N2S3, a Simulator for the Architecture Exploration of Neuromorphic Accelerators

Mahyar Shahsavari, Philippe Devienne, Pierre Boulet

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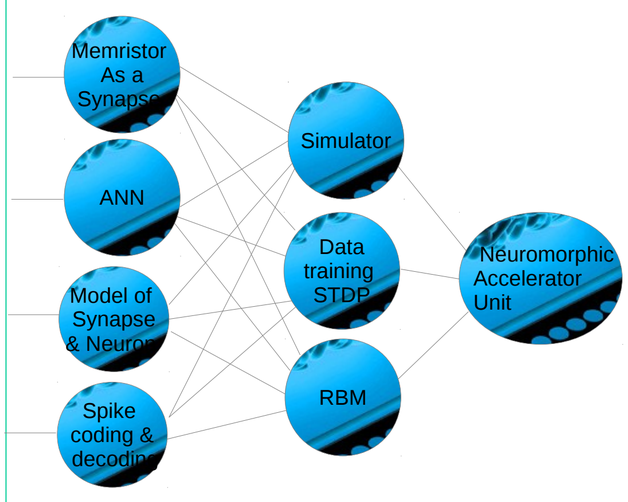
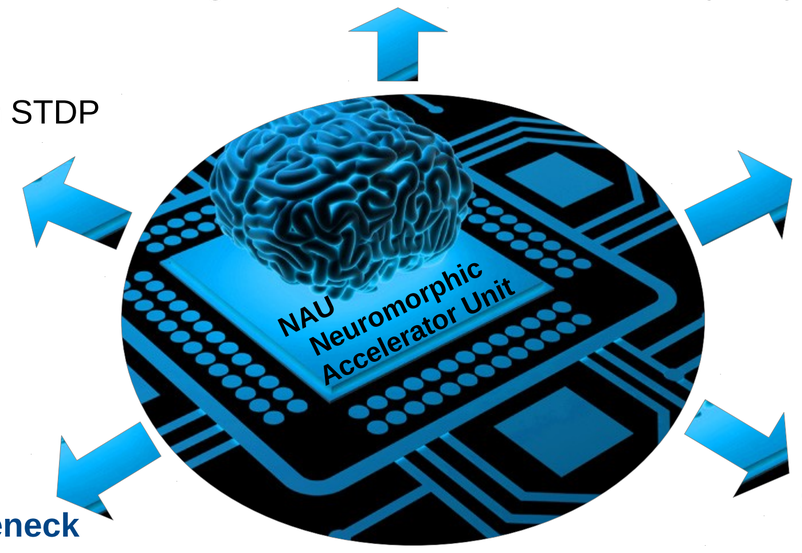
Neuromorphic accelerator



Reconfigurable/Flexible
Using Unsupervised Learning with STDP

Parallel Computing/Big Data
Using Restricted Boltzmann Machine (RBM)



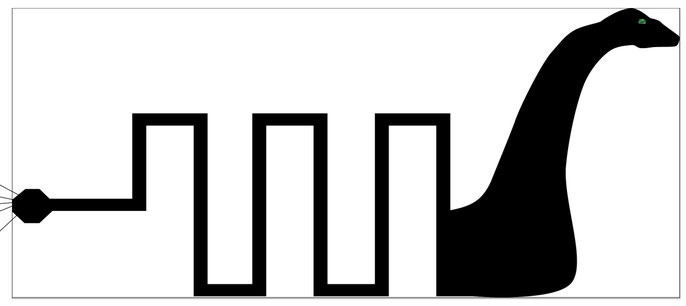
Low-Power
Using Event-driven Computing

Efficient in Speed/No Memory Bottleneck
Using Arithmetic Unit (Neuron) besides Memory (Synapse)

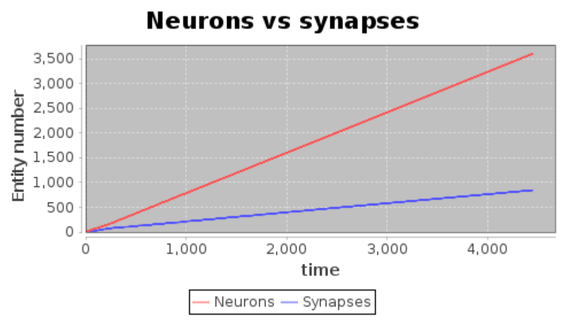
Scalable
Using Memristor Nanodevice as a Synapse

Neural Network Scalable Spiking Simulator (N2S3)

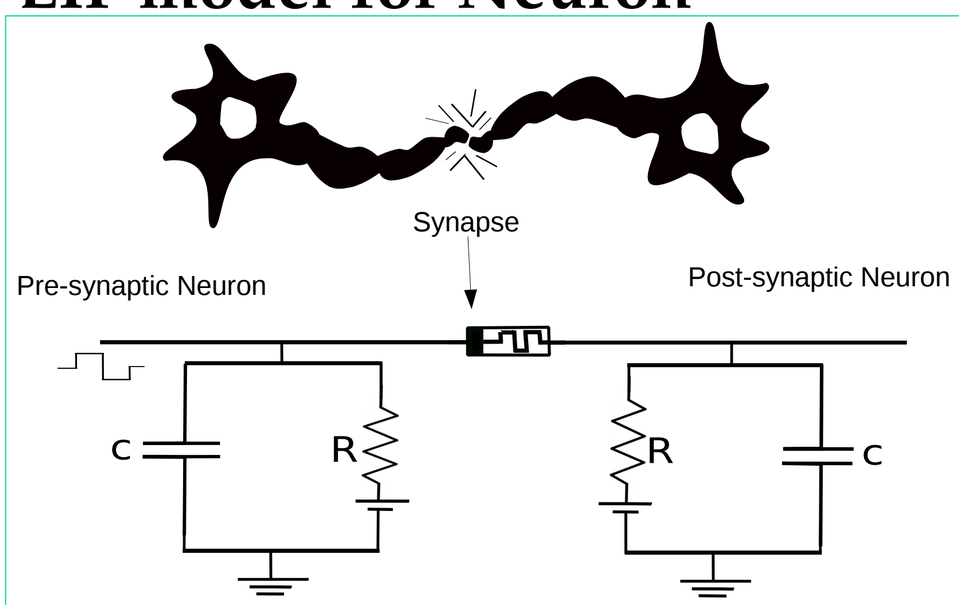
- Event-based
- Analytic Model
- Scalable
- Extensible
- Scala Language



