ARTIFICIAL NEURAL NETWORKS (SIMPLE)

A neural network is a tool which reproduces the lower structure of a human brain. A brain is a set of biological neurons connected one to each other. These matches compute simple operations, but their sinergy allows to execute complex tasks.

There signal inputs sum one to each other. When this sum exceeds a threshold, they produce an electric pulse, which travels along an axon of a neuron. All inputs in the sum are weighted, and these weights change for opposing to the error committed in the output w.r.t. the target.

Neural networks are useful to:

- reproduce a complex function, by learning how inputs are associated with outputs, without knowing a model;
- learning a model we don't know;
- implementing a classification process;
- implement a clustering process;
- forecasting; having disposed a set of points with frequency repetition, to forecast their value in the future;

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FUZZY SYSTEMS

They rely on fuzzy set, a generalization of a classical set. Here, each element belongs to only one universe. In fuzzy sets, all objects belong to all possible universes with different membership degrees.

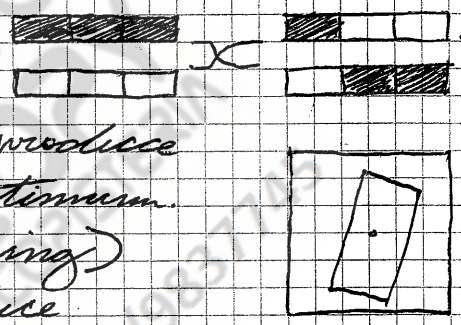
They deal with high-level reasoning process. They exactly simulate how the brain works. Intelligent and fuzzy systems are built indipendently from each other, but they complete the same tasks. Their usefulness depends on the case. Intelligent systems only deal with numbers, instead of fuzzy learning, which produces logical

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ruler. The best way would be a hybride system.

GENETIC ALGORITHMS

These algorithms try to reproduce the typical way human species evolve.
Mathematicians use optimisation to find optimal solutions. But ~~som~~ it is sometimes not possible to satisfy mathematical requirements. A genetic algorithm starts building a population of candidate solutions. Through their interaction, it gives the best individuals. They can make cross-over and produce offsprings. If an individual represents a solution, be it represents a set of genes. It's important to clarify these algorithms produce optimals, and not an optimum. (problem of the car parking)



These algorithms ~~ŋ~~ also produce mutation in children production. Randomness in generation process doesn't guarantee conservation of genetic materials. The only way not to lose genetic material is a mutation.
This makes GA powerful, beyond mathematics!
GA can be used in sinergy with neural networks and fuzzy systems, for generating optimal values of parameters.
So, intelligent systems are combination of artificial neural networks, fuzzy systems and genetic algorithms.

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A neuron is a neural computational unit. It is composed of:
- dendrites (inputs);
- soma (computational centre);

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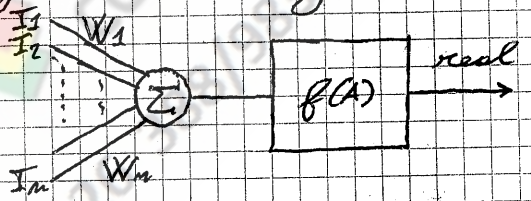
• axon (output)

Axon sends its output as input to neurons nearby. The transmission is ~~act~~ not achieved through direct contact, but through neurotransmitters, in the mechanism called synapses. Neurotransmitters may give excitatory or inibitory pulses to other neurons. Each neuron is connected to other through 10000 synapses. Brain works at much lower speed than CPU (100 Hz instead of GHz of computers), however it's able to ~~perform~~ efficiently perform computational operations, only thanks to its connectedness. Plus, its damaging doesn't compromise its overall activity and it can learn from experience.

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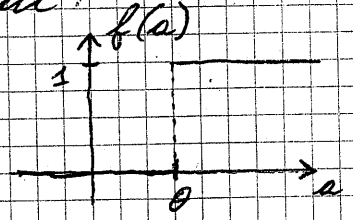
ARTIFICIAL NEURON

In artificial neuron modeling, each input is associated ~~there~~ with an adjustable weight. All these weighted inputs are then summed and this sum will become the argument of an activation function, which will provide a real number ~~belonging to an~~ (close finite) interval as output.



A typical activation function is the binary threshold function

$$y_i = \begin{cases} 1 & \text{if } a \geq \theta \\ 0 & \text{otherwise} \end{cases}$$

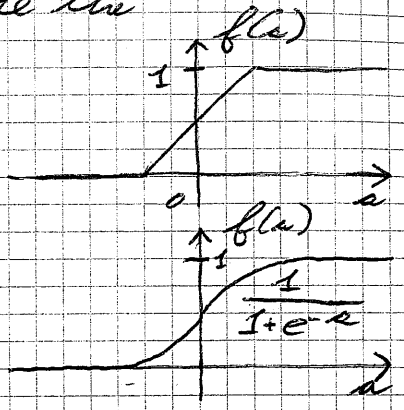


Sometimes, this threshold is subtracted from input output. So, it becomes

$$y_i = f\left(\sum_{j=1}^{n} W_{ji} \cdot X_{ij} - \theta\right) = f\left(\sum_{j=0}^{n} W_{ji} \cdot X_{ij}\right)$$

Here, W_{i0}, the opposite of the threshold, is called bias, and could be intended as a weight of a unit as always with output of 1.

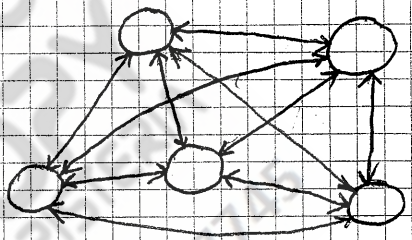
Other possible activation functions are the piece-wise linear function and the sigmoid function, with an appropriate value of slope.
Sigmoid is more used than piece-wise, because this last is not differentiable.
Other functions are signum and hyperbolic tangent function, as a sigmoid with its values between -1 and 1.

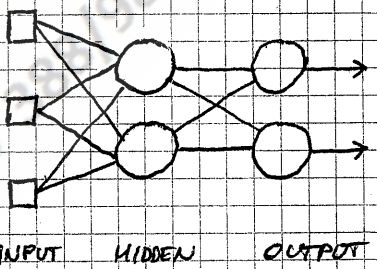


NETWORK TOPOLOGY

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First one is a completely connected neural network. Here, each node is connected to all the others.
Another one is the layered feedforward network.
A layer has to be intended as a set of neurons that perform the same type of operation. A layer solves a problem, but how many neurons are needed for each one?





For input layer, one neuron for every measurement is needed. The difficult is also in choosing the optimal number of inputs to correctly represent an object. For output layer, situation is similar to inputs. Size of output and input are chosen by the problem.
A hidden layer is a layer with no connections of with external environment. The choosing of the number of neurons of an external layer has to be made through experiments.