Neural Networks: Advanced

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□ **What is Neural Network?**[1]

- Neurons and Synapses.
- Weights, Transfer-function and Threshold.
- Layered and Fully-connected.

□ **What for?**

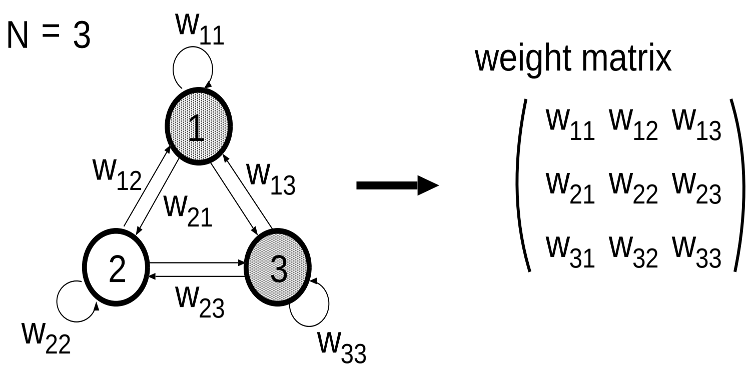
□ **How can we make them work?**
— Learning: specification of its weights.

- Perceptron Learning.
- Backpropagation Algorithm.
- Evolutionary Computation.

[1] For more in details, see “Neural Network - Basics” in this home-page.

□ Fully-connected Neural Networks.

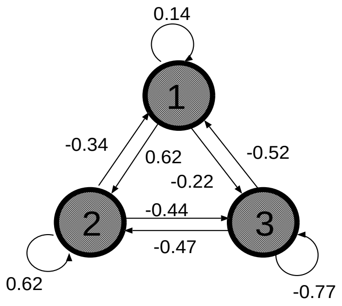
- Toy Model of Three Neurons:

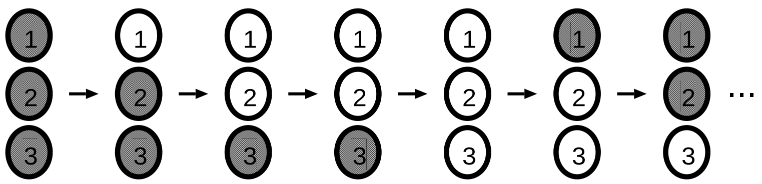


- State Transition

$$s_i\,(t+1) = sgn\,\left(\sum_{j \neq i}^{N} w_{ij} \cdot s_j(t) \right).$$

- Example 1

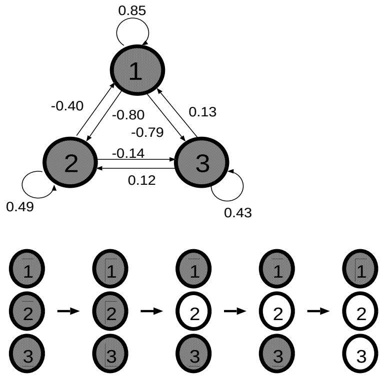




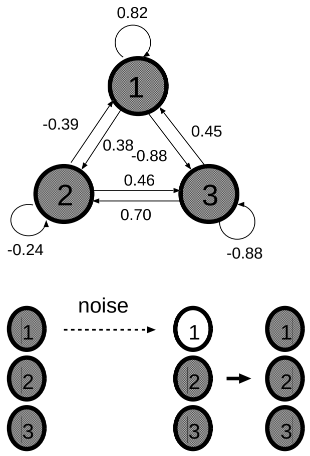
An example of state transition in the above toy example:

$$\begin{aligned} s_1\,(1) &= sgn\ (\ w_{11} \cdot s_1(0) + w_{12} \cdot s_2(0) + w_{13} \cdot s_3(0)\ ) \\ &= sgn\ (\ 0.14 \cdot 1 + (-0.34) \cdot 1 + (-0.52) \cdot 1\ ) \\ &= -1 \end{aligned}$$

