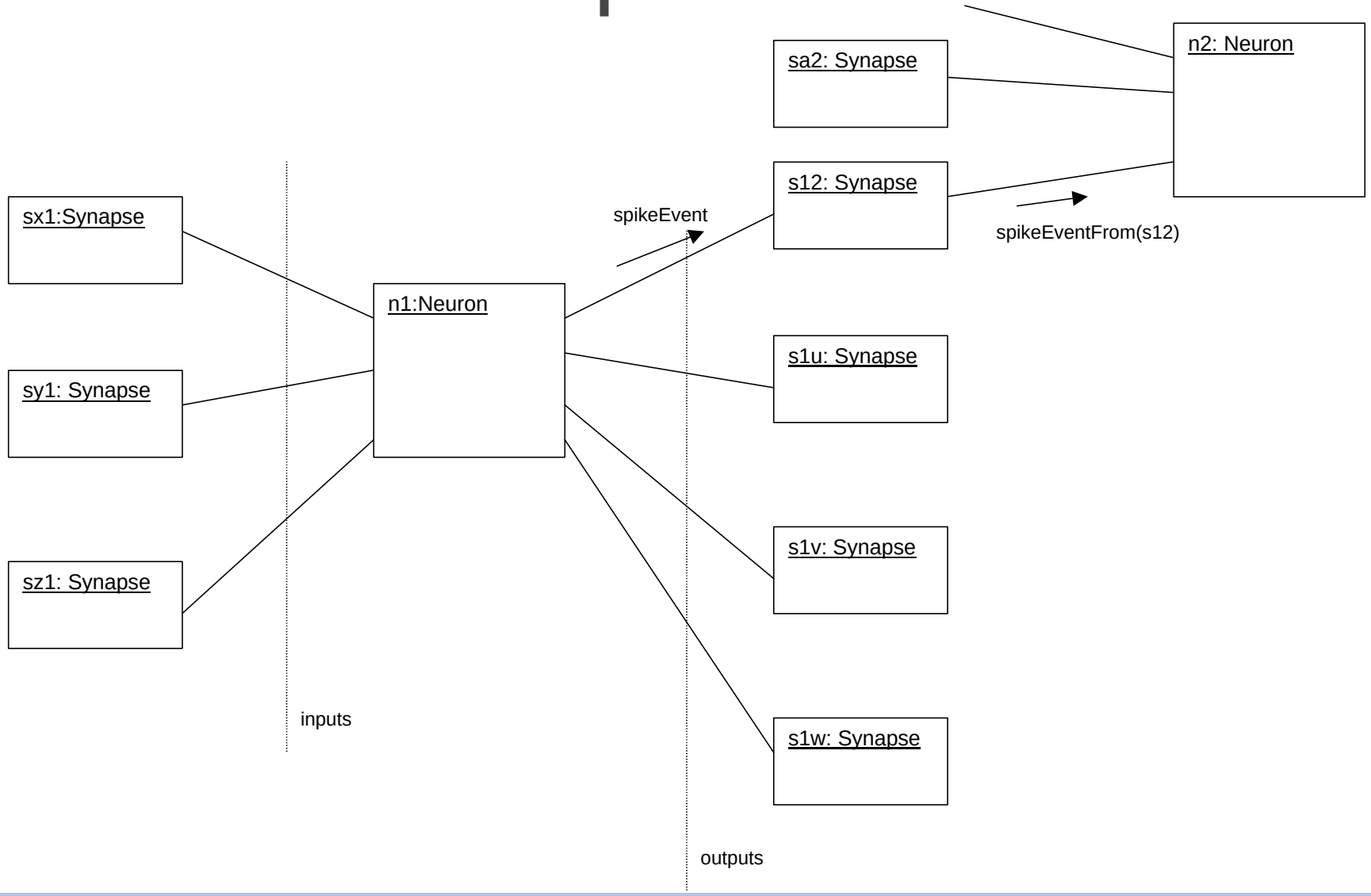
