MAI4CAREU

Master programmes in Artificial Intelligence 4 Careers in Europe

University of Ruse

INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

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LECTURE 9

INTRODUCTION INTO NEURAL NETS

1. Information processing
2. Biological neuron
3. Neural network
4. Neural network architecture
5. Neural network specifics

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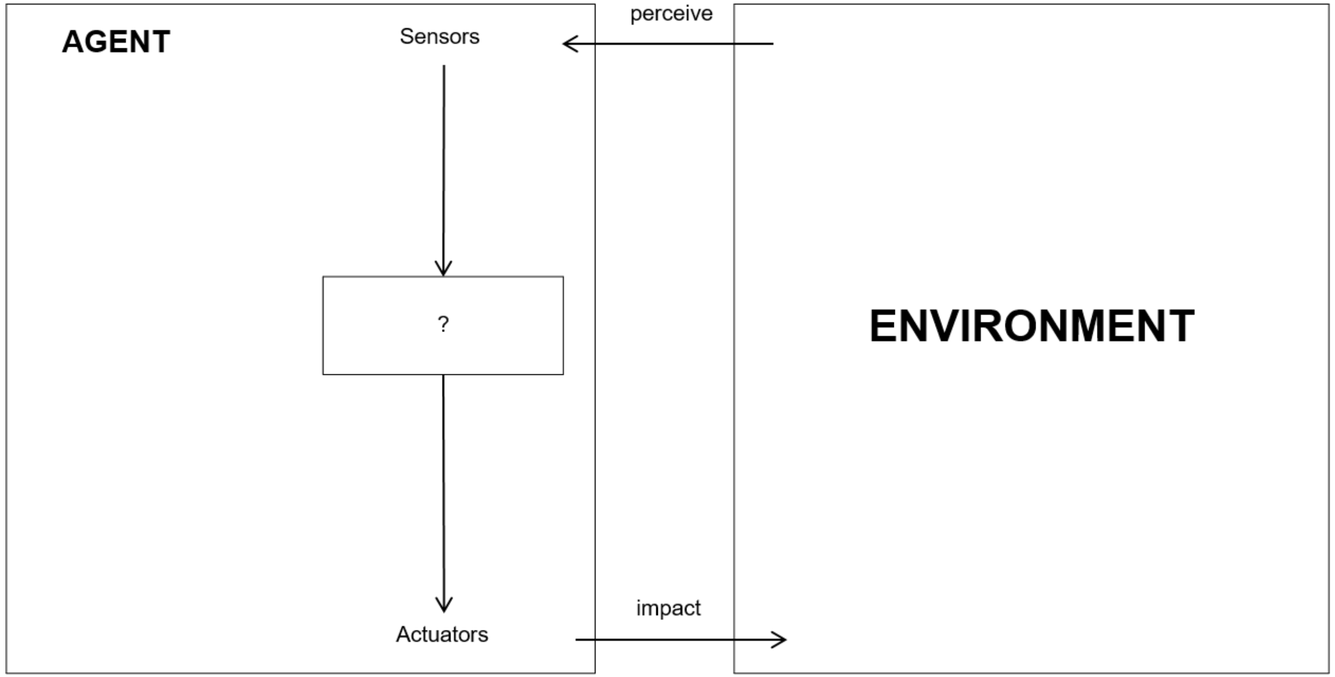
CONTENT 1

Information processing



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CONTENT 1

Information processing from ordinary vision

The function of the visual system - creating an image of the environment in a form that provides the possibility of interaction in the environment, i.e. sequentially performing a number of recognition tasks.

Example - recognizing a familiar face in an unfamiliar environment.

It takes about 100 – 200 milliseconds. For similar tasks of even less complexity, a computer can take days.

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CONTENT 1

Human brain

- **Information processing system** - a complex nonlinear parallel computer.
- Ability to organize their structural components, called neurons, so that they perform specific tasks many times faster than the fastest modern computers:

➢ image recognition;

➢ processing the signals of the senses;

➢ motor functions, etc.

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CONTENT 1

Central nervous system

Consists of:

- Multiple nerve cells along which electrical signals travel;
- Synapses, which are the connections between nerve cells.

When an electrical nerve signal reaches a synapse, it must be converted into a chemical signal.