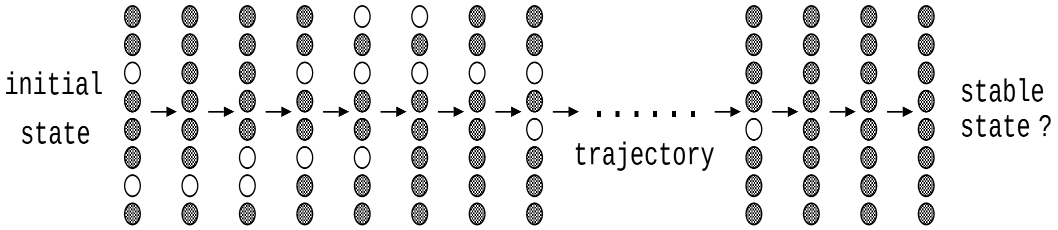
- Example 2



- Example 3

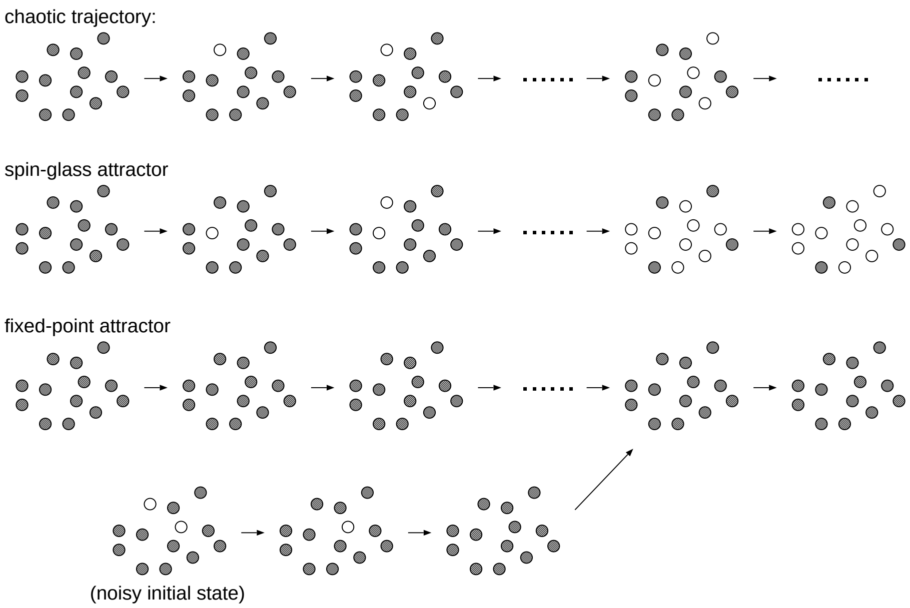


□ Associative Memory as a Dynamical System



$$\underset{u + du}{\text{initial state}} \xrightarrow{\text{converge}} \underset{u}{\text{equilibrium state}}$$

□ A category of trajectories



□ What is Associative Memory

- We store p patterns as *fixed point attractors.*[2]
- Convergence to the initial state of the noisy stored pattern implys an *error correcting capability.*
- How can we determine weights.
  - Hebbian Weights

$$w_{ij} = \frac{1}{N} \sum_{\nu=1}^{p} \xi_i^\nu \xi_j^\nu \quad (i \neq j), \quad w_{ii} = 0.$$

    In the above toy example:

$$\begin{pmatrix} 0 & 0.11 & 0.11 \\ 0.11 & 0 & 0.11 \\ 0.11 & 0.11 & 0 \end{pmatrix}$$

    An interpretation of Hebb's rule:
    * A strong weight affects neurons at both ends to be same states.

  - Many other solutions of a *weight configuration* to store a same set of patterns exist.
    * Each can *recall* from
      · partial information;
      · incorrect information
    * but has a different
      · *basin of attraction*;
      · *storage capacity.*

[2] Here we restrict patterns to bipolar patterns.