CI & A

ARTIFICIAL NEURAL NETWORKS

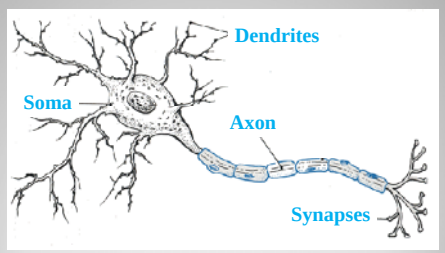
Biological sources of inspiration

There is a radical difference between how the brain of living beings works and traditional digital computers:

	Massively parallel processing
Sequential processing	

Biological sources of inspiration

Biological neuron



Biological sources of inspiration

Statistics

- Number of neurons in human brain: 10^{11} -100 billion neurons;
- Each neuron is connected through synaptic connections with other neurons (between 1000 and 10000);
- The result is a total of approx. 10^{15} - a million of trillions of interconnections.

Biological sources of inspiration

Conclusion

Although the biological neuron is about one million times slower than a transistor, the large number of neurons and connections between them gives the human brain special parallel processing capabilities that make it a "machine" much more effective than “the crowding" of transistors in a computer.

What is an ANN ?

... a machine designed to mimic how the brain solves a problem or performs a function for a particular purpose. In general, the neural network is implemented either in hardware form using electronic components, either in software form, in which case the network operation is simulated by a program.

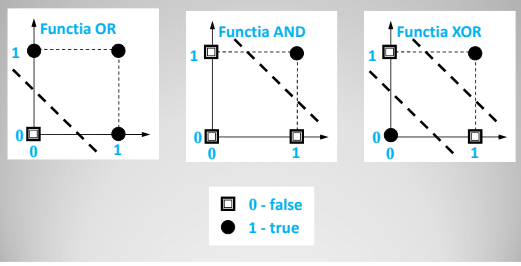
A brief history of ANNs

- 1943: Warren McCulloch and Walter Pitts proposed modeling biological neuron behavior with a model called formal neuron.
- 1949: Donald Hebb published "The Organization of Behaviour", which proposes the first models for learning in neural networks.
- Anii 1950: First computer simulations.

A brief history of ANNs

- Anii 1960: Further research by Bernard Widrow, Marcian Hoff, Frank Rosenblatt and Stephen Grossberg. Rosenblatt introduced the perceptron.
- 1969: Marvin Minsky and Seymour Papert publish "Perceptrons - An introductions to Computational Geometry," which shows the limitations of formal neuron, e.g. its inability to model XOR logical function because its values are not linearly separable.

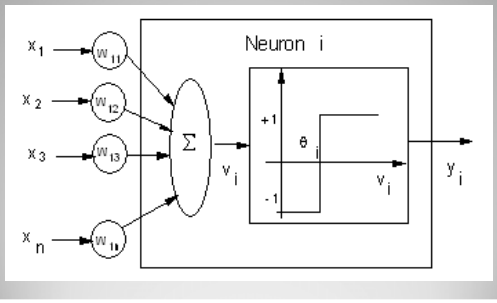
XOR (exclusive OR) logical function



A brief history of ANNs

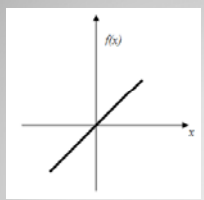
- 1982: Reviving research after publication by John Hopfield of the paper "Computing with Neural Circuits: A Model".
- 1986: Rumelhart, McClelland and Williams relaunch research in the field of artificial neural networks. They introduce the Multilayer Perceptron and the back-propagation learning rule (generalized delta rule).