- Using Address Event Representation (**AER**)
- Using **Scala** programming language
- **Akka actor** library for parallel processing and concurrency
- A synapse/neuron is presented by an **Actor**
- A spike is a **message** for the Actors
- Flexibility of the **synchronization**



LIF model for Neuron



Neuron Model:

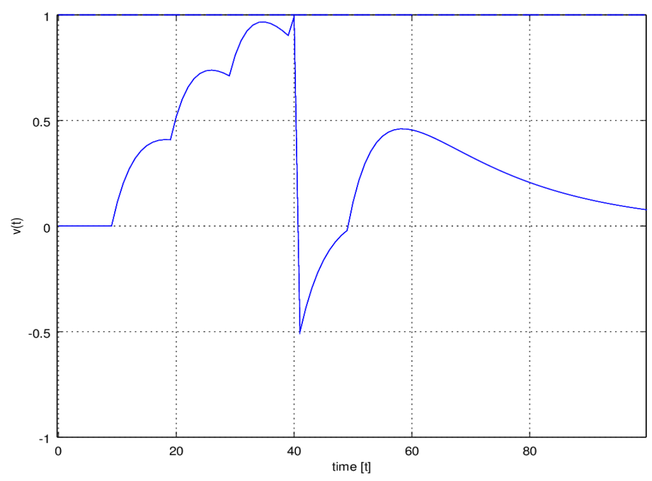
Leaky Integrate & fire

$$\tau_{neuron}\frac{dv}{dt}+G_{neuron}(t)V=I_{input}$$

$$G_{neuron}(t)=G_{leak}+G_{syn}(t)$$

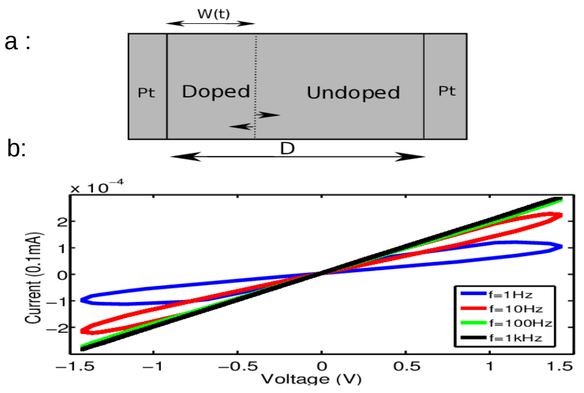
Synapse Model:

$$G_{syn}(t)=G_{syn}(t_0)\exp-(\frac{t-t_0}{\tau_{syn}})$$



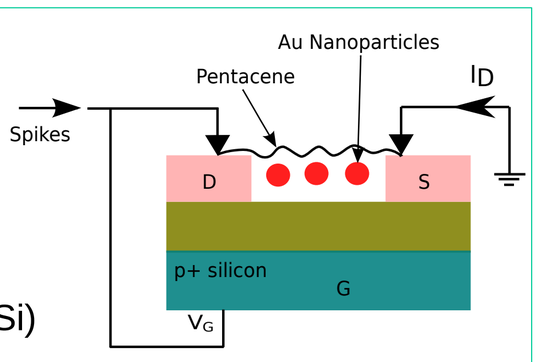
Model of Memristor as a Synapse

```
override def processSpike(s: Spike) =
    s match {
      case PreSynapticSpike(t, dest) =>
        preSpikes += s
        postSpikes retain (postS => t - postS.timestamp <= stdpWindow)
        postSpikes foreach { _ =>
          decreaseWeight(t)
        }
       fire(PostSynapticForwardSpike(t, post, g*v))
      case PostSynapticBackwardSpike(t, _, _) =>
        postSpikes += s
        preSpikes retain (preS => t - preS.timestamp <= stdpWindow)
        preSpikes foreach { _ =>
          increaseWeight(t)
        }
        done()
      case _ => super.processSpike(s)
    }
  def increaseWeight(timestamp: Int) = {
      var dg = alf_p * exp(-beta * ((g-g_min)/(g_max-g_min)))
      g = min(g_max,g+dg)
     }
  def decreaseWeight(timestamp: Int) = {
      var dg = alf_m * exp(-beta * ((g_max-g)/(g_max-g_min)))
      g = max(g_min,g-dg)}
```



a) the memristor structure, b) current versus voltage diagram, sinusoidal input with an amplitude of 1.5v, different frequencies, R_{ON}=100Ω, R_{OFF}=15kΩ, D=10nm, $\mu_v=10^{-10}cm^2s^{-1}V^{-1}$.

- Different Memristors:
  - TiO2
  - Spintronic
  - Organic (Polymeric)
  - Amorphous silicon (a-Si)
  - Ferroelectric Memristor



Organic memristor fabricated at Lille University (F.Alibart et.al 2010)

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