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→ Artificial Intelligence:
- Symbolic AI
  → Expert Systems
- Machine Learning
  → Deep learning

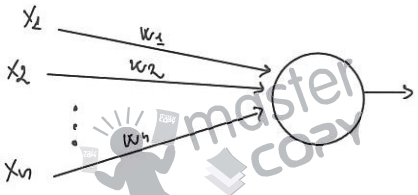
Introduction: What is the meaning of 'Intelligent Systems'?
Software systems that try to reproduce artificially human intelligence → AI: artificial intelligence

Meaning of AI: consists of two main areas
- Symbolic AI: the first paradigm in AI (1950...). Symbolic AI encodes human knowledge as a set of rules and solves problems using symbolic reasoning → reasoning process which exploits symbols in order to solve problems by manipulating symbols according for example to mathematical rules, logic rules ecc..
  Es. Rule: if $x = y$ and $y = z$ then $x = z$
  → Expert Systems: one of the most popular approaches to symbolic AI.
  ↳ a program that contains a knowledge base which stores the experts knowledge as a set of rules. A rule contained in an expert system is a _____ than structure? in which there's a part that specifies a condition and a part that specifies the action that must be performed when that condition is valid.
  A rule states that if a given condition is valid then a corresponding action must be taken. Basically, an expert system uses rules and logical inferences to solve problems in the same way as the human expert. Symbolic AI adopts the classical programming approach to solve problems because in this approach programmers explicitly write down the program and code the rules to manipulate knowledge. So, symbolic AI does not involve any learning because there is a programmer who writes the rules.
- Machine Learning: involves learning because a machine learning system can be trained with an appropriate training examples but is not programmed and it will automatically generate the rules that are necessary to solve problems. The training step/process is very important for the machine learning system.
  → Deep Learning

Main techniques that will be studied:
→ Neural Networks: they show intelligent behaviour because they try to reproduce human intelligence by modelling the low level structure of human brain
→ Fuzzy Systems: rely on the reproduction of the high level of human brain.
→ Genetic Algorithms:

NEURAL NETWORK: A neural network tries to reproduce the low level structure of the human brain. In fact, neural networks are intelligent systems that show an intelligent behaviour based on the fact that they reproduce the low level structure of the human brain. The human brain itself, consists of a network of very simple processing units → THE BIOLOGICAL NEURON: simply receives electric signals from others neurons. These signals are received through input channels and each of these channel in our brain is able to modify the value of the electrical signal (+ / −). This process is possible because in our brain the

electrical signal is trasformed into chemical signal and then the chemical signal is converted back into an electrical signal. The side effect of this process is that can change the value of the signal. Inside the cell body of the biological neuron, all the received and possibly modified signals are summed and when the sum exceeds a given threshold, the neuron emits an electrical signal which will feed other neurons and so on. One way to reproduce the biological neuron is as follows:



MODEL OF THE BIOLOGICAL NEURON

- n: inputs (x_n)
- n: real numbers (w_n) called weights

} The signal received through these channels, by the neuron, is the product of $[x_n \cdot w_n]$

The weighted sum $[x_1 \cdot w_1 + x_2 \cdot w_2 + \dots x_n \cdot w_n]$ of these inputs becomes the argument of a function which is referred to as "activation function of the neuron". The neuron produces an output which is the result of the application of a function to the way that (sums?) the inputs. There are several types of activation functions. One possible activation function is the threshold function which produces an output only when the argument is greater than / equal than a fixed threshold otherwise the output is zero. To build an artificial NEURAL NETWORK, one needs just do connect the artificial neurons in an appropriate way. In fact, the output will become itself an input of some point.

→ The NETWORK is intelligent if provides correct answers. For some inputs, the network produces the correct output.

→ The simplest neural network consists of a single neuron. How can we check if this 'neural network' behaves correctly for a given input? We just need to check if the output produced by the network for that input is the same as the desired output. We need to exploit a SET OF TRAINING SAMPLES consisting of pairs of inputs and corresponding correct outputs. We can calculate the difference between the desired output and the actual output produced by the network. If the correct output does not coincide with the actual output, we have to TRAIN the neuron to behave correctly.

How can we train a network?

Given the inputs, the output of the neuron depends on the WEIGHTS! The weights are the only values on which we can intervene.

→ Training a network is all about finding the correct weights values.

What criterion should we use to change the weights?

We can interpret the difference between the desired response and actual response as the error made by the network, and we can use these errors to change the weights such that the next time we present the same input to the neuron but the actual output is AT LEAST closer to the desired output. The error has to be less than the previous one.

The idea is to teach the network to model correctly not only the mating between a single input and corresponding out but we want also to teach the neuron the correct mating between a set of inputs and the corresponding outputs.

TRAINING OF A NETWORK:

- Preparing the training set consisting of pairs input / desired output
- Exploit a training algorithm which presents training samples to the network in a random order in order to teach the network to associate each input with the correct desired output without relying on the order of the presentation of the samples.

- For each training sample, this algorithm will calculate the error as the difference between the actual output and desired output
- The algorithm will change the weights in a direction oposite to the increase of the error.
- At the end of the presentation of the entire training set, this training algorithm evaluates the total / average error across all the training samples and if this error is less than the desired value, the algorithm stops, otherwise all the training samples still randomly extracted are presented to the network until the error ~ 0.

To assess the goodness of the training process we will test the behaviour of the network on an INDEPENDENT TEST SET. This set is different from the training set but is the same format. At the end of the complete presentation of the test samples, we will calculate the test set error and based the test set error we will be able to say that the network has a good performance.

