SYNAPTIC PLASTICITY IN SPINNAKER SIMULATOR

SpiNNaker – a spiking neural network simulator developed by APT group – The University of Manchester

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Neural network simulators

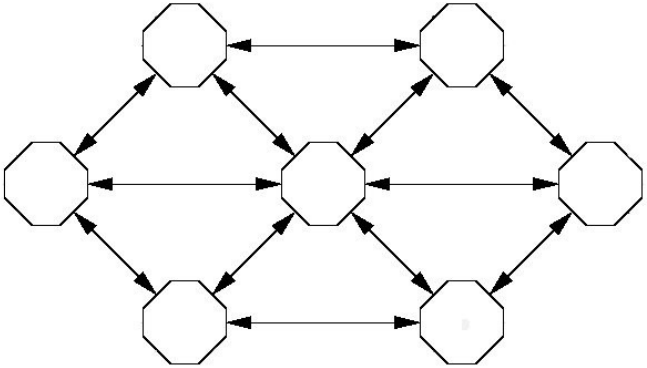
- Neural network simulators are used to:
  - Understand natural biological neural networks;
  - Understand biological processes involving neural cells (e.g. learning);
  - Solve specific problems of classifying information without creating models of real neural networks;

SpiNNaker

- Features of this simulator:
  - Real time simulator (1 msec stepping);
  - Not tied to a specific neuron model:
    - Izhikevich model (currently in use);
    - Leaky Integrate and Fire (almost ready);
    - Hodgkin–Huxley model (very accurate, but very complex).
  - Not tied to a specific synapse model:
    - Weighted and delayed connections between neurons (currently in use);
    - NMDA synapse (currently under construction).

Simulator structure

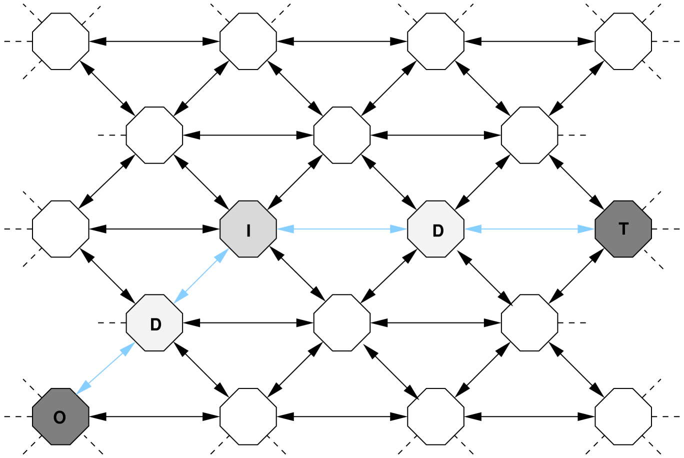
- Spinnaker chip:
  - Test release (two cores) - currently in use;
  - Final release (twenty cores) under construction.



- Network structure:
  - Each chip contains a router to connect it to other 6 chips.
- Neuron simulation:
  - Each core can simulate up to 1000 neurons;
  - Depends on the complexity of the mathematical model (real time bond).