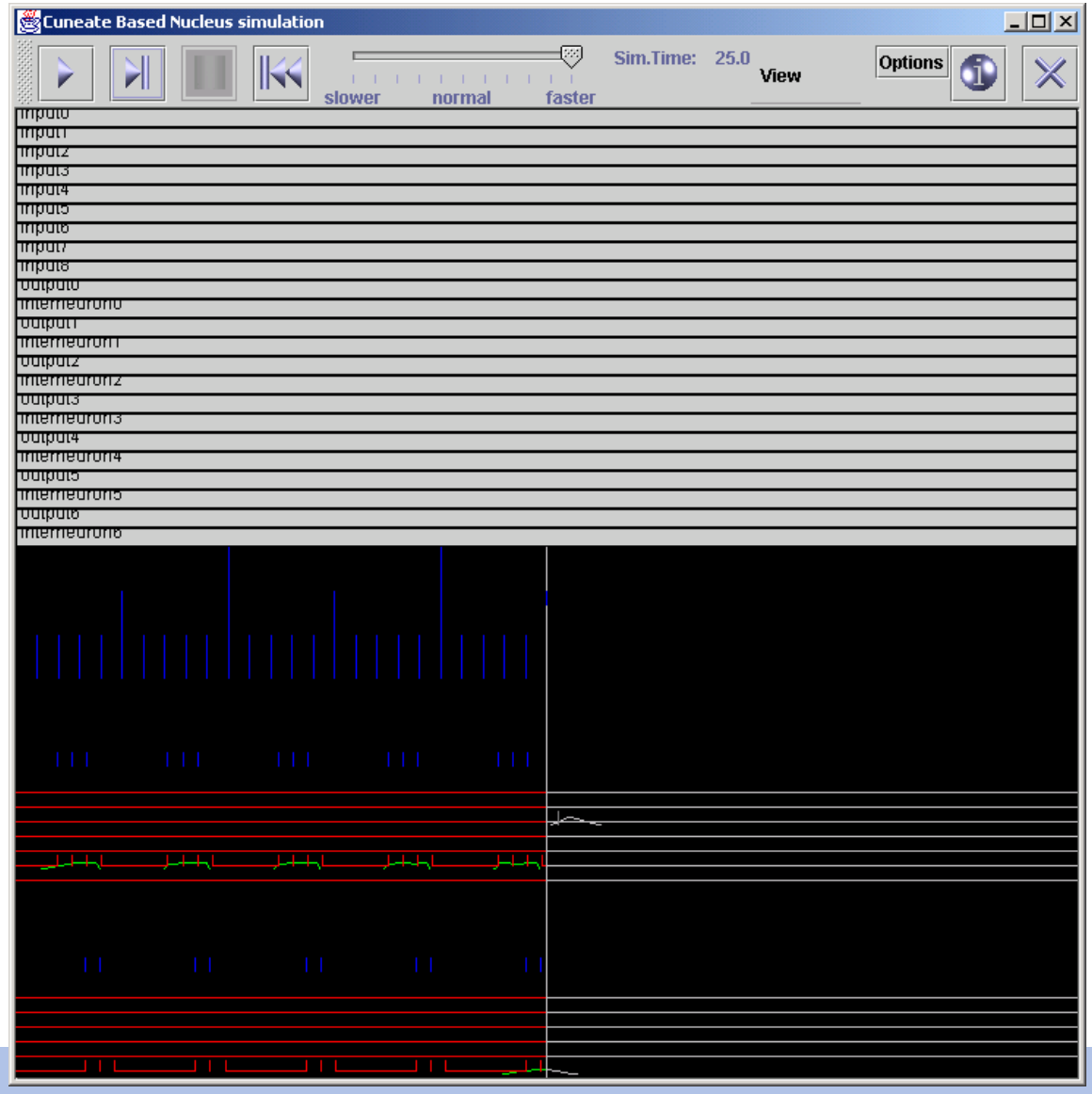
Basic Concept