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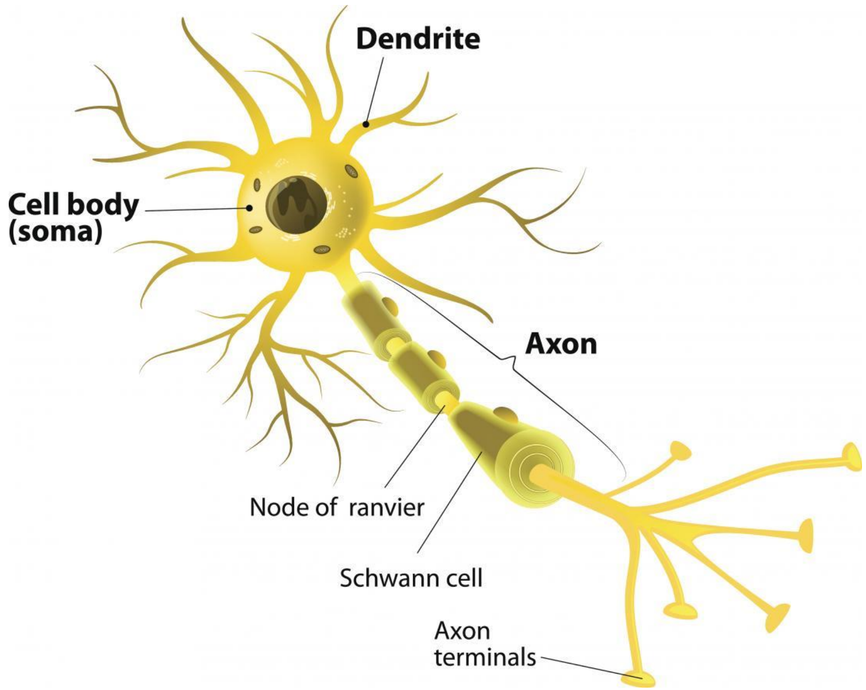
Biological neuron



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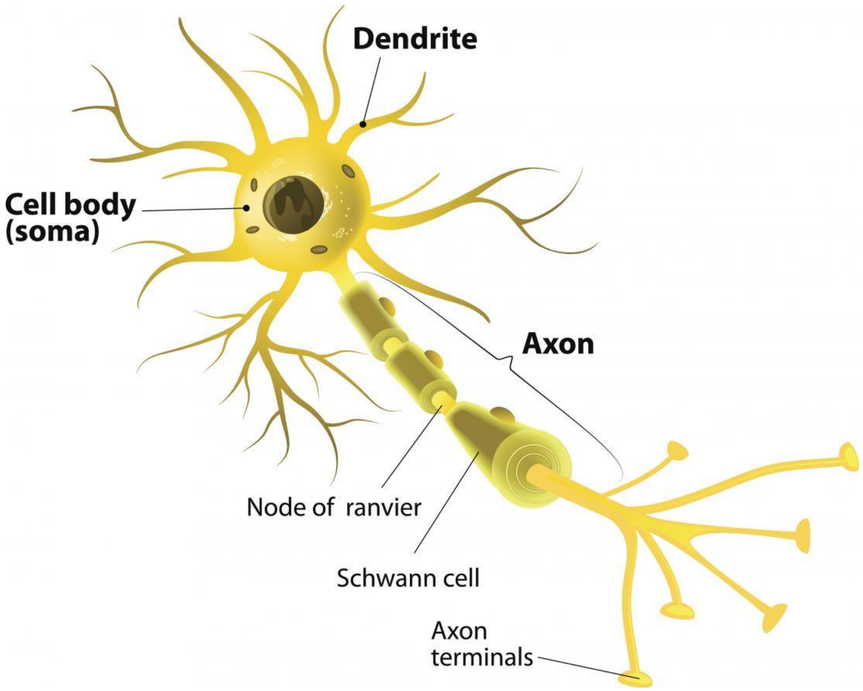
Biological neuron

- **Neuron -** an electrically excitable cell that processes and transmits information by means of electrical and chemical signals.
- **Dendrites** - part of the neuron that serves to receive signals from other nerve cells.
- **Axon** - part of the neuron that transmits signals to other neurons. It can be up to 1 m long and have thousands of branches, thus transmitting signals in a highly branched network.
- **Synapses** - the ends of the axon branches. They transmit signals to other nerve, muscle or glandular cells.



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CONTENT 3

Neural network (NN)

A structure of neurons organized in a certain way.

It can be:

- **biological** - formed by the structural units in the human organism (about 86 billion neurons)**;**
- **artificial -** the mathematical analogue of biological and represent a set of interconnected simple computational elements.

Artificial neural networks are able to learn, store and reveal the connection between data by providing solutions to problems that usually require a person's natural ability to think and observe.