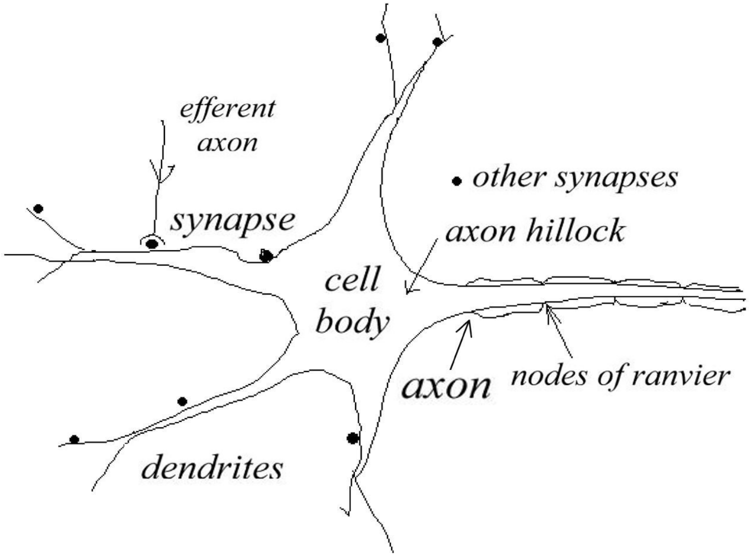
SpiNNaker network

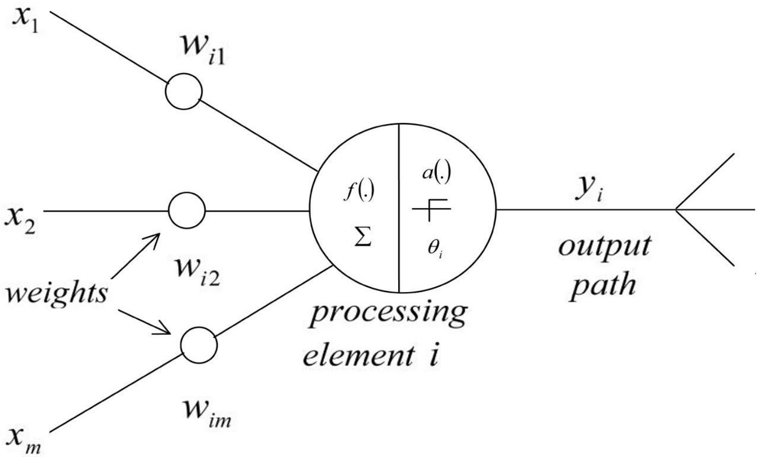
- Network packets simulates spikes.
- Routing entries at the beginning, on corners and at destination.



- Default route: the packet continues straight through.
- Possibility of multicasting defined by the routing entries

Neuron structure





- Several inputs each with its weight and its delay;
- An "elaboration" core (the nerve cell);
- One output synapse which is input to several other neurons.

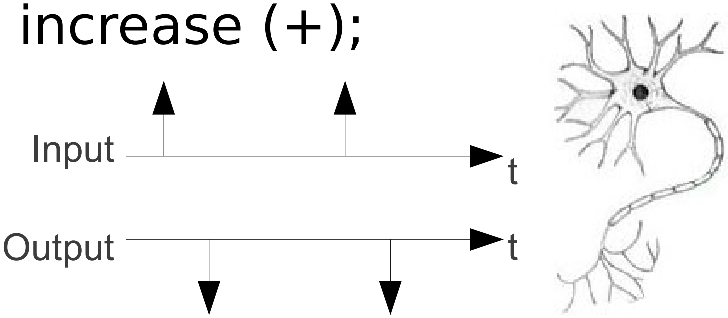
Synaptic plasticity

- Modification of synapse parameters (i.e.: weight);
- Deletion of synapses with a very low weight;
- Creation of new synapses for each removed synapse;

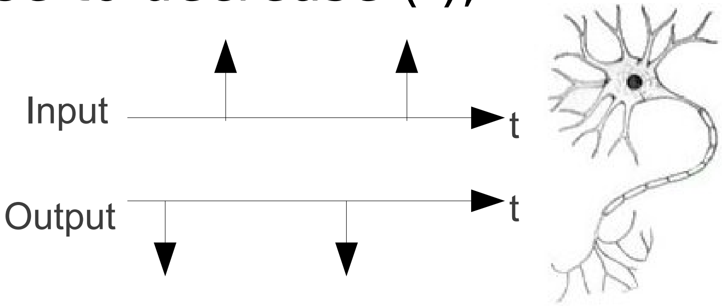
The last two events are generally referred to as “synaptic rewiring”.

Synaptic weight modification (1/2)

- Weight modification connected with sequence of spikes:
  - Causality in the input – output causes the weight of the input synapse to increase (+);