„How is it implemented ?“

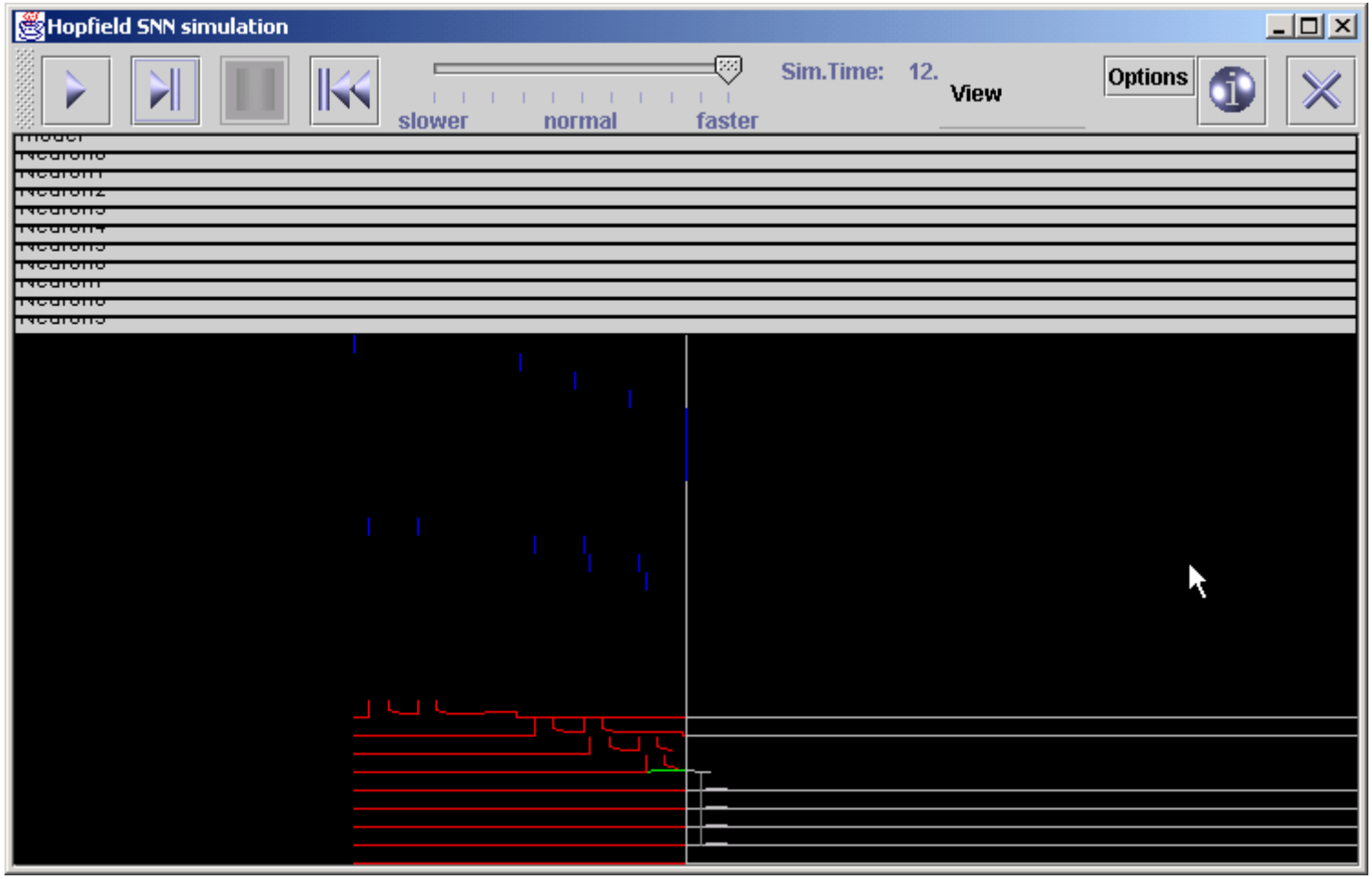


Simulator



„Does it really work ?“

Simulator



„Does it really work ?“

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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 are we now ?“

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

„Where will we go ?“

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 ?“

Thank you for your attention