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History of NN

The 40s of XX century – the study of nonlinearity in the processing of information by neurons begins.

1943 - The first models of NN were created by Warren McCulloch (neurosurgeon) and Walter Pitts (mathematician).

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Structure of NN - neuron

- receives signals from others as numbers;
- sums them;
- the sum goes through the activation function and the activation/the level of excitement is;
- the level of excitement is transferred through the exit connection to the other neurons.

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Structure of NN - connections

They have a weight, which multiplied with the signal determines its meaning/strength. The weights of the connections are analogical to the strength of the impulses of the synapses, transferred between the biological neurons.

- negative value of the weight – corresponds to a suppressed impulse;
- positive value of the weight – corresponds to an excited impulse.

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NN as a mathematical system

- **Processing/processing unit** - corresponds approximately to an actual neuron. Each processor receives signals from other neurons, combining them, transforming them and giving a numerical result at its exit.
- **Transfer function** - the processing unit weighs the input value with a set of weights, transforms it nonlinearly and generates an output value.
- **Computing system** - a set of processing units connected to each other in a network.

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NN according to traditional processors

- **traditional processor** – a central processor (CPU) which is just one and performs each action sequentially;
- **NN** - a number of simple processing units, each of which deals with a part of a basic problem.

The power of neural computing – comes from the dense coupling structure of processing units that share a common processing load.

NNs are often called **neural computer networks** for connection of parallel processors.

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NM vs. traditional information storage

- **traditional computers** - data storage (memory) and data processing (processor) are separated.
- **NN** - store and process the information, i.e. there is no need to fetch the data from memory to process it.

Data can be stored in the neurons themselves:

- **briefly** - they can be aroused or not at any given moment;
- **for longer periods —** in weights of connections between neurons.

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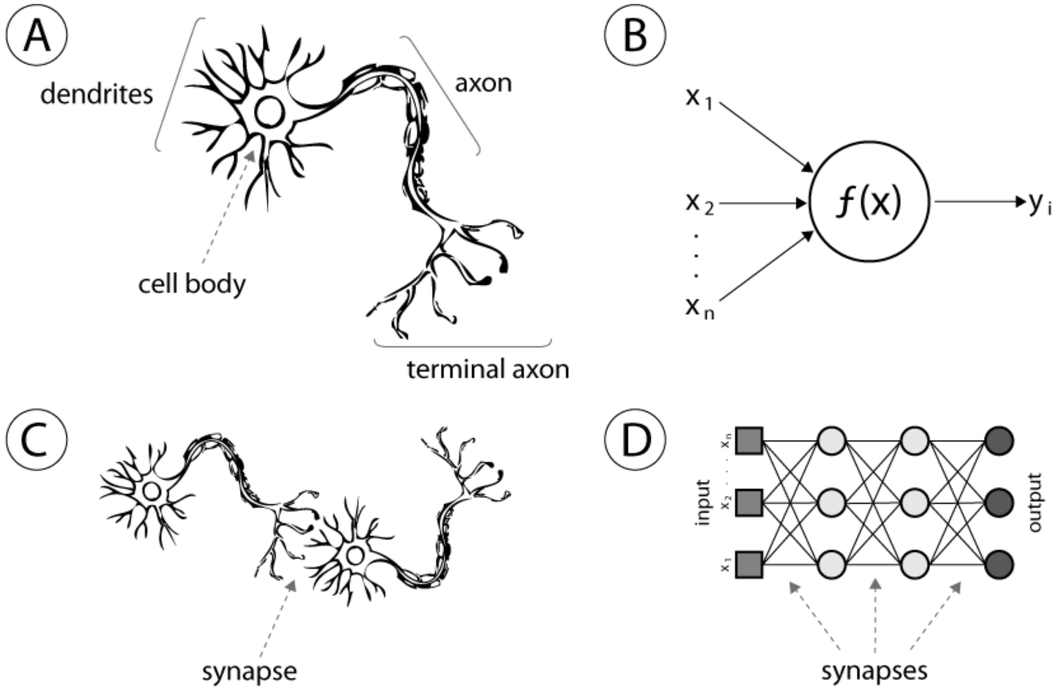
Biological vs. artificial neural network

- A – Biological neuron
- B – Transfer function
- C – Biological neural network
- D – Artificial neural network