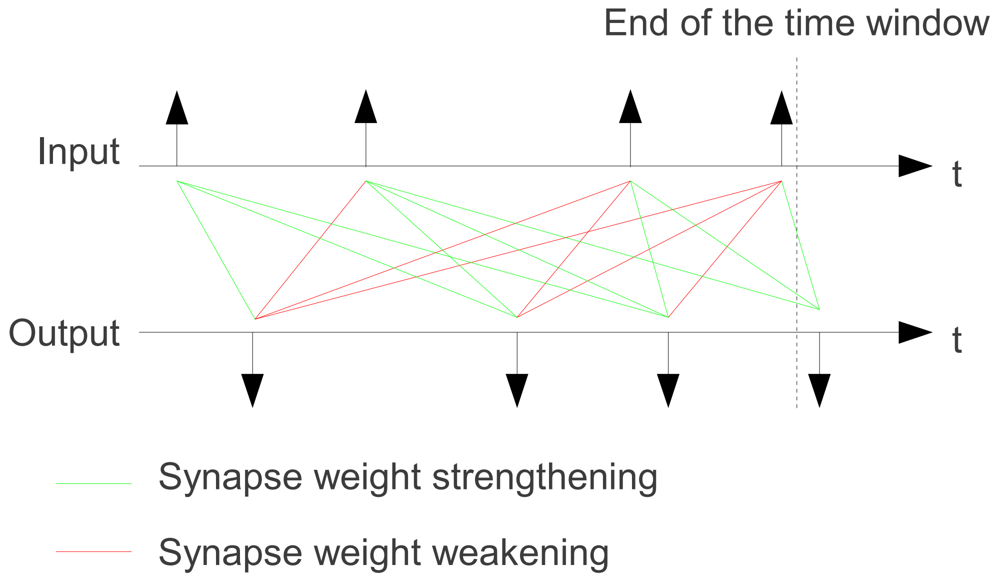


  - Anti-causality in the input – output causes the weight of the input synapse to decrease (-);



Synaptic weight modification (2/2)

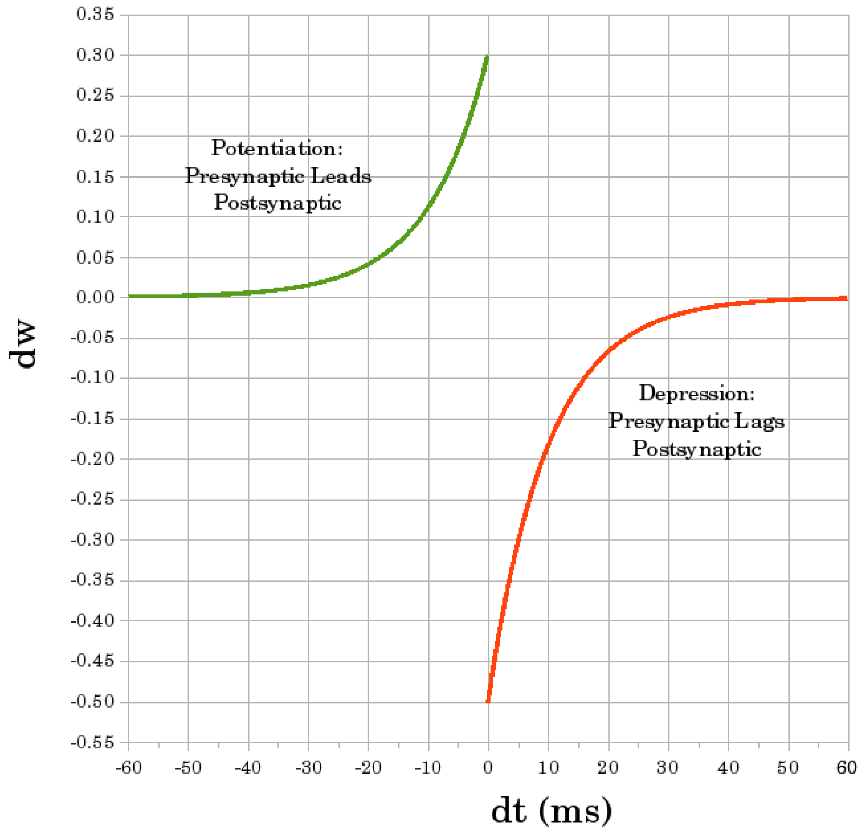
- "Synaptic Time-Dependent Plasticity" (STDP) to evaluate the weight of the synapse:
  - The original algorithm computes the time difference between spikes for all the possible combination of input and output spikes (in a time window).



This algorithm is very complex and needs future information to compute the weight in a specific moment.