→ Main problems to deal with:

- Function fitting: about the ability of the neural network to approximate any function with any degree of accuracy. We just need to know the value produced by the function, not the analytical expression of the function, an appropriate set of inputs which will be used to train the network
- Classification: the ability of the network to associate each object with its own class within a set of two or more classes.
  - → Binary classification
  - → Multiclass classification
- Clustering: refers to the ability of the network to identify a structure within a a set of points. A cluster is a set of points representing objects that are very close to each other.
- Forecasting: the ability to predict the future values of a variable based on the past values of that variable and other variables → TIME SERIES.

FUZZY SYSTEMS: In this case, fuzzy systems are forms of intelligence which relies on the reproduction of the high level of the brain structure. Fuzzy systems use

→ Fuzzy sets: a generalisation of a classical set (← a collection of elements which belongs to a given universe and generally an element can or cannot belong to the set with no value inbetween). A fuzzy set is characterised by the fact that each element of the universe belongs to the fuzzy set with A DEGREE OF MEMBERSHIP (any number between 0 and 1).
Fuzzy sets can be used to represent linguistic terms. Es. The temperature is high, the pressure is low ecc. → Temperature, pression, speed are linguistic variables which can assume as values linguistic terms (low, medium, high ecc... represented by an opropriate fuzzy set.). We can define FUZZY RULES: 'If the temp. is high, then the air conditioner speed is high'.
The idea is to enable the computer to understand these rules because previously we have defined fuzzy sets and linguistic variables → linguistic expressions as values

→ Fuzzy logic: with fuzzy logic we rely on similarities between what we observe and what we read in the premise part of the rule (and based on the similarities we will be able to infere ...)

A FUZZY SYSTEM is a set of different types of fuzzy rules. For any type of problem, you can always find, design and develop a fuzzy system that solves that problem for any given function. We will be able to let neural network and fuzzy systems collaborate with each other. They will produce a system (Neuro-fuzzy System) that is capable of

having the advantages of both → neural network: universal function approximators (black-box)
→ fuzzy systems: can be trained and are a faithful reproduction of the process.

Neuro-fuzzy systems: can reach a good degree of interpretability!

GENETIC ALGORITHMS: technique which reproduces the typical way in which the human species evolves. It's possible to reproduce the (3) fundamental processes that characterise the natural evolution:
- → SELECTION
- → RECOMBINATION
- → MUTATION

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Genetic algorithms are very good optimization algorithm as they perform systematic random search in order to improve the likelihood of finding a globaly optimal solution.
All these techniques can be integrated to produce intelligence systems that are referred to hybrid intelligence systems. These systems show a very remarkable ability to reason, to learn in precise environments.

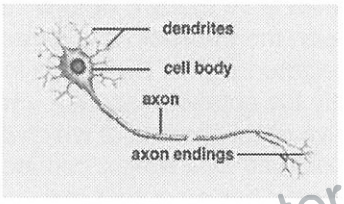
In summary we can → train a Neural Network
→ train a specific type of Fuzzy System
→ optimize and exploit genetic algorithms to improve some parameters of neural networks and fuzzy systems.

MACHINE LEARNING → includes deep learning which means that is the deep neural network that learns the features directly from data. The features are no more given as inputs by the programmer.

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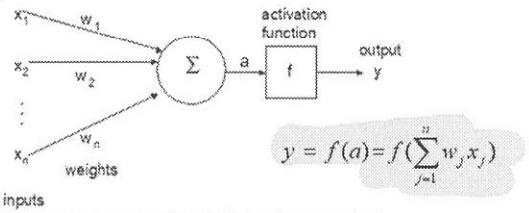
Biological neuron



A neuron has:
- Dendrites (inputs)
- Cell body
- Axon (output)

A neuron receives inputs from many other neurones and these inputs sum up. Once this sum exceeds a given value, the neuron is activated and 'fires' a spike, an electrical impulse that propagates along the axons and its terminations branches to subsequent neurons. These terminations do not exactly touch the dendrites of the next neuron because their link between each axon and dendrite of recieveing neuron is called a synapse.
What is a synapse? It refers to a gap between the sending neuron and the receiving neuron. This gap is filled when the electrical impulse arrives, by a chemical substance called neurotransmitters which bind to receptors in the receiving neuron. The passage of information (electrical signals) through a synapse occurs through a electrochemical process. Depending on the type of these chemical released by the neuron, the effect is to increase or decrease the electrical potential within the body of the receiving neuron and if this potential exceeds a given threshold the receiving neuron is activated.
This is the mechanism that takes place in a network of neurons. Learning is primarily concerned with altering the strength of these synaptic connections. This process of transformation from electrical to chemical and then again to electrical signal is the key point to reproduce the learning capability of the brain.

Artificial neuron



- An artificial neuron has many inputs but only one output.
- Each input connection has an associated adjustable *weight* (a real number). A positive (negative) weight has an excitatory (inhibitory) effect on the neuron.
- A neuron computes some function *f* (called *activation* function) of the weighted sum of its inputs.
- The output can be a real number, a real number restricted to some interval (e.g., [0,1] or [-1,1]), or a discrete number (e.g., {0, 1} or {+1, -1}).

The output of the artificial neuron can be used as input for many other neurons and to model synaptic learning we associate an adjustable weight which is a real number with each input connection to the neuron. This weight will be the target of the training process. We can already observe that a positive weight has an excitatory effect on the neuron whereas a negative weight has a inhibitory effect on the neuron. Basically, a neuron computes some activation functions of the weighted sum of these inputs. In general the output is real numbers restricted to some intervals or discrete numbers ecc.
The most intuitive form of activation function is the *BINARY THRESHOLD FUNCTION.*