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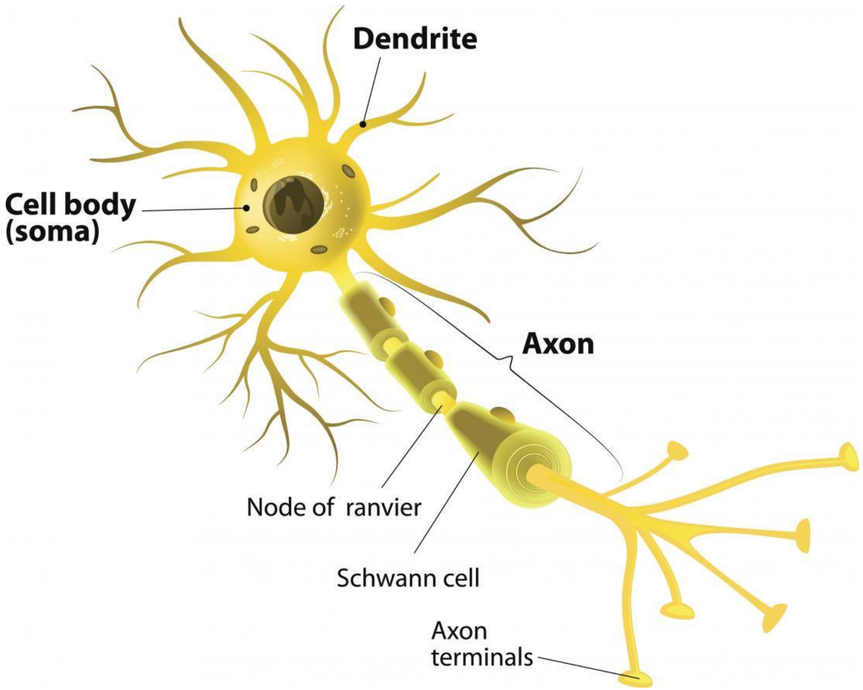
CONTENT 3

Biological vs. artificial neuron

Biological neural system	Artificial neural system
Neuron	Processing unit
Dendrite	Reception zone
Cell core	Transferring function
Axons	Transmission lines
Synapses	Connections



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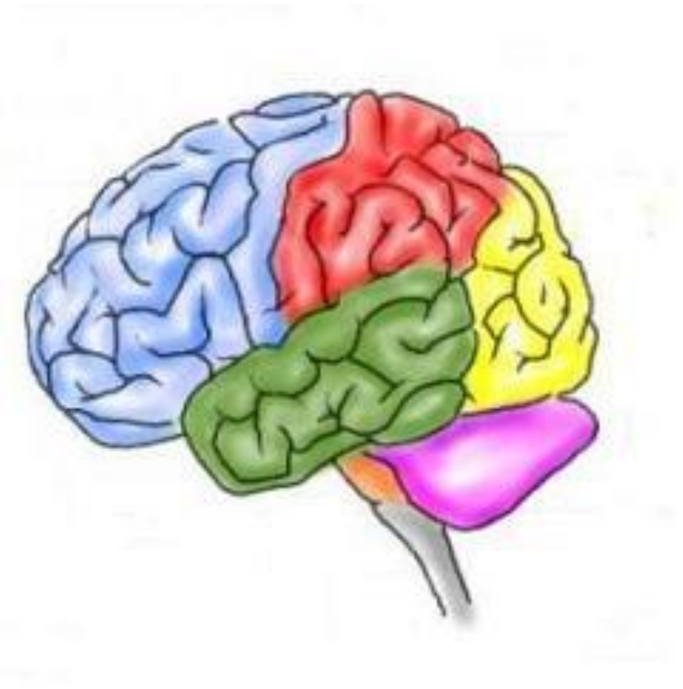
CONTENT 4