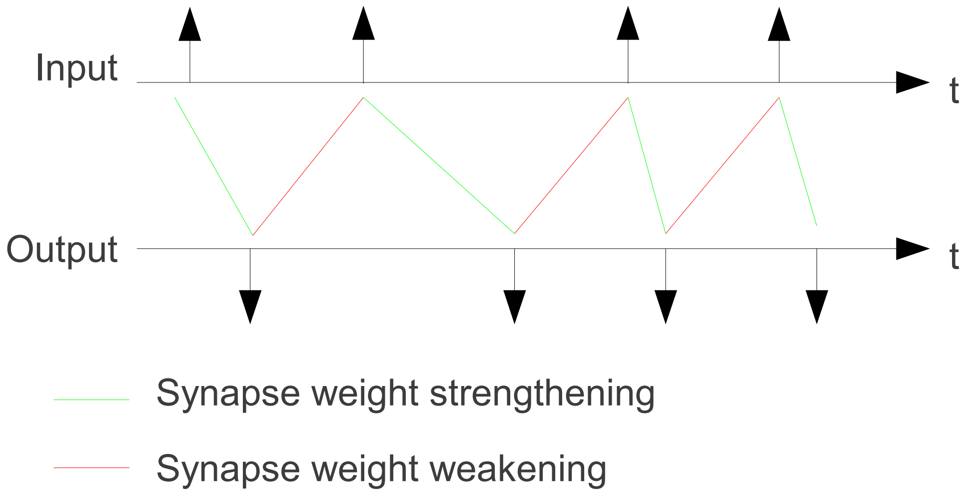
Weight modification

- The modification of the synaptic weight is described by an exponential law:



Simplified STDP

- An improvement of this algorithm takes in to account only the nearest sequence of input – output spikes:



- The state variables of the nerve cell can say if consequently to an input spike it is going to spike (before it spikes really), so that the STDP evaluation can be done in advance.

Synaptic rewiring

- Two main phases for this process:
  - Creating new synapses to substitute the one which have been removed;

    In the SpiNNaker system means adding a new path in the routing tables.

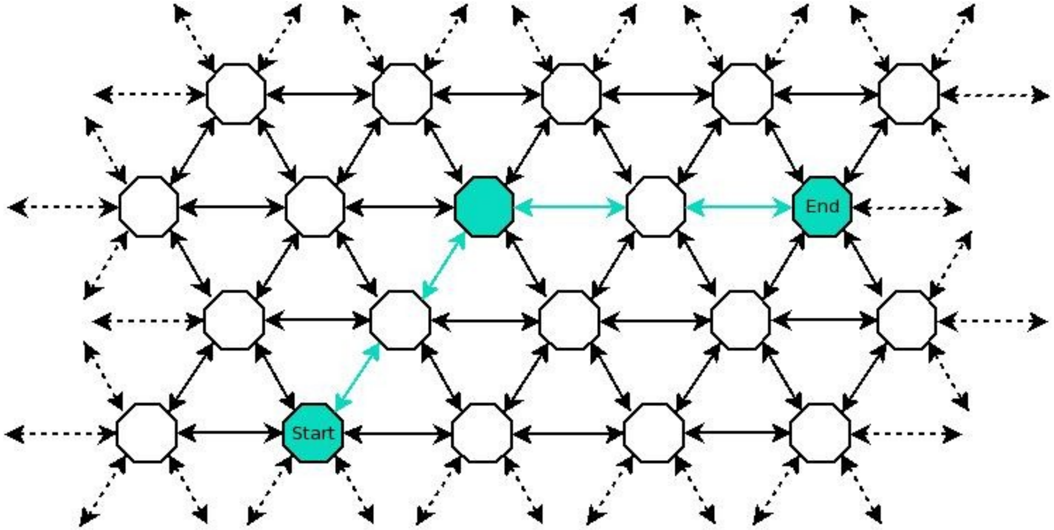
  - Deleting synapses which are too weak;

    In the SpiNNaker system means deleting a path from the routing tables;

Synaptic rewiring – new connection In depth analysis (1/3)

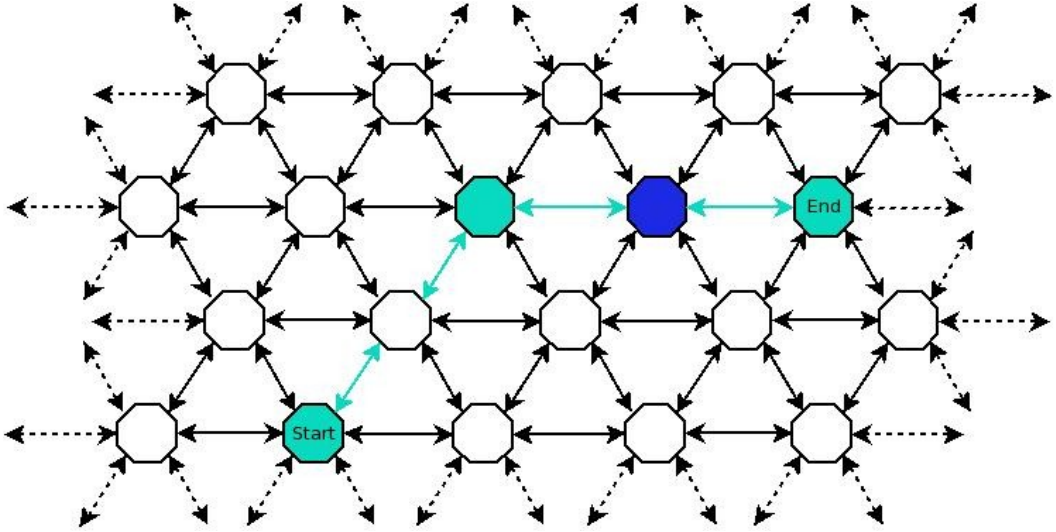
Three possibilities for the new connection:

- New synapse in the same chip where there is another connection;
  - The routing path is already written in the routing tables, modifications are needed only at the endpoint.