Formal neuron



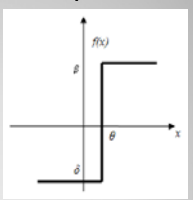
ANNs classification based on activation function

Linear



$f(x) = a \cdot x + b$

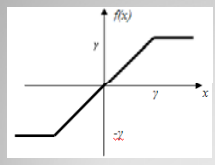
Stepwise



$f(x) = \begin{cases} \beta \text{ dacă } & x \geq \theta \\ -\delta \text{ dacă } & x < \theta \end{cases}$

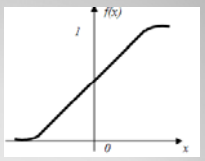
ANNs classification based on activation function

Ramp



$$f(x)=\begin{cases}\gamma \text{ dacă} & x\geq\gamma\\ x \text{ dacă} & |x|<\gamma\\ -\gamma \text{ dacă} & x<-\gamma\end{cases}$$

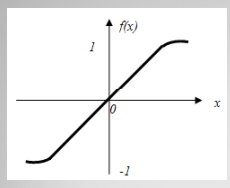
Logistic sigmoid



$$f(x)=\frac{1}{1+e^{-\alpha\cdot x-\theta}}$$

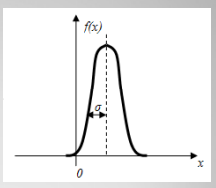
ANNs classification based on activation function

TH sigmoid



$$f(x)=\frac{1-e^{-\alpha\cdot x-\theta}}{1+e^{-\alpha\cdot x-\theta}}$$

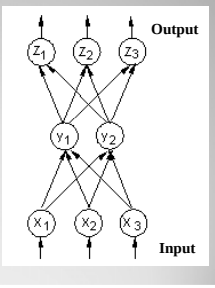
Gaussian



$$f(x)=e^{-(x-x_m)^2/\sigma}$$

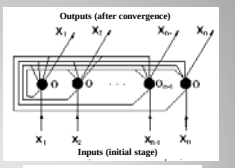
ANNs classification based on propagation type

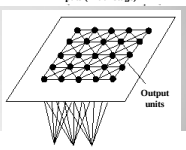
Feed-forward ANNs - information flows in one direction, from input layer to output lauer; static structures (e.g. MLP).



ANNs classification based on propagation type

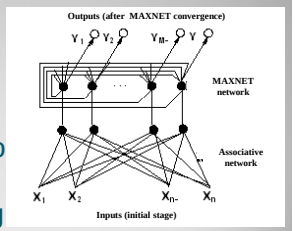
Feedback ANNs - has connection graphs that contain cycles; information flows in both directions; dynamic structures (e.g. Hopfield and Kohonen networks).





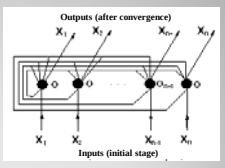
ANNs classification based on propagation type

Hybrid networks (feed-forward and feedback networks) a combination of two types of network (e.g. the Hamming network).



ANNs classification based on topology (number of layers)

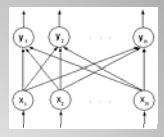
Single layer ANNs - the single layer plays a dual role: input and output (e.g. Hopfield networks).



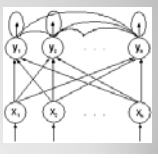
Applications: pattern completion, filtering of signals or solving optimization problems.

ANNs classification based on topology (number of layers)

Double layer ANNs - input layer and output layer (e.g. feed-forward and hybrid ANNs).



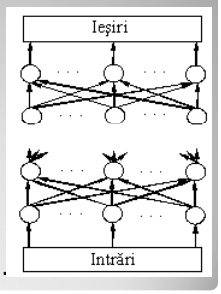
Applications- clustering and classification problems



ANNs classification based on topology (number of layers)

Multilayer ANNs – one input layer, one output layer and one or more hidden layer(s) (e.g. MLP).

Applications - classification and function approximation.



ANNs classification based on leraning / training type

Supervised learning uses a learning / training data set consisting of a finite number of patterns, organized as input – "desired" output pairs. The attribute "supervised" refers to the existence of "desired" values for the network outputs, which during the learning stage are constantly compared with the actual values generated by the network output units (e.g. MLP).

ANNs classification based on leraning / training type

Unsupervised learning or self-organization – uses only input information. Network outputs actually describe the organization of input data. Unsupervised learning networks organize themselves the input information by weights adjustments (e.g. Kohonen network).