General architecture of the brain



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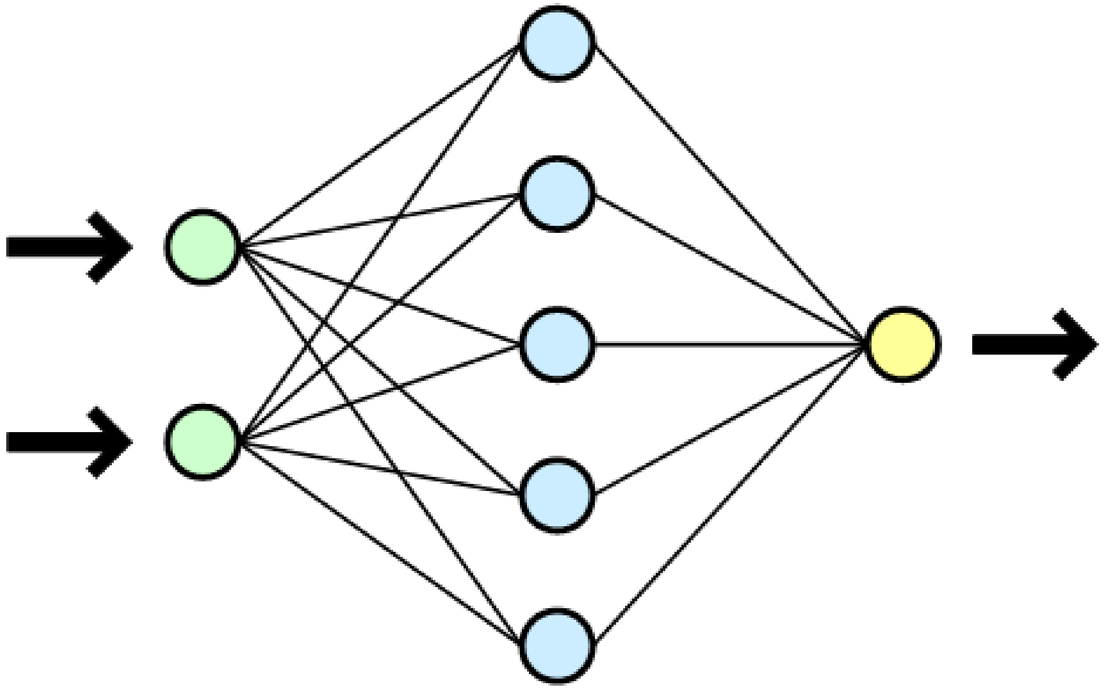
CONTENT 4

General architecture of NN



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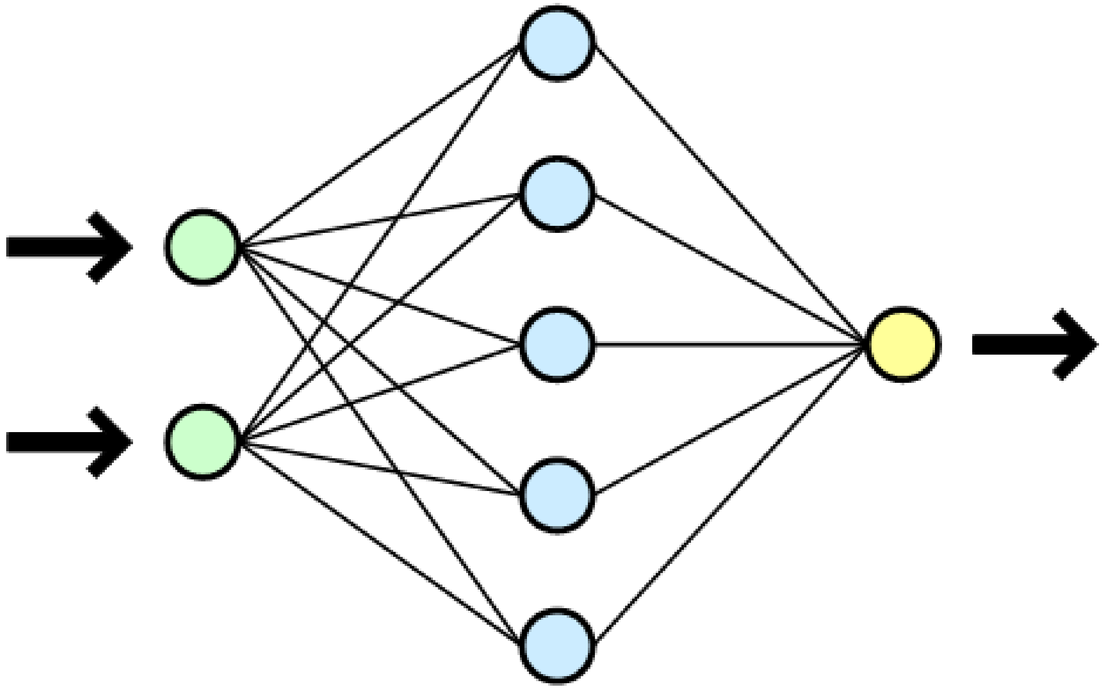
Architecture of NN

- Neurons are structured in layers and transfer functions are executed simultaneously.
- There is always an entrance and exit layer of neurons:

1. the information to the network is introduced through the entrance layer;

➢ the signals from the entry neurons pass through 1 or more layers of middle/hidden neurons, depending on the topology of the NN;

➢ signals arrive at the exit layer, from where the received information is being read.