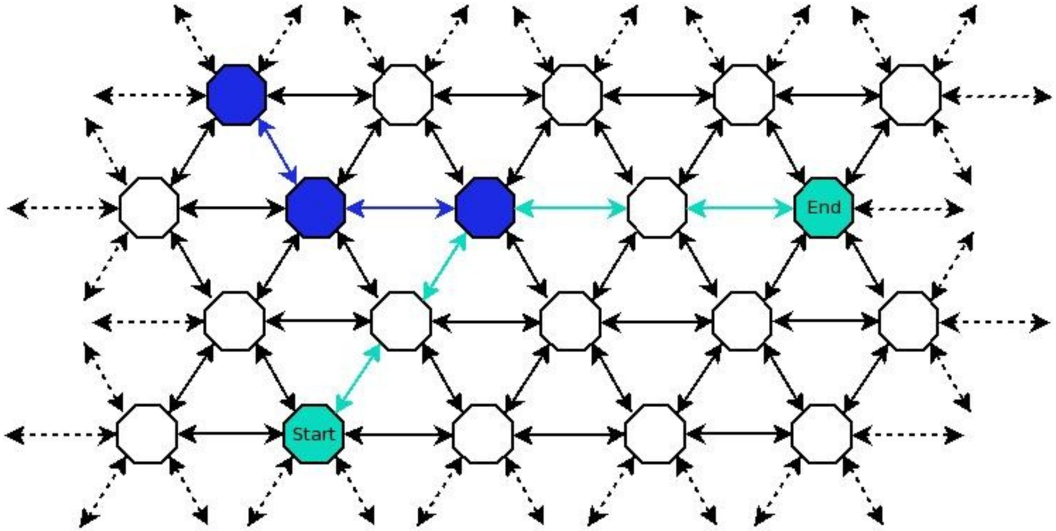
Synaptic rewiring – new connection In depth analysis (2/3)

- New synapse along the path the network packets follow;
  - The routing path is already written, but one routing entry must be modified or added.



Synaptic rewiring – new connection
In depth analysis (3/3)

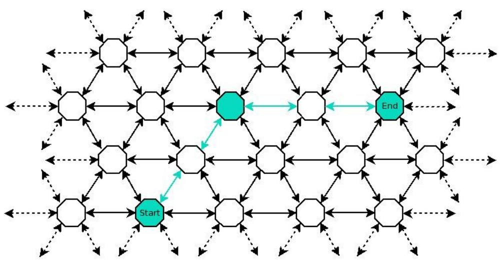
- New synapse somewhere else far away from the path defined;
  - The routing path must be defined from scratch possibly re-using some of the previous routing path already defined.



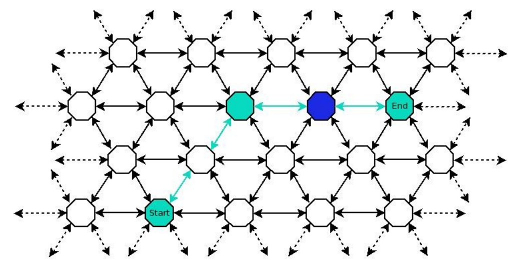
Synaptic rewiring – Deleting connection - In depth analysis

- Conversely, to remove synaptic connections which are not anymore needed there are the same three possibility as for the new connections:

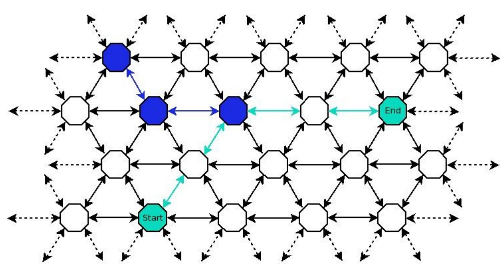
Other synapses present in the same chip



The synapse to delete is on the path for other destinations



The synapse to delete is a branch with no other connections



just to see the attention!!!

Thank you!!!