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Modelled behavior

It is mathematically proven that any NN with at least 1 hidden layer of sufficient number of neurons can model the behavior of any existing function.

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Functional NN

- **Construction:**

➢ **Mathematical function** – the main element of a NN. It is formed by the architecture of the network and the size of the weights;

➢ **The weight of the connections between the neurons –** define the specific functionality and behavior of the NN.

- **Learning** – for a NN to be applicable to a specific problem, it has to be preliminary trained.

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CONTENT 5

Characteristics of NN

- Nonlinear systems;
- Parallel operation;
- Adaptiveness
- Tolerance towards mistakes and flexibility;
- Working with missing data;
- Usage of many variables and parameters;

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CONTENT 5

Application of NN

- Data extraction and filtration;
- Interpretation and usage of data;
- Classifications;
- Predictions;
- Correlation of data - filling in the missing information.
- etc.

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Fields of application of NN

- electronics;
- energy - load flow analysis in energy systems, etc.
- automotive industry;
- space sciences;
- finance and banking;
- the military sector;
- healthcare;
- traffic control, etc.

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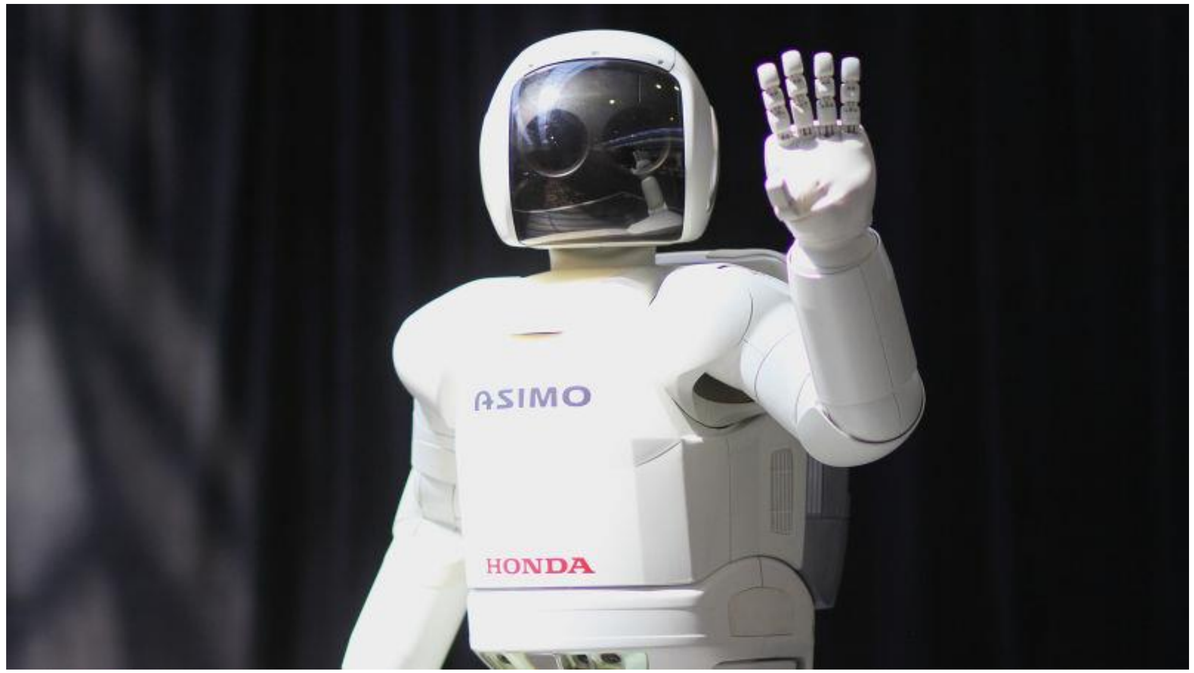
An example of NN applicability

The most common use of NN is in the development of humanoid robots.

Example: the humanoid robot Asimo ("Advanced Step in Innovative Mobility"), developed by Honda in 2000, which can walk and even run like a human (max. 6 km / h).



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CONTENT 5

Forward-looking

Today's interfaces are limited and are primarily used for:

- a rough recreation of what a person sees;
- controlling robotic arms or drones through thought.

Among the research areas in the field of neuroscience is the “brain-computer” interface:

- to create mind-reading machines that perceive precise instructions;
- to introduce information into the brain by stimulating it with light electronic pulses - currently such stimulation is used for therapeutic purposes.

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